Mitigation plan

The mitigation of 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

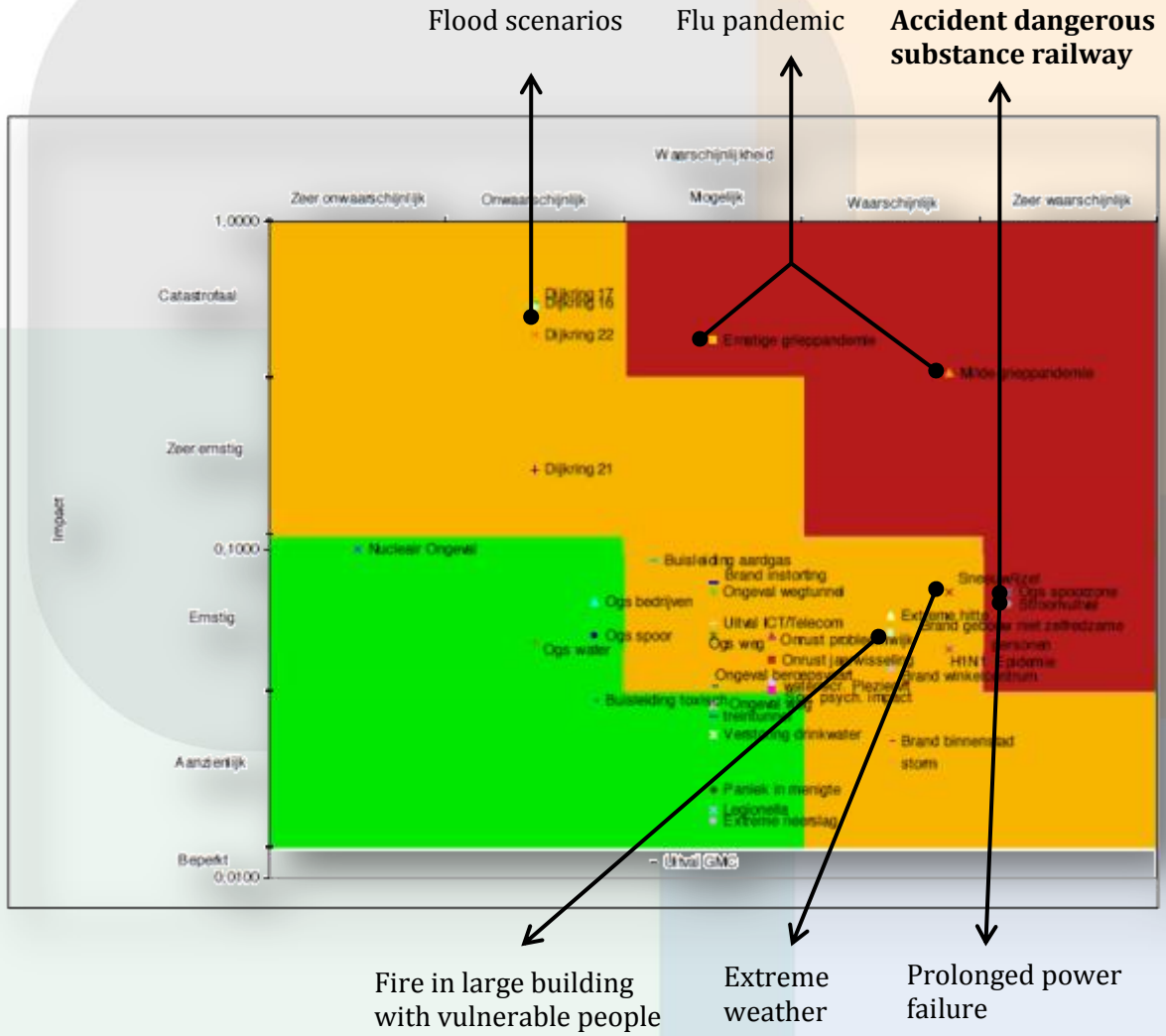
1.1 Risk setting of South-Holland South

The Safety Region South Holland South (in Dutch Veiligheidsregio Zuid-Holland Zuid, abbreviated as VRZHZ) is situated in the south-western part of the Netherlands. The region is situated close to Rotterdam and it consists of 17 municipalities of which Dordrecht is the largest. Due to its strategic location, the regions logistics and transport sector is of national importance. Two major rivers flow through the region and Dordrecht has an inland seaport. The A15 and A16 are two important transportation hubs for the transport of dangerous goods and other goods from the port of Rotterdam to Belgium and Germany. Also in the field of rail transport the region is critical, with the 'Betuwe' railway line and the north-south connection between Rotterdam and Antwerp. Both lines are intensively used for the transport of dangerous substances. At the junction of both lines lies the municipality of Zwijndrecht and its shunt yard Kijfhoek, the largest of its kind in Europe. In Kijfhoek freight trains are shunted from the Rotterdam and Antwerp port, reconstituted and finally distributed over the whole of Western Europe, using the Betuwe line and the Brabant Line.

The regional risk assessment of South-Holland South (2011) resulted in 6 priorities of which rail transport of dangerous substances is one (see risk diagram).[1] Based upon the risk assessment in the policy plan for the Safety Region one of the main objectives of the region is defined as "taking measures to contain the risks and ensure the accesibility in the Spoorzone, as commisioned by the municipalities Dordrecht and Zwijndrecht".[2] In cooperation with the Ministry for Infrastructure and Environment for the Spoorzone a special project has been started. Furthermore the Safety Region has committed itself to play an intermediary role between the municipalities and the national ministries, to ensure that all previous agreements on risk and crisis management are implemented according to plan.

[1] Regional risk profile Safety Region South-Holland South, March 2011.
[2] Policy plan (beleidsplan) Safety Region South-Holland South, 2012-2015.

Risk diagram South-Holland South with 6 priorities



1.2 "Spoorzone"

Substantial quantities of hazardous materials are transported in the categories of flammable and toxic gases and liquids. The railway zone ("spoorzone") also runs through a very densely populated area. All this creates a substantial safety risk. Within the national network for transport of dangerous goods by rail is the "railway zone Dordrecht, Zwijndrecht" the biggest bottleneck. The orientation value for the "societal risk" (literally from Dutch: "group risk") is exceeded many times. As a consequence, in the risk profile of the Safety Region South Holland South, the "spoorzone" emerged as one of the main risks within the region, in addition to flooding and pandemic influenza. The government is taking various safety measures on the track to reduce the risk of an accident. The likelihood, however, cannot be completely reduced to zero. This would be possible only if the transport of hazardous substances is completely stopped. However, that is not an option, because transportation is economically indispensable. The State government has therefore given money to the local government, the municipalities Dordrecht and Zwijndrecht, to improve the emergency response services along the track. These activities are bundled in the project Spoorzone.

1.3 Long term

The project Spoorzone aims to improve the assistance and disaster relief given the current risk of hazardous materials transportation. However, it provides no structural solution to this fundamental problem in the basic network. On the basis of the risk profile the Safety Region has indicated in its policy paper the intention to develop a risk management plan for the Spoorzone, with a time frame going beyond the currently ongoing project. The concrete objectives for the long term have yet to be determined. The safety region overall goal is to optimize both safety by preventing and reducing risks and by properly preparing the actual assistance as well. This is the raison d'être of the safety region. However, optimum safety is not the same as ever striving for more or a maximum safety. Indeed, the level of risk is achieved by a continuous balancing of security interests against other societal interests, such as economic development. For example, it's a fact transport (including hazardous materials) is crucial for the Dutch economy. Other partners can thus have different goals for the long-term strategy for the railway zone. This difference in interests is a given. Where partners may be able to find each other is the pursuit of sustainable safe solutions - transparent democratic legitimacy - which provide safety for residents, but also space for economic and spatial development.

1.4 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. 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 Spoorzone can set the agenda for our work towards the future, but are non-contractual.

1.5 Cooperation

In the PRISMA project cooperation is key. Internationally, but also locally. Each of the five PRISMA partners have created a local network for its own specific risk. In the case of South Holland South, the basis for this network is project Spoorzone. The steering committee Spoorzone also acted as a steering committee for the Dutch activities of PRISMA. The core staff of the local working group was composed of experts of the Safety Region, fire services, municipal health, the environment department and the municipalities of Dordrecht and Zwijndrecht.

1.6 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.

During the project the MiSRaR partners have shared and collected a great amount of practical experiences. The main practical lessons have been described in the MiSRaR handbook. The most important ones can be summarized in what the MiSRaR project has come to call the RISCE approach (pronounce: 'risky'). This approach states that for a successful mitigation strategy at least the following five basic principles have to be taken into account:

Risk assessment: insight in risks is the starting point for successful mitigation.

Integral: only when all effects and all vulnerabilities are taken into account a meaningful mitigation strategy can be designed. A successful strategy includes measures in all layers of multi layer safety.

Structural: mitigation is a continuous process, which has to be embedded in the relevant organizations.

Cooperation: all relevant government agencies, civil society, industries and inhabitants need to cooperate.

Early: risks can be most effectively mitigated if safety is considered in spatial development as early as possible.

1.7 Content of this plan

This plan has the following content:

- a short overview of the **organization of safety**: the different entities involved and their legal responsibilities;
- the outcome of the **risk assessment**, of which the full version is also added as a separate annex;
- the **objectives** for the mitigation policy based upon the risk assessment;
- the proposed **mitigation strategy** based upon the capability assessment, of which the full version is also added as a separate annex;
- the potential **resources** for the implementation of the strategy.

Of the potential content of a mitigation plan as suggested by the MiSRaR partners in the MiSRaR handbook, the following aspects are left out:

- a chapter on public participation: this is presented as an integral part of the chapter about the mitigation strategy, because public participation and resilience are an essential part of it;
- an updating chapter or paragraph: because this is a testing project and because the plan is in English instead of Dutch, the plan in its present form will not be structurally maintained. If possible the relevant aspects will be implemented in the regular policies and plans of the Safety Regions.

Also thoughts on a lobby and advocacy strategy cannot be part of this plan.

1.8 Status of this plan

This mitigation plan 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 assessments and the plan are 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 assessments 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.

2. Organization of safety

2.1 Safety on the 3 main government levels

The Dutch constitution distinguishes 3 government levels: the central government, the provinces and the municipalities. Concerning safety the responsibility of the central government is limited to national issues. The national coordination is primarily dedicated to the Ministry of the Security and Justice and ultimately to the prime minister's office. Part of the Ministry of the Security and Justice is also the National Police which includes all the former regional police . For specific issues several other ministries hold responsibilities, such as the Ministry of Infrastructure and Environment, Ministry of Health, Welfare and Sport, Ministry of Economy and the Ministry of Defence.

However, the main responsibility for safety and security, and risk management policies, is dedicated to the so-called 'de-centralized governments': primarily to the 403 municipalities and secondary to the 12 provinces. The municipalities are responsible for firefighting, police and security, risk management and disaster preparedness. The provinces are responsible for risk policies only concerning SEVESO industries that transcend the level of the municipalities.

Moreover, the municipalities are primarily responsible for spatial planning, including (environmental) permits, monitoring and enforcement. This means they hold the best policy options for fundamental proaction and prevention by means of spatial planning.

2.2 The safety regions

While the formal responsibilities for safety and security are mainly concentrated in the 430 municipalities, effectively the main government authorities for safety are, however, organized on the level of 25 regions. Formally the Dutch constitution does not recognize these 'regions' as a fourth government level, separate from the central, provincial and municipal governments. However, to ensure that safety policies are corresponding between municipalities by law the 403 municipalities are clustered into 25 Safety Regions (since 2010). The mayors of the municipalities within these 25 regions together form the Board of Safety Regions. This ensures that these supra-municipal regions execute the policies the municipalities demand.

The Safety Regions only exist since 2010, but have a long history that includes some very tangible events that have led to its formation, such as the fireworks disaster in Enschede in May 2000 and the New Year's fire in the 'De Hemel' bar in Volendam in 2001. As the economy, technology, ecology, culture and administration have become increasingly entwined, society has become substantially more complex. Because the threat from 'classic' disasters was broadened to include different types of disaster – like the foot and mouth crisis of 2003, the threat of a flu epidemic, the threat of terrorism and the 'gritting salt crisis' – disaster management has also been expanded over the years to include crisis management. The new forms of threat require a

different type of approach, different partners and a different strategy. The need arose for a bigger organisational scale than the municipal scale: most municipalities are too small to be able to perform all tasks required for disaster and crisis management. The need for multidisciplinary cooperation involving both the traditional security partners and new partners grew, as citizens are entitled to expect that the public authorities will be able to work together in the event of disasters and crises. In short, the effectiveness and professionalism of the emergency services in the Netherlands had to be increased. In order to bring this about, uniform service levels had to be established within cooperation areas (safety regions) to facilitate mutual assistance and escalation.

According to the Safety Regions Act the 25 newly formed Safety Regions are, on behalf of the municipalities, responsible for the fire services, the medical emergency management, the joint emergency room of police, fire services and ambulance services (112)[3], and the disaster preparedness and response. Furthermore the Safety Regions give advice to the municipalities and provinces on risk reduction policies. Implementation of risk reduction policies, however, effectively remains a responsibility of the municipalities and provinces itself.

The regional risk profile

Effective safety policies require insight in the actual risks that threaten society. The Safety Regions Act requires the 25 regions to develop (and continuously revise) a regional risk profile, as a basis for the policies on risk and crisis management. This profile, or risk assessment, forms the basis for the regional risk management and disaster preparedness 'policy plans' of the Safety Regions. This means the main objective of the risk assessment is to enable local politicians to make strategic decisions upon the policy priorities of the Safety Regions. In other words: which risks are deemed most important by the local government to invest the limited time and resources of the Safety Regions upon? This means the risk profiles enable the municipalities to directly influence the policies of the Safety Regions on the basis of real insight in the actual risks.

A secondary objective of the risk assessments is to provide the Dutch people insight in the risks that threaten them. By means of the representation of the identified hazards on a 'digital risk map' on the internet, all inhabitants can gain insight in the industries, infrastructures, natural risks and so on, in their neighbourhood.

Finally, the third objective is to professionalize the network management capabilities of the Safety Regions. To effectively address the risks within their borders, the Safety Regions need to cooperate with various kinds of public and private partners, including the Police Regions,

[3] The coming years the 25 emergency rooms will be transformed into one national organization with 10 locations, as part of the National Police.

Regional Water Authorities, public services and industries. By jointly developing the risk profiles with all the relevant public and private partners, the regions are enabled to reach agreement with them on joint risk management policies and together work in the same direction on risk reduction and disaster preparedness.

Advice on prevention and mitigation

By Law one of the tasks of the Safety Regions is to provide advice on risk prevention and mitigation to the municipalities. The Law specifically assigns an advisory role for the Safety Region on safety policy for SEVESO companies and on external safety policy for SEVESO and for transport (localised and societal risk). In specific Decrees the extent of this advisory role is regulated. Furthermore the Law explicitly creates the option for municipalities to delegate to their Safety Region other "non-legal" advisory roles on prevention and mitigation (transcending the legal minimum of the advisory role). Up to now in the policy plan of the Safety Region South-Holland South such additional advisory roles have not been assigned. Concerning the risk of rail transport the formal advisory role on external safety provides a first basis. However, an additional advisory role concerning the spatial planning of municipalities could provide more fundamental options opportunities for mitigation.

2.3 Responsibilities concerning rail transport safety

The responsibility for the inherent safety of rail transport itself firstly resides with the transporting companies themselves. They have to make sure that their machinists comply with the regulations far safe conduct and have the right licences to operate the trains. In case of shunting the company operating the shunting yard has to make sure the personnel complies to regulations and have the right "safety culture". Secondly the national agency responsible for rail road maintenance (ProRail) holds a very important responsibility. It has to make sure the railway is properly maintained and all the safety systems are working. 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

Image: ATB-vv

BLEVE' (a BLEVE triggered by heat radiation from a pool fire).

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.[4]

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

3. Risk assessment

The full risk assessment is presented in a separate document. In this chapter the main conclusions are presented.

3.1 The risk assessment process

The mitigation process begins with understanding the nature of risks. This risk assessment consists of three phases:

- *Risk identification*. Risk identification is defined as "the process of finding, identifying and describing existing and future risk situations." Identifying risks requires both the identification of risk causes (risk sources) and risk receivers (vulnerabilities). The combination of both provides insight into the spatial distribution of risk, or in other words the presence of high-risk locations or situations.
- *Risk analysis*. This step can be defined as "the process to determine the nature and relative magnitude of risks." The goal is to prioritize which risks need most policy attention.
- *Risk evaluation*. In this phase, the conclusions of the risk identification and risk analysis are submitted to the (political) decision-makers. The aim is transparent and accountable decision-making: assessments are made as objectively as possible, but in the end politicians decide upon the priorities.

3.2 The concept of 'risk'

The understanding of mitigation 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:

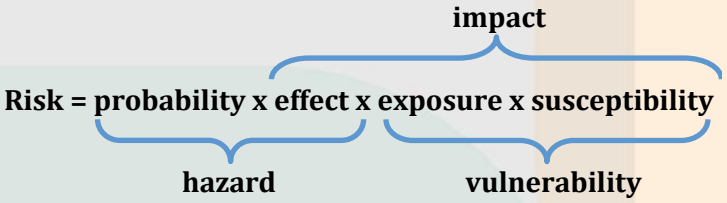
Risk = probability x impact

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:



3.3 Risk identification

The region South-Holland South is situated at a key point in the Dutch railway system: the connection of the railway from the Rotterdam Harbour with the Betuweline to Germany and the southern transport to Belgium (Antwerp Harbour) and the 'Brabant route' to Germany through the Dutch southern province of Brabant. 7 of the 17 municipalities in South-Holland South have transport of dangerous substances by rail on their territory. The transport routes in South-Holland South are divided into 5 subsections, which all come together on the territory of the municipalities of Dordrecht and Zwijndrecht.

In the municipality of Zwijndrecht (45.000 inhabitants) the railways from the Rotterdam Harbour enter the region. In the municipality is located the Kijfhoek shunting yard. The shunting yard is the turntable for the rail transport in Western Europe and in consequence the most intensively used shunting yard in Europe. The shunting yard is the starting point of the so-called "Betuwe route" railway to Germany and the place where all transports from the ships and industries in the Rotterdam area are recombined into trains to their final destinations to the east and south. Also the shunting yard is used for the recombination of trains from the Antwerp Harbour in Belgium. In consequence the railway in the municipalities of Zwijndrecht and Dordrecht is one of the most intensively used in Europe. The maximum allowed number of goods trains on this stretch is 7 an hour in both directions (14 in total).

The transport volumes of dangerous substances on the Spoorzone route are the highest ones in The Netherlands and presumably one of the highest (if not *the* highest) in Western-Europe. The largest part of the transport concerns flammable liquids (42%) and flammable gasses (32%). Due to the international crisis the transport has significantly decreased during the last years. In 2012 (the most recent available numbers) the transport was as much as 63% lower than in 2007 (the last year before the start of the economic crisis). The transport decreased from an average of about 110 wagons in 2007 a day to 40 wagons a day in 2012. In the Law Base-net Transport of Dangerous Substances new maximum transport volumes have been set, based upon the prognosis for transport in the year 2020. The coming years a new growth of transport is foreseen, mainly because of the completion of the *Tweede Maasvlakte* (literally: second Meuse plain): a whole new area of container handling and docks in the Rotterdam Harbour. The prognosis for 2020 is an increase of over 3 times more transport through the city centres of Dordrecht and Zwijndrecht and over 10 times more transport on the Betuwe route.

The risk identification has leaded to a more specified focus of the risk assessment. It is focused on the on-going railway from the north(-west) to the south, meaning only within the municipalities of Dordrecht and Zwijndrecht. This means the following parts of the rail transport routes are not taken into account:

- The **Betuwe route** is not part of this assessment, because this railway line is built especially for transport of dangerous substances. This means that the risk levels and mitigation measures have been thoroughly taken into account during the construction, rendering an additional assessment useless and anyway not possible within the project period of PRISMA.
- Furthermore the **Kijfhoek shunting yard** is not part of the risk assessment. According to national legislation Kijfhoek is considered a SEVESO ("BRZO") location, to which all specific SEVESO regulations apply. Kijfhoek is a major risk and receives specific attention from the Zwijndrecht municipality and the Safety Region. It was deemed impossible to include all aspects of this specific risk location in the risk assessment during the relatively short project period of PRISMA. However, this does not mean it is of less consequence or should be a lesser priority then the transport on the on-going railway tracks.
- Finally, the specific line to the **SEVESO industry DuPont** is not taken into account, because the transport volumes there are significantly lower than on the other route (10 times less) and are expected to have the lowest increase to 2020 (only 2 times more). This lower volume does not mean there is no risk at all, but for the purpose of the PRISMA testing during the limited project time a focus had to be made.

3.4 Risk analysis

The second phase in risk assessment is the risk analysis. The goal is to prioritize which risks need most policy attention. For the analysis of the rail transport risk in South-Holland South 3 different approaches have been used, in order to obtain as much insight in the risk as possible.

All hazard approach: regional risk assessment

The first method is the all hazard approach of the Dutch national Guideline for Regional Risk Assessment. This method analyses on impact and probability. Impact in this case is defined by 10 different criteria for the different vital interests of society. In this case the all hazard methodology is applied to several scenarios for a *single* hazard. Based upon the 6 substance categories and their example substances several primary scenarios have been selected. For the probability calculations of these scenarios a national method has been developed by the Ministry of Infrastructure and Environment, the so-called "HART" (*manual for analysis of transport risks*). The total of incidents for the railway in Dordrecht and Zwijndrecht (without the Betuwe route) is calculated at once every 16 years and the total of incidents with emission of dangerous substances is calculated at once every 55 years, as specified in the following table.[5]

	TOTAL Region ZHZ			**TOTAL Region ZHZ without Betuwe line**		
Substance category	Probability per year	Probability once every .. years[6]	Probability class	Probability per year	Probability once every .. years	Probability class
A. Flammable gasses	2.30×10^{-4}	4,339	B-middle	4.81×10^{-5}	20,796	A-high
B2. Toxic gasses	3.77×10^{-5}	26,553	A-middle	1.53×10^{-5}	65,317	A-middle
B3. Very toxic gasses	5.67×10^{-7}	1,762,173	A-low	4.45×10^{-8}	22,449,616	A-low
C3. Flammable liquids	3.37×10^{-2}	30	D-middle	5.68×10^{-3}	176	C-high
D3. Toxic liquids	2.97×10^{-4}	3,368	B-middle	1.37×10^{-4}	7,303	B-low
D4. Very toxic liquids	1.36×10^{-4}	7,356	B-low	3.77×10^{-5}	26,557	A-middle
Total incidents with significant release	**3.44×10^{-2}**	**29**	**D-middle**	**5.92×10^{-3}**	**169**	**C-high**
Small scenarios (<100kg)	7.29×10^{-2}	14	D-high	1.24×10^{-2}	81	D-low
Total incidents with release	**1.07×10^{-1}**	**9**	**E**	**1.83×10^{-2}**	**55**	**D-low**
Incidents without release	1.93×10^{-1}	5	E	4.38×10^{-2}	23	D-middle
Total all incidents	**3.00×10^{-1}**	**3**	**E**	**6.21×10^{-2}**	**16**	**D-high**

[5] All calculations are only for the ongoing railway tracks, so without the probability of Kijfhoek shunting yard.

[6] The figures for the "probability per year" can be added to a resulting total probability. All figures can also be expressed as a "probability once every … years". However these figures cannot be added because they are a fraction (1/x).

The impact of the selected scenarios is analysed on the 10 criteria set in the Dutch national guideline for regional risk assessment.

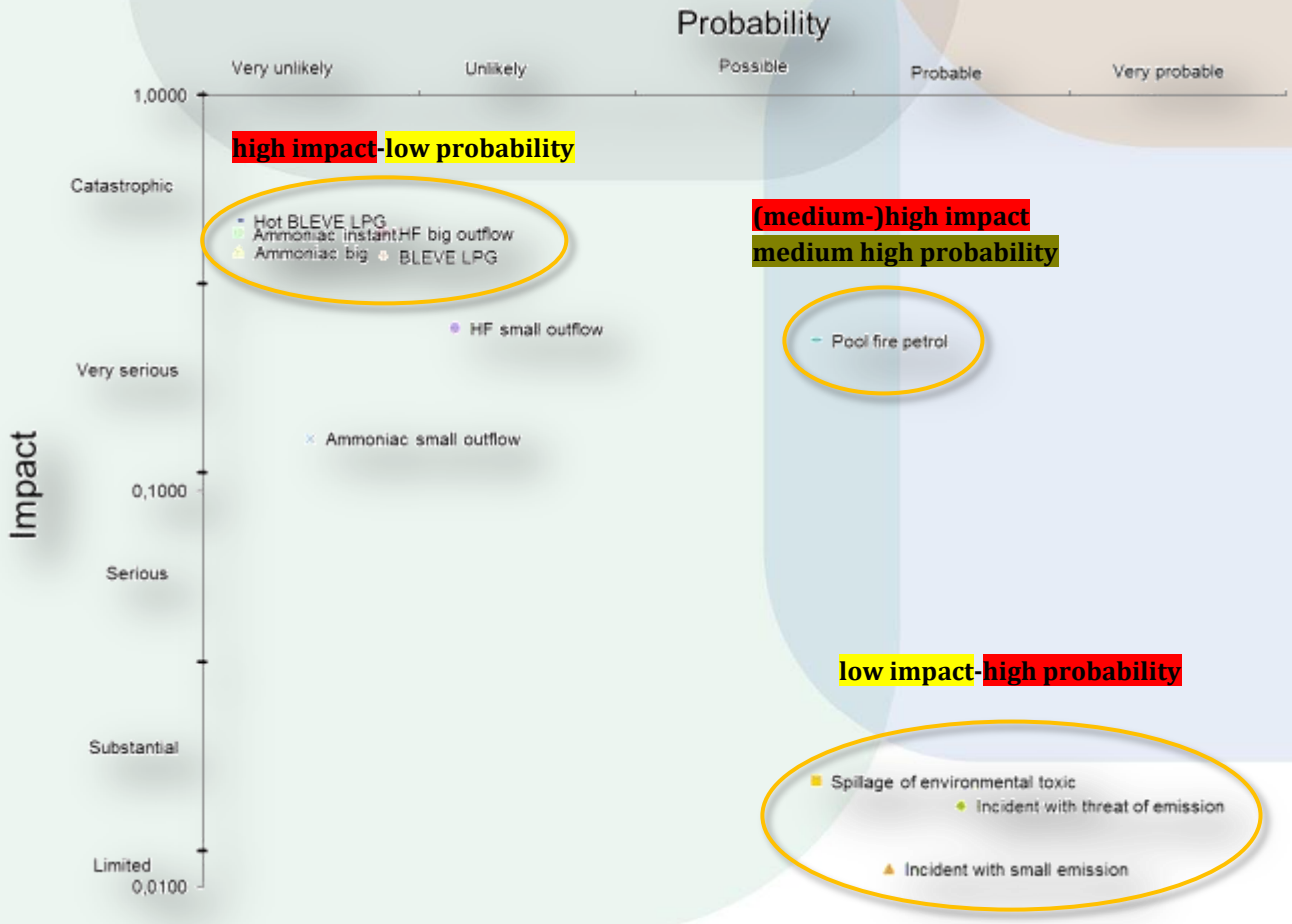
	B2. Toxic gas: Ammoniac			**D4. Very toxic liquid: HF**		**A. Flammable gas: LPG**		**C3. Flam. liquid: petrol**	**Miscellaneous scenarios**		
	Instantaneous release	Big outflow	Small outflow	Big outflow	Small outflow	BLEVE	Hot BLEVE	Pool fire	Threat of emiss.	Spillage of eco toxic	Small emiss.
1.1 Infringement of the territorial integrity	A	A	A	B	A	C	C	B	0	0	A
2.1 Number of fatalities	E	E	D	E	Dhigh	E	E	Dhigh	0	0	0
2.2 Number of seriously injured & chronically ill	Dhigh	Dhigh	D	E	E	E	E	E	0	0	A
2.3 Physical suffering (basic necessities)	0	0	0	0	0	0	0	0	0	0	0
3.1 Financial costs	D	C	C	D	D	D	E	D	A	B	A
4.1 Long-term damage to the ecosystem	A	A	A	A	A	0	0	0	0	C	0
5.1 Disruption of everyday life	E	E	C	E	C	E	E	C	C	0	A
5.2 Violation democr. system and rule of law	D	C	C	C	C	D	D	C	0	0	0
5.3 Social psychological impact (outrage/anx.)	E	E	D	E	D	C	D	C	B	B	B
6.1 Damage to cultural heritage	C	C	0	0	0	B	B	B	0	0	0
Total impact	**E**	**E**	**D**	**E**	**D**	**E**	**E**	**D**	**B**	**B**	**A**

The impact analysis shows that the scenarios with toxic gasses and liquids and with flammable gas have the highest impact. However, the impact of flammable liquids is not far behind. The smaller, miscellaneous scenarios clearly have smaller impact. Of the ten impact criteria the physical impact (injured and fatalities) at average score highest, followed by social-political stability (disruption of daily life and social psychological impact) and costs.

Using the excel calculation file of the Guideline for Regional Risk Assessment the a risk diagram was generated (seen next page). The probability analysis and impact analysis combined provide the insight that in general terms there are 3 categories of scenarios:

- *High impact-low probability scenarios*. All the serious (maximum credible) incidents have a relatively low probability, approximately between once every several thousand up to millions of years. The potential impact of these scenarios is catastrophic, meaning several hundreds to thousands killed and injured and very high costs.

- *Low impact-high probability scenarios*. These are the scenarios smaller than 100kg release and with 'just' the threat of a release after a derailment or collision, as well as the ecological toxic scenarios. These have significantly smaller impact on physical and economic safety, mostly impacting on the social and political stability (outrage and anxiety and the consequent impact on the democratic system). However, the probability is significantly higher, up to once 20 to 80 years, so once or more in a lifetime.
- *Medium-high impact and medium-high probability*. This concerns only the flammable liquid scenarios (i.e. pool fire). These have a higher probability than the other substance categories, both due to the large transport volume and the higher inherent probability of failure (rupture, puncture) in case of a derailment or collision. At the same time the potential impact is significant ('serious impact'), although smaller than in case of a BLEVE or toxic scenarios. Although the risk assessment method specifically states that impact and probability should not be multiplied to one aggregated score the risk diagram directly seems to support the choice of the national government to declare prevention of pool fires a specific priority.



Single hazard approach: societal risk

The second method is the single hazard approach as defined in the External Safety Decree ('BEVI'). This decree requires calculations for the so-called 'local risk' and 'societal risk', which take into account only fatal casualties and no other kinds of impacts. 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. In fact this fN curve can be regarded as a *risk diagram*, which differs in two ways from the risk diagram used for the regional risk assessment:

- the x- and y-axis are the other way around, because for the regional risk assessment the x-axis indicates probability (opposed to impact i.e. number of fatalities) and the y-axis denotes impact (opposed to probability).
- the societal risk only takes into account fatalities and not all the other kinds of impact, like wounded, costs, ecology etc.

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. 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.

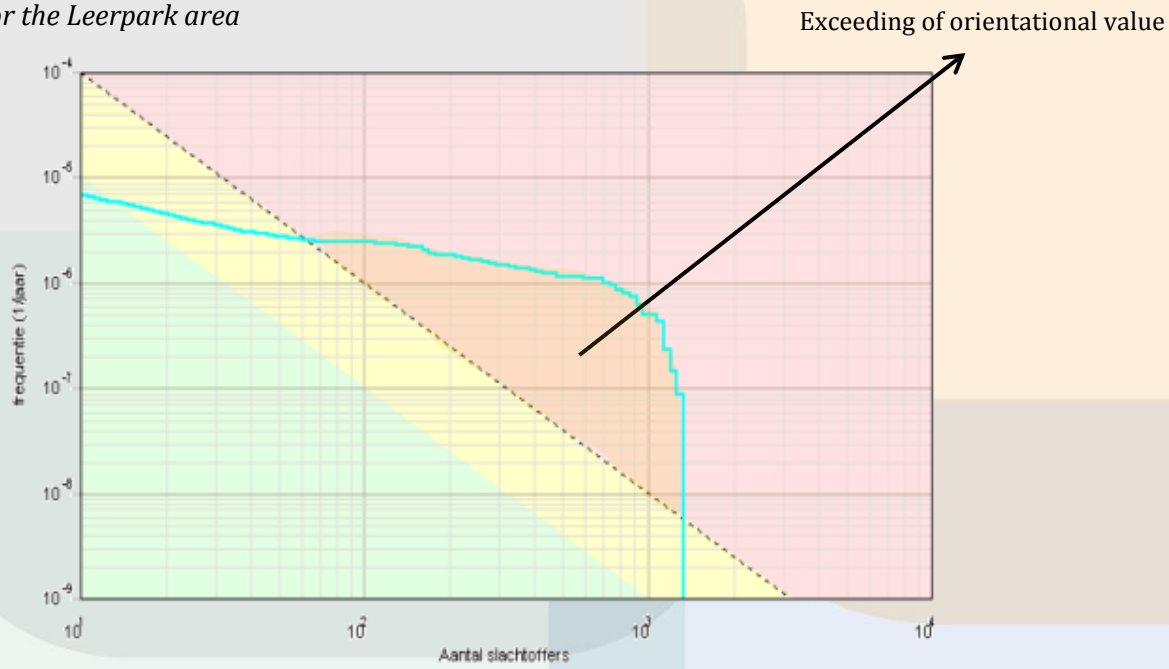
For the "base net transport of dangerous substances" the societal risk has been calculated nationally. Figure X shows that the Dordrecht-Zwijndrecht area have the highest societal risk in this part of the country (in fact in the whole country): 11 times above the orientational value in the year 2008.[7]

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.[8] Also the societal risk has been calculated for the separate "kilometre sections" of the railway zone. The societal risk for the Leerpark area has originally been calculated at 43 times higher than the orientational value in the year 2008, growing to an (at time) expected 61 times

[7] *Base net transport of dangerous substances*.
[8] *Analysis external safety Leerpark*, page 9.

higher in the year 2020.[9] The fN curve for the Leerpark area is presented in the figure below. This shows the significant elevation of the curve above the orientational value in the original calculations of 2008.

fN curve for the Leerpark area

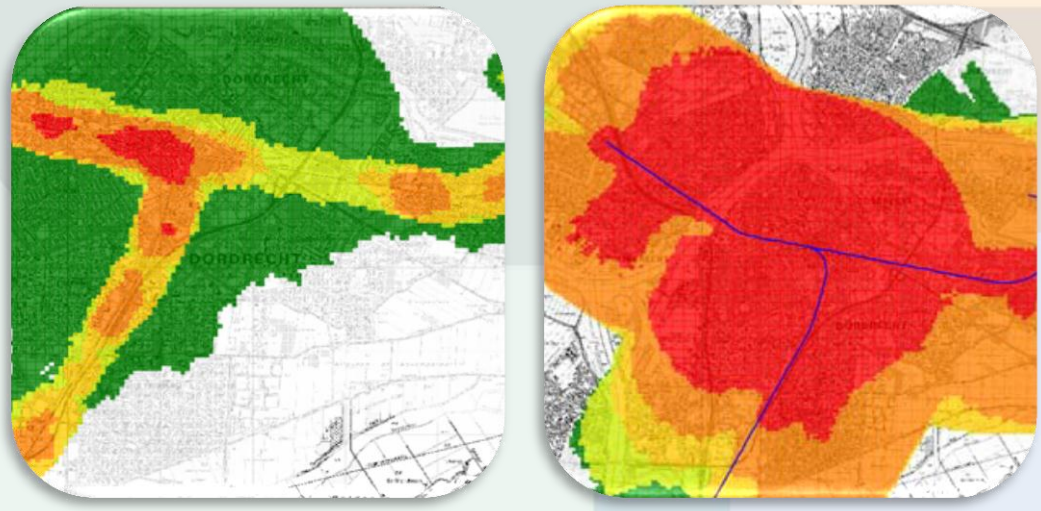


In 2013 the municipality of Dordrecht has presented a new spatial plan for the Leerpark area. Using the new Law on the Basenet rail transport (enacted in 2012) a new societal risk calculation was made, taking into account the changes made in the spatial plan after the previous calculations. The new situation generated 'only' an exceeding of the orientational value of 5.3 times, showing the added value of risk analysis.[10]

In 2007 the railway zone Dordrecht-Zwijndrecht has been a test case for an attempt to map the societal risk. This resulted in several experimental maps showing the height of the societal risk for respective areas and the relative contribution of specific areas to the calculation of the societal risk. It is clearly that the area around the Dordrecht Station and the Dordrecht curve have the highest societal risk. However, in the same experimental mapping study an attempt was made to gain more insight in the relative contribution of the different substance categories to the total societal risk. Using the experimental mapping at first it was concluded that the flammable gasses (like LPG) have to largest contribution to the societal risk. However, after

[9] *Advice pre-design zoning 2nd review Leerpark*, page 10 and *Analysis external safety Leerpark*, page 11.
[10] *Gewijzigd vaststellen bestemmingsplan 2e Herziening Leerpark* (changed enactment of 2nd revision spatial plan Leerpark), letter from the Mayor to the city council, April 22nd 2014.

taking into account the full population, instead of just the population in the first 500 metres, it was concluded that the influence of toxic liquids is much larger than estimated in the first approach. At a distance of 350 metre the influence of the flammable gasses is significantly lower, whilst the influence of the toxic liquids and gasses remains the same (and therefore relatively larger). Even at 1350 meter the toxic liquids still have a large influence.[11] This is easily explained by the effect distances: a BLEVE scenario has much smaller effect distances than the toxic scenarios. Main conclusion was that the normal approach of taking into account the population up to 500 metres, is not valid in case there is a substantial transport volume of toxic substances, because those have a significant larger area of influence. The whole population should be considered in the calculations, although by Law beyond 200 metres in principle no spatial limitations have to be made. The difference is best illustrated by the comparison of the mapped societal risk on the basis of the limited population (up to 500 meter) and the whole population (see figures).[12]



It is very striking that the prescribed methodology has such a different outcome if the scope of the analysis is widened. Instead of a focus on preventive measures for BLEVE scenarios around the station area, the second maps indicates a focus on preventive measures for toxic scenarios in the whole city.

Mapping approach: probability, effect zones and vulnerabilities

The third method is the mapping of risks in order to obtain concrete insight in the spatial distribution of probabilities, effects and vulnerabilities. This method concerns the full width of

[11] Ditto, page 65.
[12] Ditto, page 64.

the risk definition, so also vulnerability. To gain insight in the spatial components of the risk (as a basis for mitigation), the probability can be specified to spatial dimensions up to a certain point. First of all the inherent probability of incidents on specific parts of the transport routes has been calculated. Although not in the national methodology for probability calculations, specific higher probability points can be identified:

- Dordrecht Station, because of the many tracks and switches with corresponding signs and the crossing of passenger trains and goods trains;
- the Dordrecht curve, because it is one of the sharpest curves in Europe meaning an inherent higher probability of derailment in case of too high a speed, whilst at the same time trains coming from Kijfhoek and Rotterdam towards the curve have to speed up to clear the Dordrecht bridge;
- Kijfhoek shunting yard, because of the large amounts of wagons and because of the inherent risks of shunting.

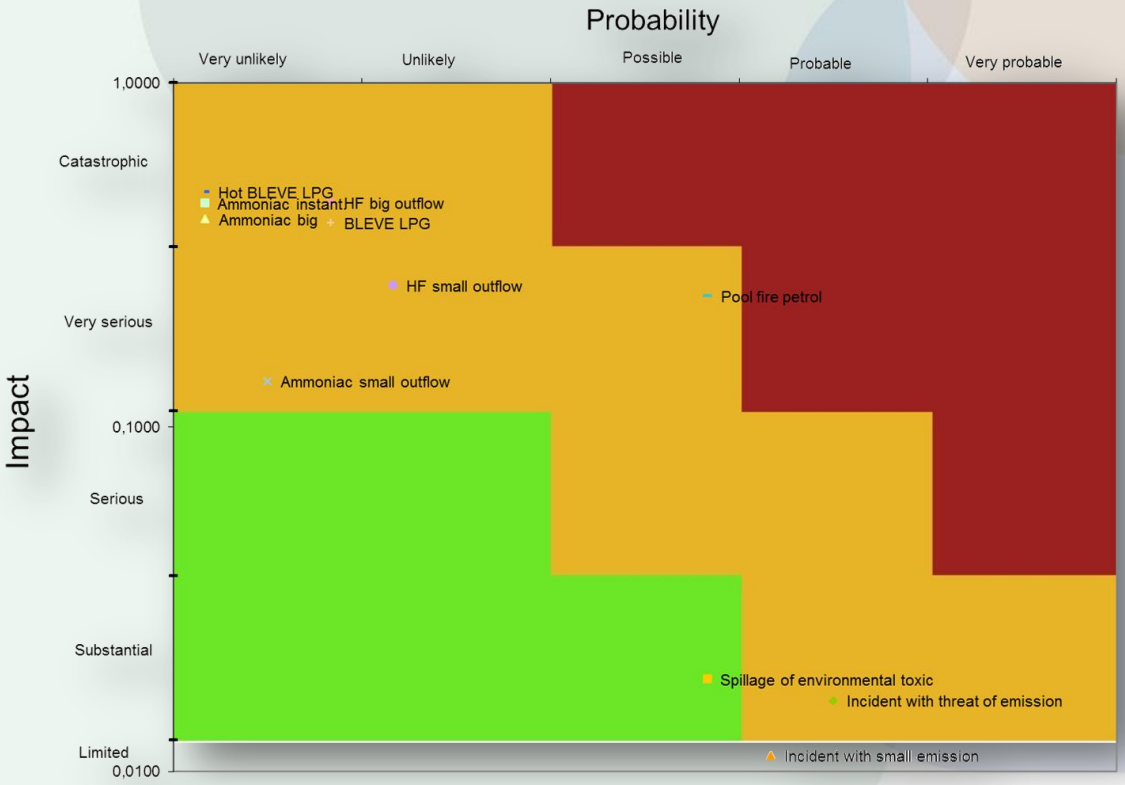
Another specification of the spatial distribution of probability concerns the effects. More specifically the probability of toxic fumes (from a toxic gas or toxic liquid release, but also the toxic fumes of flammable liquids) travelling downwind to a specific direction. The map (see the risk assessment report) shows that on the straight parts of the railway the probability is higher on the north side (on the west-east track) and the east side (on the north-south track), because the winds in this part of The Netherlands are prevailing from the directions west to south (mainly south-southwest). However, in the area around the sharp "railway curve" the probability is highest at the inside of the corner, because this is surrounded by the railway tracks (within 2 km) on 12 of the 14 wind directions (although with exception of the prevailing directions west-southwest and south-southwest).

To help the understanding of the nature of the risk (and as a potential basis for spatial planning) the effect distances as calculated can be projected as potential effects zones on a map. Likewise the different vulnerabilities and also potential sites for domino scenarios can be projected (see risk assessment report). However, it was deemed impossible to aggregate the probability, effects and vulnerability maps into a single, overall *risk* map (meaning a map which combines all aspects of the risk concept into one overview of the spatial distribution of the risk). For this step the mapping in The Netherland has not yet been developed far enough. In comparison to other countries, the mapping capabilities of the Dutch safety regions is underdeveloped and the importance is underestimated. This actually is one of the an important lessons of PRISMA. The inherent wish to gain insight in the spatial distribution of risks seems the be lacking, perhaps partly due to the fact that the provinces instead of the safety regions are responsible for risk mapping.

3.5 Risk evaluation

The third and final phase of risk assessment is called risk evaluation. In this phase, the conclusions of the risk identification and risk analysis are submitted to the (political) decision-makers. Risk and crisis management is not intended to achieve absolute security, but is part of a political-social assessment process, taking into account the public interest of risky activities. For example, modern society can simply not do without hazardous substances. Ultimately the aim must be to achieve a level of safety which is acceptable for both politicians and citizens. This means that the political and administrative decision-makers always shall have to evaluate the outcome of a risk analysis on basis of their own values and preferences. The aim is transparent and accountable decision-making: assessments are made as objectively as possible, but in the end politicians decide upon the priorities.

A first way of helping politicians to decide on priorities is to literally 'colour' the risk diagram in order to depict different risk levels. In the figure below the risk diagram for the railway scenarios is coloured to give an indication for potential prioritization.[13]



[13] The colouring is the same as that in the risk diagram of the regional risk profile of South-Holland South.

Regional risk profile method

The risk diagram and the regional risk profile method supports the following first recommendations for prioritization:

1. **Give specific priority to pool fire scenarios**, because they both have a medium-high impact and a medium-high probability. This supports the previously made national choice to focus on the so-called "pool fire attention area" in which mitigation measures might be required.[14]
2. **Give priority to reduction of injured, fatalities, disruption of daily life, psychological impact and costs/economic impact**, because those vital interests of society are threatened the most.
3. **For BLEVE and toxic scenarios give extra priority to effect and vulnerability reduction**, because their probability is low already, but the potential impact is catastrophic.
4. **For the smaller scenarios (small emission, threat of emission and eco toxic) give extra priority to probability reduction**, because their high probability is the main concern.
5. **Give priority to toxic effects (of toxic liquids and toxic gasses, but also of flammable liquids and smoke and ash from fires)**, because accumulated that is the primary effect that has highest probability.
6. **Give priority to preparedness measures which are helpful for all scenarios for the whole region**, because the combined probability of all scenarios in the whole region is very high (a transport train incident once every 3 years, a serious incident involving a substance emission of more than 100kg once every 29 years).

Societal risk analysis

The societal risk analysis supports other/additional recommendations:

7. **Give priority to BLEVE**, because it has the highest contribution to the societal risk according to the formal calculation method (only taking into account the inhabitants up to 500 metres).
8. **Give priority to toxic scenarios**, because they have the highest contribution to the societal risk if the whole potentially affected population is taken into account.
9. **Give priority to the areas of Dordrecht Station and the Dordrecht curve (Leerpark)**, because at those sites the societal risk is highest. Although not part of the actual risk analysis (as described in paragraph 3.7), also the **Kijfhoek shunting yard** should be a priority, because even without a detailed analysis it is certain that there the risk is high due to the high transport volumes, the concentration of many trains (with different substances) on the same location and the inherent risk of the shunting process.

[14] However, the distance of the pool fire attention area in which legally specific safety demands might be set, is too small. It concerns only an area which might completely burn down despite (expensive) mitigation measures. The effectiveness of this area is a real concern. For more discussion about this topic, see the separate capability assessment report.

10. **For measures against the toxic scenarios give extra priority the whole city centre of Dordrecht**, because also at a larger distance from the railway the population still contributes to the societal risk.

Mapping approach

From the mapping analysis the following priorities can be added:

11. **Give priority to all tracks, except the line to DuPont**, because on that line the transport is substantially lower.
12. **For measures against the toxic scenarios give extra priority to the inside of the Dordrecht curve and more in general the north side of the railway**, because of the higher probability of toxic effects being blown in that direction by the wind.
13. **For measures against BLEVE scenarios give priority to the areas (at least) up to 360 metres from the railway**, because up to that distance there might be significant effects.[15]
14. **For measures against pool fire scenarios give priority to the areas (at least) up to 60 metres from the railway**, because up to that distance there might be significant effects.
15. **For measures against toxic scenarios give priority to the areas (at least) up to 2,000 metres from the railway**, because up to that distance there might be significant effects.
16. **Within these zones give extra priority to the protection of buildings with vulnerable people**, because there are a lot of them.
17. **Give attention to industries and installations within the BLEVE zone (up to 360 metres)**, because they might lead to a domino scenario.[16]

These different perspectives give different and sometimes (more or less) opposing priorities. For example: the risk diagram supports the (already nationally set) focus on pool fires, whilst the societal risk places the emphasis on BLEVE and toxic scenarios. Therefore it is advised not to use the one priority to exclude the other, but to accumulate the priorities, meaning that you take them all into account.

Perspectives for risk evaluation

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 risks should be chosen as a priority, many different evaluation criteria can be taken into account. Therefore, an option is to ask the

[15] Distances measured from the outside perimeter of the railway track and not from the central transport axis, as is done in the external safety policy.

[16] As specified in paragraph 4.3 the probability and combined effect of domino scenarios could not be taken into account during the limited project period of PRISMA. However, the risk identification supports the conclusion that further attention should be given to the analysis domino scenarios, to determine whether they should be an additional priority.

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 en methodologies. The potential priorities concluded from the "technical" analysis have not been presented to or discussed with actual politicians in the region. However, several perspectives are provided below.

The relative importance of the vital interests

One perspective is that of the (conflicting) vital interests of society. For example, for one decision-maker risks with potentially a lot of casualties might be most important, while another might want to give priority to risks with severe economic or ecological consequences. Directly related to the "vital interest of society" as defined by the national government the following perspectives can be distinguished:

- **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 primarily leads to priorities as set from the perspective of the societal risk: focus on pool fire and BLEVE, although from the broader perspective of the whole area also on toxic scenarios. For these scenarios the traditional perspective is that of probability reduction and general preparation, in combination with specific demands for buildings close to the railway. An important addition is the focus on vulnerability reduction.
- **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.[17]
- **Psychological perspective**. 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

[17] It is important to realize that the criterion for economic security as defined by the national government does not include (structural) damage to the economy, but only direct costs of an incident. If this definition would be widened, the impact scores of the scenarios on the economy might be higher than up to now.

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. This perspective not only places emphasis on other kinds of scenarios than the physical safety perspective, but also may result in other kinds of objectives for mitigation, like early warning and crisis communication, but also protection against toxic fumes. Because these smaller incidents have a much higher probability (accumulating to once every 3 years an incident of some sort somewhere in the region), the perspective of a cost-benefit analysis is also completely different.

- **Ecological perspective.** 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. These scenarios have a quite high probability, for example once every 110 years a release of a toxic liquid into the water system. Because environmental damage has proven to be serious and with high costs in the past (for example the Moerdijk chemical fire), and at the same time not that well prepared, this might be another perspective for prioritization. However, the probability of a spill of a specific *aqua toxic* liquid (disastrous for the aquatic ecosystem) directly in one of the rivers (from the bridges) is deemed too little to take into account, both because these specific toxics are transported very little and because it only affects the water if it happens on the small distances of the bridges. Furthermore, the volume of just one rail container is very little compared to for example a potential incident with a ship.

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.

Because no actual political judgement has been made about the risk evaluation, all these different perspectives have been taken into account in the next step of capability assessment (see separate report).

Public risk awareness and concerns of inhabitants

A totally different perspective is that of public risk awareness. When comparing different risks (all hazard) to one another, the public concerns might be a relevant factor. The rail transport as such is a known issue and generates public concerns, although not always very outspoken. There are no direct indications there is a difference in the feelings about the different subscenarios for rail transport. Sociological, psychological or cultural research about the risk awareness concerning these specific scenarios could not be found. In general it might be said that probability reduction will mostly be preferred above impact reduction or disaster preparedness ("prevention is better than cure"). Also it can be assumed that people prefer good rescue services and disaster relief above being left to their own resilience. From the spatial angle a

hypothesis is that people living close to the railway have higher awareness and more concerns and therefore will press more for mitigation and will be more willing to play their own part in prevention and preparation. Overall, the perspective of public risk awareness has no clear leads to prioritize mitigation policies towards specific scenarios or impacts. For this more research or a clear public participation process would be necessary. However, one general option results from this perspective: risk acceptance. If there is no real public concern, even if there would be transparent awareness, a policy option is the acceptance of the risk. Because this should always be accompanied by transparent risk communication, it can be doubted whether in the end there will be real acceptance if people realize the hypothetical political choice "not to do anything". Because acceptance also is directly related to the costs of prevention, it is advised to postpone this option until after the capability assessment.

Existing policy priorities and political programs

The need for prevention is also derived from existing programs already in place. For this we have to refer to two perspectives:

- **Probability reduction**. The national government, together with the transport companies and railway maintenance company (ProRail) is responsible for measures to ensure the inherent safety of the transport and to monitor and enforce (inspection agency and police). This encompasses measures for the rail infrastructure itself (like normal and electronic signs, safety systems and general state of maintenance), for the trains (pressure resistance of wagons, linking of trains, maintenance of seals), for shunting yards and their systems and for the personnel involved (training, procedures, safety culture). Especially the safety breaking system has long been an important discussion in the national parliament, resulting in the upgrading from ATB to ATB-vv and in some years to ERTMS. However, all these policies are a national responsibility and have already been subject to improvement and have been discussed between the national government and the municipalities of Dordrecht and Zwijndrecht. From this perspective further probability reduction as a whole is not a priority for the local risk mitigation policy which is the focus of PRISMA.
- **Disaster preparedness**. Also the disaster preparedness for the Railzone is an existing policy. With national money the project Railzone is aimed at improving the disaster preparedness by several means. The project includes measures to ensure accessibility of the railway for emergency services, the water supply for the fire brigade, early warning and surveillance with cameras, a special fire truck with foam for chemical fires and specific risk communication to the inhabitants. Because of this existing project disaster preparedness is supposed to be optimized and is therefore not a priority for the risk mitigation plan of PRISMA.

Prestigious projects

Sometimes prestigious projects might be part of risk prioritization. Mostly this has a negative impact: projects concerning economical and spatial development very often obtain priority above risk mitigation or even prevention of an increasing level of risk. In case of the railway zone the so-called Maas terrace might have been such an example. This is a site on the waterside directly next to the Dordrecht railway brigde, where a housing project was envisaged. However, external safety certainly was a main concern in the design, showing the willingness of the responsible politicians to take risk issues into account, even though the site at itself is certainly not ideal. Because of the financial and economic crisis for the moment this kinds of projects is not expected, although it cannot be ruled out that the options for future developments also will play a part in the decision about risk mitigation priorities.

Imbalance between the risk level and the actual potential to save people

A final risk evaluation perspective (although more perspectives are possible) is that of a fundamental imbalance between the risk and the potential or capabilities of the emergency services to battle an incident and rescue people. Disaster preparedness measures only can achieve so much. In the end there are always scenarios possible which transcend the capabilities of disaster relief and therefore lead to high impact. Because most of these scenarios have a low probability, in most case the risk is just accepted. However, in some cases this fundamental discrepancy between the potential impact and the preparedness is an indication for targeted mitigation measures. In this case this is particularly so for the toxic scenarios. Their impact is potentially catastrophic, whilst the options for disaster relief are limited. From this perspective a priority can be given to combination strategies of mitigation measures, disaster preparedness and risk communication for toxic scenarios.

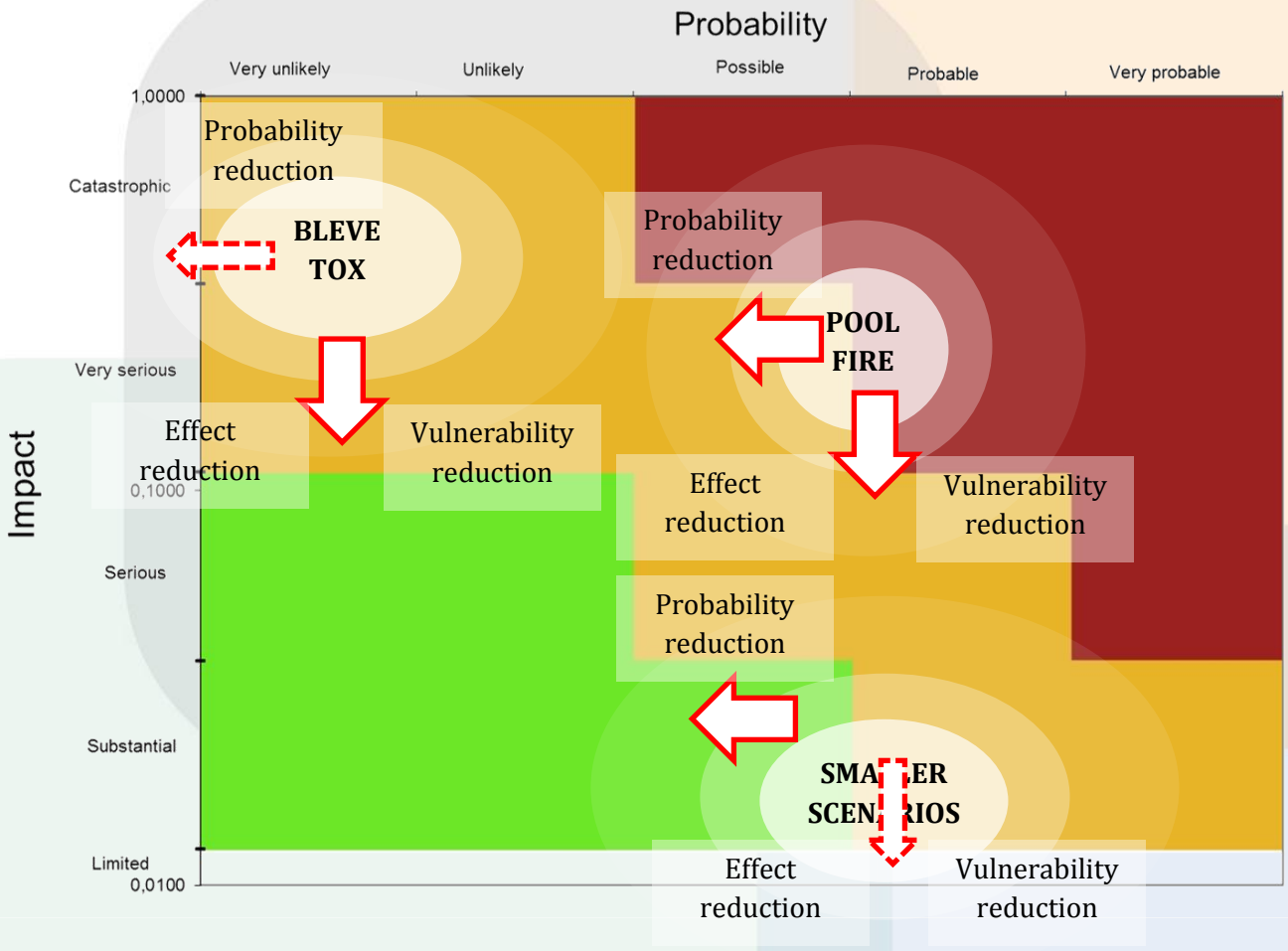
4. Objectives

Once insight is gained in the nature of risks and the political preferences regarding the prioritization of risks, the following step is to set general objectives for each of the chosen priority risks. In the context of MiSRaR an objective is defined as a (political) decision on a concrete policy for mitigation (and also disaster preparedness), in terms of a desired, measurable outcome on society.

This kind of political objectives is deemed necessary as a guideline for further identification and (cost benefit) analysis of mitigation measures, resulting in a concrete mitigation plan. Without insight in the political objectives there is a serious risk that the further technical assessment of mitigation measures is directed at the wrong kinds of policies. For example, in case of tunnel safety the experts might do research into lifesaving mitigation measures, while for the politicians maybe the most important is to prevent a tunnel from collapsing and thus inflicting serious damage to transportation and industries and the national economy in general. Without political consultation beforehand the technical research and expert judgement on mitigation might become useless.

On the other hand the expectations of such a political consultation on objectives should not be to high: without knowing the financial consequences of the final mitigation strategy it is not certain whether the chosen political objectives will prevail till the end of the mitigation process. Preferences might shift and even more so when the costs of the objectives prove to be high. Moreover, before the assessment of mitigation measures it cannot be known for certain which kind of measures will be most (cost) effective. The setting of objectives therefore must not limit the further technical research too much. There must be room for assessing other mitigation measures which not directly address the set objectives, for they might prove to be more desirable in the end. For this reason the setting of objectives should be restricted to the desired societal outcome and should not include actual concrete mitigation measures.

The risk diagram again provides 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, the following objectives have been selected as the starting point for the capability assessment (see separate report). As said before, 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[18]

[18] The national policy for probability reduction is a very current topic in The Netherlands. The deputy Minister for Infrastructure has decided to implement an update of the rail safety system on all railway

- 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 (separate report) should therefore be 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 is mainly focused on measures to reduce exposure and susceptibility of humans, the man-made environment and the natural environment.

signals. However, an undesirable side effect will probably be that the Ministry will decide to lower the probability estimates for train incidents. Because the zoning alongside the railway is directly related to the probability calculations, the safety zoning might become smaller, leaving more room for housing projects closer to the railway, whilst the effect distances of an actual incident stay the same. In this case future incidents (though maybe lower in probability) will cause more fatalities, injuries and damage.

5. Mitigation strategy

The full capability assessment is presented in a separate document. In this chapter the main conclusions are presented.

5.1 The capability assessment process

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.

5.2 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. 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*.

Existing capabilities

Before the identification of new mitigation measures and policies, the capability identification is also meant to resume the existing policies.

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), replacement on the middle long term of ATB(-vv) by the European Rail Traffic Management System (ERTMS) and the so-called 'BLEVE free' train concept. Furthermore, the Ministry for Infrastructure and Environment has implemented the so-called 'basic network' (Basisnet) for the transport routes of hazardous materials.

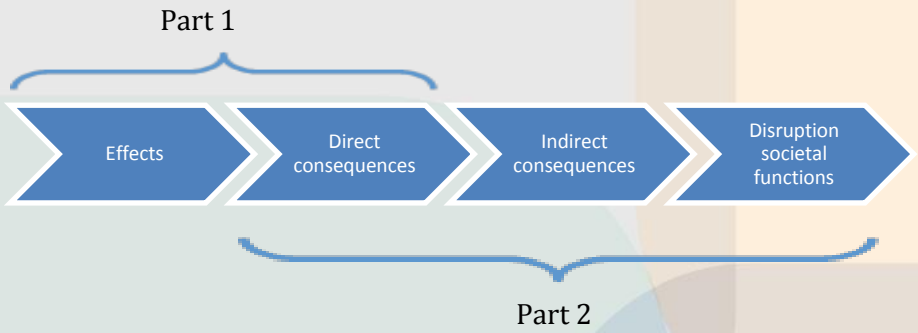
In The Netherlands the (single hazard) risk analysis for external safety of industries and transport of dangerous substances is regulated by Law and Decree. Municipalities and provinces are required to calculate the so-called "localised risk" and "societal risk" and ask for advice by the fire services on mitigation and prevention policies. 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. The fire services provide advices on how to lower the societal risk, by means of prevention and preparation.

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'. 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 fire resistances rules should be observed.

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

Event tree analysis

As a first step a detailed experimental event tree was designed for the pool fire. 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. Therefore the decision was made to divide the first experimental event tree in two 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.

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. The capability identification resulted in three main strategies in which the identified capabilities have been divided.

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.[19] 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. 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 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.

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

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 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[20] might lead to increased distances at some points.[21] 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.

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

[20] 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.

[21] 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.

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.[22] 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).[23]
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".

[22] 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).
[23] 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 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.

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.[24] 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 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

[24] 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.

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[25] 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 paragraph 5.3 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.

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.

[25] 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.

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[26]:

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 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[27] (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).

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

[27] 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.

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.[28] 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. [29] This could not only provide extra protection against incident with toxic liquids[30] 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 unhealthy, but too quick is energy insufficient and also more dangerous in case of rail transport incidents. The inclusion of safety in the existing isolation advices and subsidies requires targeted attention for the recognition of "air leaks".[31]

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

[28] The municipality of Zwijndrecht itself seems to have no specific housing isolation subsidies.
[29] 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.
[30] 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.
[31] *Bouwkundige maatregelen externe veiligheid (architectural measures external safety)*, InterProvincial Counsel, 2010, pages 34-35.

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.[32] 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).

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

[32] 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.

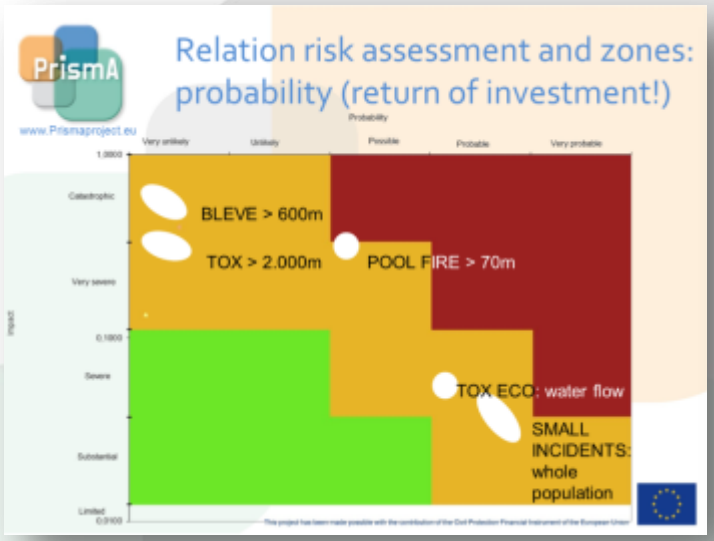
incidents: during the second one in 2014 the emergency services could directly build on their experiences from the first one in 2011. This enabled quicker answers and better insight in the actual strategic questions and demands of the population. Because this was only for a "smoke scenario", the same still has to be developed for toxic gas and liquid scenarios.

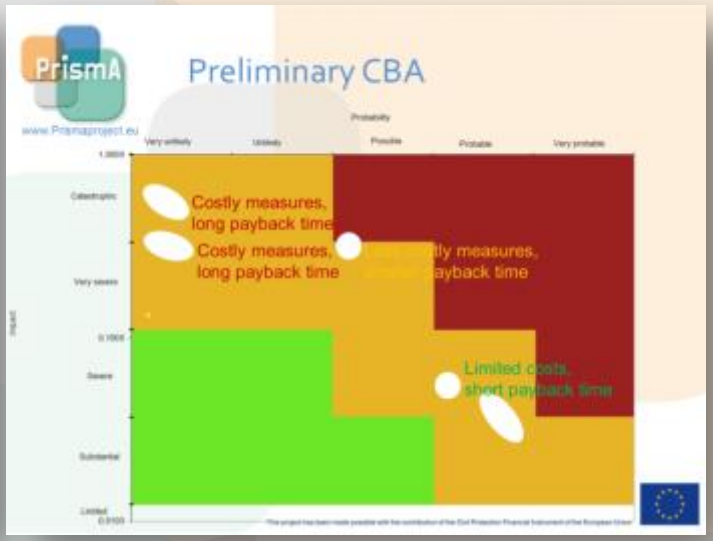
3.6 Improved preparation of containment of ecological spills

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.

5.3 Capability analysis

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. 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.

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.

	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[33] (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),

[33] 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[34]	Benefit score	Benefit per year
1. Spatial safety				
1.1 Assessment tool spatial safety	All	N/A[35]	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[36]	55	78	1,42
1.6 Integration of defence against toxic fumes in housing isolation subsidies	All incidents emission[36]	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[37]	3	59	19,67
3.3 Improved preparation of decontamination	Toxic scenarios >100kg emission	5.265	37	0,01

[34] 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.
[35] 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.
[36] 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[37]	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	+/-

[37] 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.

5.4 Capability evaluation

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.

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

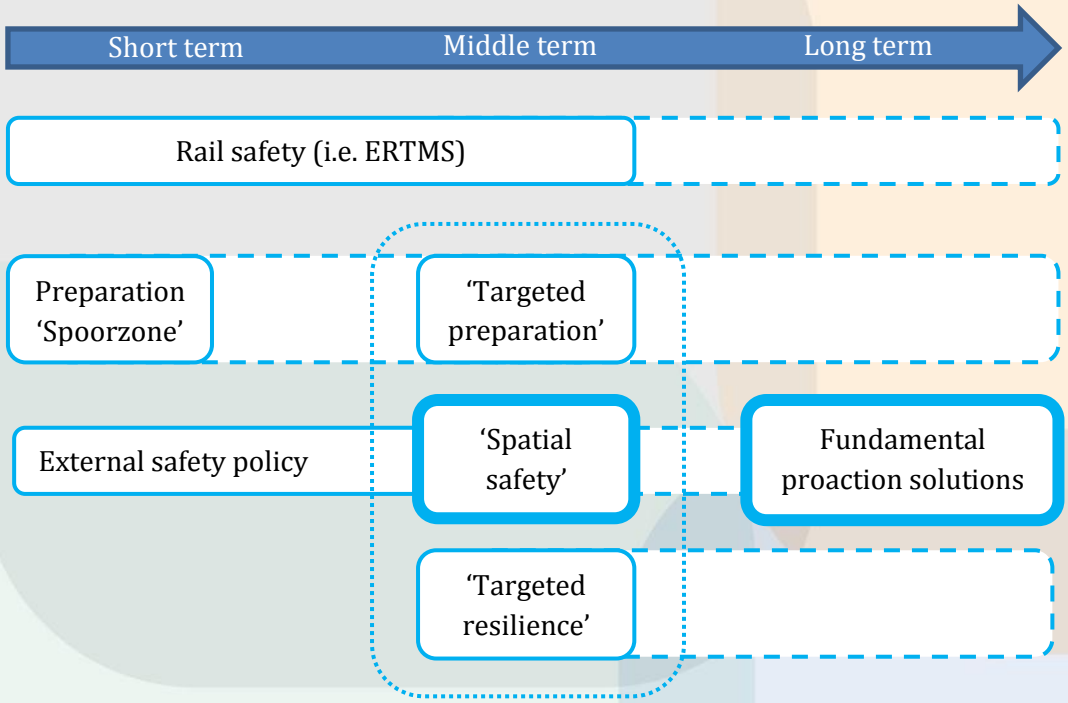
part of the economic perspective does not suggest any specific prioritization between the measures as identified and analysed for vulnerability reduction. However, this perspective does suggest serious attention for potential long-term solutions. Concerning prevention of secondary societal impact (which 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.

5.5 Summary of the proposed mitigation strategy

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



Capability analysis PRISMA

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.[38]

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.

[38] 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.

1.3 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.

5.6 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.

6. Resources

For each of the recommended middle term actions the following use of resources is suggested. Because PRISMA is a testing project not aimed at actual implementation, no concrete budget is presented. The proposed resources are mainly to be found in cooperation and forming alliances.

1. Spatial safety	
1.1 Develop an assessment tool spatial safety ('afwegingskader ruimtelijke veiligheid'), test and implement it.	The development of the assessment tool and research into safety distances requires a strong coalition between the municipalities and the safety region. The required time investment of the partners can be quite substantial, as this tool is very fundamental for the future cooperation. It is recommended for the future to look more detailed into the municipal policy for 'ground exploitation' (abbreviated as GREX). If you want to implement concrete measures in buildings you have to know which of them you could formally demand and which the municipality could take into account in the financial valuation of grounds in the GREX. The same is also valid for the implementation of water supply for the fire brigade in the spatial plan. Ideally one should also try to assign value of 'increased attractiveness' of an area if the risks are reduced (economic benefits and increased ground value). Relatively cheap mitigation measures could easily be incorporated in the GREX, because in building projects very often big sums of money are involved.
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.	For this action an alliance is suggested with the critical infrastructures. This action fits within the proposed EU project FRENDS, of which the safety region will be one of the main participants if it is awarded.
1.4 Implement increased zoning of vulnerable objects as part of the assessment tool for spatial safety.	See 1.1 and 1.2.

1.5 Expand closable mechanical ventilation.	The annual costs for an organization to be connected to the automated system are around 1,500 euros. The main aim should be to convince organizations and citizens about the necessity of the system.
1.6 Integrate defence against toxic fumes in housing isolation subsidies.	The costs of actual measures are part of the existing subsidies. Some costs will have to be made to adapt the current advices to the guidelines for defence against toxic fumes. This might be possible within the current policy capabilities (personnel)of the municipalities.
1.7 Perform further research with the water boards to see if compartmentalisation of the sewage system is possible.	The recommendation is to perform research in alliance with the water boards. This might be possible within the current policy capabilities (personnel) of the safety region and the water boards.
2. Targeted resilience	
2.1 Implement targeted risk communication in correlation with the safety zones of the assessment tool.	This action might be possible within the current policy capabilities (personnel) of the risk communication department of the safety region. However, a prioritization of activities might be needed.
2.2 Strengthen local networks to increase community resilience.	For this public participation is key. The current capabilities of the safety region to address such an approach are limited. The implementation of this action might be seriously impeded if no solutions are found.
2.3 Advocate for additional preparation (procedures, training) of the "internal office assistance" (BHV), to increase the self-reliance of organizations and to expand the internal focus with an external one.	For this action an alliance could be formed with Falck. The required investment of the safety region might be limited to some conservations and the drafting of some general principles about what would be expected of BHV in case of an (external) rail transport incident.
3. Targeted preparation	
3.1 Research and implement further options for improved early warning.	Research into the options could be done with the existing personnel of the safety region. The costs and required capacities for actual implementation of the outcome of this research cannot be forecasted beforehand.
3.2 Improve the crisis communication.	This fits within the existing policy priorities of the safety region and will have to be done in close cooperation with the 2 municipalities.

3.3 Improve the preparation of decontamination.	This probably requires quite a substantial investment of time and resources. An alliance should be made between GHOR (medical emergency management), fire brigade, ambulance service and hospitals. Recently a national guideline has been presented for 'small decontaminations'. This might be an incentive for the partners to invest in the decontamination for Spoorzone scenarios. Perhaps national partners could be found (RIVM, IFV).
3.5 Improve the preparation of public health reviews.	In many aspects the preparation of public health reviews is a national responsibility of the RIVM. However, also locally preparations have to be made. With the experience of 2 Moerdijk incidents the safety region might be able to improve the preparation in close cooperation with RIVM.
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.	This starts with just a dialogue. An alliance can be formed with water boards, Rijkswaterstaat and the water police. The actual investment in case the partners really want to prepare, is not very large and might be solved within the existing working programs.
Long term proaction	
Research into long term fundamental solutions	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. The first required resource for this action is to lobby with the national government and the industry and transport sector to raise awareness about the potential economic impact of local incidents and the need to prevent this.
National agreement to prevent risk substitution	The required first step is to lobby nationally for 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. For this lobby a shared vision of Dordrecht and Zwijndrecht is

	needed. Furthermore the lobby should be facilitated by juridical advice about the formulation of the agreement and its relation to the formal legislation of the Law on transport safety and the Decree transport routes external safety.

Index annexes

Annex I.

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