CHEMICAL ENGINEERING TRANSACTIONS

VOL. 48, 2016

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Eddy de Rademaeker, Peter Schmelzer

ISBN 978-88-95608-39-6; **ISSN** 2283-9216

DOI: 10.3303/CET1648159

Rail Transport of Hazardous Substances from the Perspective of 'All Hazard' Risk Management

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In the Netherlands the method of Quantitative Risk Analysis for external safety risks of transport of hazardous substances is solely focused on fatal casualties. The transference of this methodology into spatial planning principles results in limited safety zones wherein expensive measures are required. In the EU PRISMA project this current approach was compared to the new Dutch 'all hazard' risk assessment methodology. In this method the scope of the assessment is broadened to all kinds of impacts, including physical, economic, ecological and social effects. Using event tree analysis for all these impacts, a broad set of potential prevention measures can be identified. A preliminary societal cost-benefit analysis has indicated that cheaper safety measures in a much larger zone could be advisable, as well as protecting against other kinds of scenarios. A whole different approach towards spatial safety comes into view, aimed at correlating spatial zones with the cost-benefit ratio of measures for different scenarios, from an 'all hazard' and 'all impact' perspective and in cooperation with all relevant stakeholders.

1. Introduction

Within the European Union the question arises how sectoral risk management for SEVESO industries and transport of hazardous substances relates to a public 'all hazard' approach. The EU has an active policy to encourage Member States to build transparent and integrated risk management processes, both at national and local level. This effort is strengthened by the recent Sendai Framework for Disaster Risk Reduction, which aims at a better understanding of risks, integrated risk governance and cooperation across all relevant sectors (United Nations 2015). The current central paradigm is integrated risk assessment as a basis for prevention, combined with integral resilience against all kinds of hazards: from floods to disruption of critical infrastructures, from social unrest to pandemic zoonosis, from extreme weather to industrial accidents. In this kind of integrated risk management processes the involvement of stakeholders from all relevant sectors is crucial, in order to analyse interdependencies and cascade effects and to increase support for intersectoral safety policies. The EU therefore aims at cooperation across sectoral and administrative borders, trying to involve public entities on all levels, critical infrastructures and different kinds of 'risk sources', like industries. However, at the same time the interconnection of this all hazard approach with existing sectoral safety regulations, environmental protection policy and spatial planning processes remains a daunting quest. In the long term, the EU aims at the integration of safety distances and spatial measures into spatial and land-use planning policies (European Commission 2010), but in the actual local practice across Europe this ultimate goal is still faraway. The experiences of South-Holland South in the EU projects MiSRaR and PRISMA are a showcase for the EU-wide lessons for the development of this kind of cross-sectoral connections.

2. EU projects MiSRaR and PRISMA

From 2010 till 2014 local and regional governments from the Netherlands, Portugal, Italy, Bulgaria, Estonia and Greece have cooperated in the EU projects MiSRaR and PRISMA. The aim of MiSRaR was to exchange knowledge on spatial risk mitigation, including methods for risk assessment, capability planning and stakeholder involvement. The shared insights have been compiled into the practical, non-technical MiSRaR handbook, aimed to help local governments to develop risk management processes. In PRISMA the lessons

Please cite this article as: Houdijk R., 2016, External safety from the perspective of public "all hazard" risk management: lessons on spatial planning for rail transport of hazardous substances, Chemical Engineering Transactions, 48, 949-954 DOI:10.3303/CET1648159

of MiSRaR have been simultaneously tested on local cases for external safety, urban fire safety and wild fires, whilst the international project partners were learning from each other's experiences. For the Safety Region South-Holland South (the Netherlands), lead partner in both projects, the test case was rail transport of hazardous substances in the Dordrecht-Zwijndrecht area, one of the busiest 'transport hubs' in Western Europe. The risk of rail transport and the potential safety policies were assessed, using on the one hand the Dutch legal framework for external safety and on the other hand the Dutch methodology for all hazard risk assessment. The comparison between the two methods resulted in remarkable conclusions and denote a new beginning for spatial planning principles along transport axes.

3. The case of the Safety Region South-Holland South

South-Holland South is situated at a key point in the Dutch railway system. It is at the junction of the transport routes between the Port of Rotterdam, the Port of Antwerp and the German industrial Ruhr area. A decade ago the Dutch government has built the so-called 'Betuwe' cargo railway line to Germany. A significant part of the resulting transport movements passes directly through the centres of the cities of Zwijndrecht (pop. 45,000) and Dordrecht (pop. 120,000). The forecast is 50 thousand wagons with hazardous materials for the year 2020. In the densely populated city centres of both municipalities the housing is built as close as 20m from the railway (Houdijk 2013). Needless to say that according to the national 'external safety calculations' the Dordrecht-Zwijndrecht area is the main bottleneck in the Dutch railway system (IenM 2011a).
In recent years the national government has implemented the so-called 'basic network for transport of hazardous substances', accompanied by building restrictions alongside transport routes. For the Dordrecht-Zwijndrecht area a special 'Spoorzone' project, mainly directed at disaster preparedness, was implemented. Furthermore, fundamental mitigation options for Dordrecht have been discussed, such as a tunnel (IenM 2009) and a completely new trajectory around both city centres. Up to now, these options have been deemed economically infeasible, leaving the municipalities of Zwijndrecht and Dordrecht with a significant risk. To protect their inhabitants, the municipalities have to consider the consequences for their main policy instrument: spatial planning. Therefore, already in 2004 the municipalities have adopted an assessment framework with spatial principles (TNO 2004), based upon the Dutch external safety regulations. But what would be the result if the assessment is not based upon these sectoral regulations, but brought in line with the recent all hazard risk assessment methodology in the Netherlands? Does this result in different spatial planning principles?

4. The external safety approach

4.1 QRA methodology

In the Netherlands for external safety of industries and transport of dangerous substances a Quantitative Risk Assessment (QRA) method is used. Municipalities and provinces are required to calculate the so-called 'individual risk' (IR) and 'societal risk' (SR). The IR is defined as the probability that a person will die as a direct consequence of an occurrence involving a hazardous substance. By Law the IR for stationary objects and transport may not exceed once every million years (10^{-6}). The 'societal risk' is a cumulative distribution function of the annual probability of at least 10, 100 or 1000 persons dying due to an unusual occurrence involving a hazardous substance (IenM 2014). The SR is expressed as a curve, the so-called fN curve (frequency-numbers). For the SR the legislator has consciously adopted a non-normative approach, only providing a holdfast in the form of the so-called 'orientation value'. Any exceeding of the orientation value or any substantial growth of the fN curve still below the orientation value should be "justified" by the responsible government (municipalities and provinces), meaning they are publicly accountable for their decision to accept the SR under the condition of specific measures. The Safety Regions provide advice on how to lower the IR and SR by means of specific prevention and preparedness measures.

4.2 Outcome of the QRA

The Dordrecht-Zwijndrecht area has the highest SR of the whole country: 11 times above the orientation value in the year 2008. The SR for the so-called 'Leerpark' area is 43 times higher than the orientation value, growing to an expected 61 times higher in the year 2020. The IR calculations for the same area resulted in a 10^{-6} zone of 25 metres for 2008 and 99 metres for the forecast transport in 2020 (Arcadis 2009). The QRA suggested priority for BLEVE scenarios, because it has the highest contribution to the SR and for the areas of Dordrecht Station and the Dordrecht curve (Leerpark), because at those sites the SR and IR are highest.

4.3 QRA based principles for spatial planning

The IR '10^{-6} contour' is represented as a fixed 'safety zone' wherein by Law (IenM 2014) no buildings for people with impeded self-reliance, e.g. elderly homes, hospitals, schools ('vulnerable objects'), may be built. Because the transport volumes might differ each year and the numbers of inhabitants might fluctuate, the

calculated size of the safety zone is not absolute. The calculated difference between 25 metres in 2008 and 99 metres for the year 2020 is difficult to implement in a general spatial principle. However, it is important to realize the restrictions only apply to new buildings and not to existing housing.
By Law (IenM 2014) an additional zone called the 'pool fire attention area' has been set. In this area the realization of 'vulnerable objects' is limited. Before building this kind of objects the potential consequences of an incident with flammable liquids have to be taken into account. If the building of such an object within the 30 metres zone is considered nonetheless, specific precautionary safety rules should be observed, like the use of building materials with an increased fire resistance, manual shutdown of mechanical ventilation systems and locating escape routes outside the 30m zone (Safety Region SHS 2011).

5. The 'all hazard' risk assessment approach

5.1 All hazard methodology

In recent years the Safety Region South Holland South has obtained practical experience with the Dutch method for all-hazard risk assessment. This method was first developed for the National Safety and Security Strategy (Ministry of Security and Justice 2007) and later adapted for regional use (Houdijk et al. 2009). The method consists of risk assessment and capability assessment. In the risk assessment the 'impact' and 'likelihood' of disaster and crisis scenarios are analysed. To compare the completely different kinds of risks, a distinction is made between the different sorts of consequences for the various kinds of 'risk recipients'. These different impacts are defined by the so-called 'vital interests of the society', a concept that has become part of the joint approach to national risk assessment within the EU (European Commission 2010). The six vital interests used by the Dutch Safety Regions are territorial security, physical safety, economic safety, ecological safety, social and political stability and safety of cultural heritage (Houdijk et al. 2009).
In order to rank the risks a 'risk diagram' is used. In this way the two dimensions of risk (impact and likelihood) can be taken into account separately. The analysed scenarios are presented in the risk diagram and evaluated by the decision makers on specific subjective criteria. These political criteria can differ for each region, municipality and in fact for each individual decision maker and might include such aspects as public risk awareness and concerns of inhabitants, existing policy priorities and political programs, quick wins and/or an imbalance between the risk level and the actual disaster preparedness (Houdijk 2013). The outcome of this political risk evaluation is a prioritization of the assessed risks, as well as objectives for the safety strategy.
In the second stage a capability assessment is performed for the prioritized risks. The goal is to enable the political decision-makers to make strategic choices on concrete policies and measures that contribute to the selected objectives (Houdijk 2014). To identify potential measures a 'bow tie analysis' is made. Subsequently the identified measures have to be analysed on their respective merits: what are the costs and their benefits. Because the risk is defined in terms of vital interests, the respective benefits of measures for these vital interests have to be taken into account as well. Paramount in this whole process is the involvement of all relevant stakeholders. On the one hand because they have the expertise to identify measures and on the other hand because a shared understanding helps to build support for the resulting safety strategy.

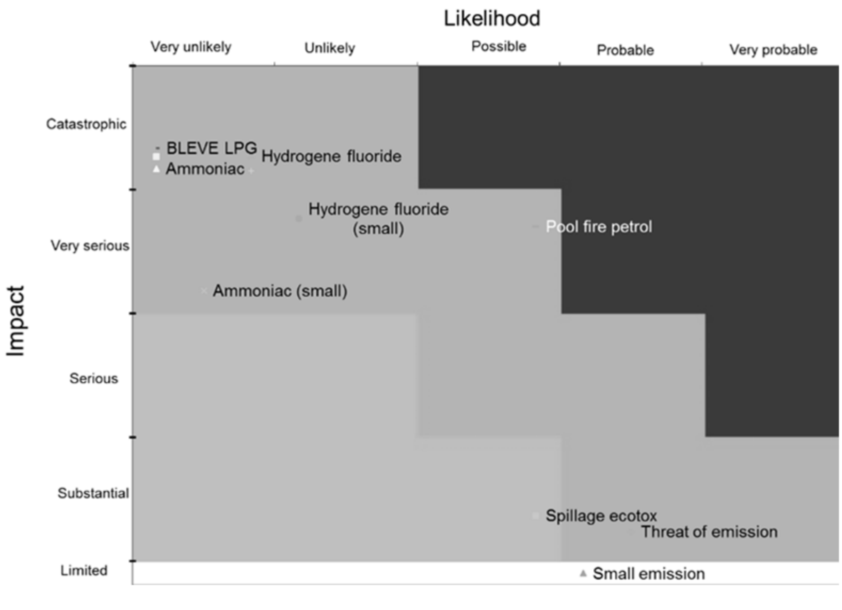

Figure 1: Risk diagram of rail transport scenarios based on the all hazard risk assessment methodology

5.2 Outcome of the all hazard risk assessment

The risk assessment on the rail transport in the Dordrecht-Zwijndrecht area, using the all hazard methodology, included scenarios for BLEVE, pool fire, toxic gas (ammoniac), toxic liquid (hydrogene fluoride), ecological toxic, small emissions (less than 100kg) and “threat” of an emission. The risk diagram (see Figure 1) showed BLEVE and toxic scenarios to be of catastrophic impact-low likelihood, the pool fire as very serious impact-medium likelihood and the smaller scenarios as low impact-high likelihood. This resulted in the following recommendations: give priority to reduction of injured, fatalities, disruption of daily life, psychological impact and economic impact, because those vital interests are threatened the most. For BLEVE and toxic scenarios, give extra priority to effect and vulnerability reduction, because their probability already is low, but the potential impact is catastrophic. For the smaller scenarios give extra priority to probability reduction, because their high probability is the main concern. 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. Give priority to preparedness measures that are helpful for all scenarios and for the whole region, because the combined probability of all scenarios in the whole region is very high: a rail incident once every 3 years, a serious incident involving a substance emission once every 29 years. Give specific priority to pool fire scenarios, because they have a medium-high impact and a medium-high probability (Houdijk 2013).

5.3 All hazard assessment based principles for spatial planning

Because the capability assessment focuses on expert judgement and stakeholder involvement, the resulting safety measures differ in various aspects from the legalistic focus of the QRA. The first recommendation was to have a voluntary decision by 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. The proposal designed in the project was to set the increased distance at a level which reduces to zero the probability of an inhabitant or worker inside of a building being killed by a pool fire, because the pool fire risk has highest probability, making it more difficult to explain why it has not been mitigated (Houdijk 2014). Based upon the Guideline for Risk Analysis of Transport (IenM 2011b), this would mean a safety zone of 60m, that would protect against inside fatalities for 94,7% of the total incidents. The second recommendation was zoning of specific functions, like ‘vulnerable objects’. But instead of the legalistic approach of the QRA -focused on expensive measures for limited zones- the selection of measures could be based upon a cost-benefit analysis. Starting to consider measures in the ‘maximum credible’ effect zone, the ratio might be negative, because of the big areas and low probability. But this can be ‘sized down’ to a smaller scale until the ratio is neutral (smaller scenarios, smaller area, higher probability). This approach brings into view measures against toxic scenarios, which are not considered in the QRA. Therefore, a recommendation has been made to expand the closable mechanical ventilation. In case of toxic clouds and vapours and also in case of smoke, it’s desirable to shut ventilation. The regulations on the pool fire attention area require the ability (at least manually) to shut down mechanical ventilation in vulnerable objects within 30m of the railway. In the Spoorzone project South-Holland South has developed a devise to shut down mechanical ventilation automatically by the 112 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, which is cheap compared to most of the other measures. Based upon the risk assessment and the fact that it has a positive cost-benefit ratio it is preferable to implement this system up to 2000m or even more (Houdijk 2014).

A further recommendation has been made to prevent the discontinuity of vital infrastructures. 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. This might even result in additional direct and indirect fatalities and wounded, because people are overexposed to effects and the rescue and medical aid is delayed and obstructed. The main focus therefore should be infrastructure for communication and electricity. The most important measure here is zoning: have enough space between the railway and vulnerable objects in the electricity grid and communication systems. But also specific physical vulnerability reduction measures could be undertaken.

Finally, it’s important to have ‘room to manoeuvre’ for urban planning. Insight in the different effect zones helps to 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 to another. To this end risk mapping and mapping for spatial planning should be more closely connected. The assessment on rail transport in the Portuguese city of Aveiro -

performed in the PRISMA project- has shown that mapping of all components of risk (probability, effect, vulnerability) can really build a bridge between safety professionals and spatial planners (Seabra 2014).

6. Discussion: problems using the QRA method for spatial planning

There are fundamental doubts about the validity of the outcomes of the Dutch QRA method. The results of different software calculation packages can differ dramatically (Van Xanten et al. 2013). Also in the PRISMA project this problem has been encountered. In the search for valid scenarios the outcomes of the RBM-II software and EFFECTS software have been compared to each other. This comparison brought to light significant differences in effect distances for the exact same scenario input. This raises serious questions about the validity of the current QRA based safety policies. In the policy practice it matters little whether this is caused by the 'robustness oriented' methodology itself or mainly by the (lack of) knowledge and experience of the users as Van Xanten et al. suggest (2013), because the outcome is the same: safety choices that are presented to public decision makers as a rational and informed decision, but in fact cannot live up to that claim and are more of a 'ritual' (ibid.). Moreover, the QRA provides little or no insight in the positive effect of safety measures (ibid.) and therefore has limited relevance for spatial planning. The result in some cases may even be cosmetic land-use choices aimed at reducing the calculated risk, but lacking a common sense judgement. The most tangible example is the focus on expensive construction measures in the 'pool fire attention area'. This is a legal requirement to be able to build close to the railway, but in many cases lacks a positive cost-benefit ratio. In case of most pool fires and certainly of a BLEVE the buildings in question will simply burn down, with all the expensive measures in it. Certainly, the measures could save some lives in that first area (up to a point), but will not protect the inhabitants that are situated just a few meters outside the legal zone, but are equally in danger. The question remains at what locations and in which zones could each Euro invested in safety provides the most benefit.

Illustrative for this problem of spatial relevance of the QRA is the study of RIVM & TNO (2007) for the railway zone Dordrecht-Zwijndrecht. This test case was an attempt to 'map the societal risk'. The study resulted in several experimental maps showing the level of the SR for respective areas and the relative contribution of specific areas to the calculation of the SR. The resulting maps have shown clearly that the area around the Dordrecht Station and the Dordrecht curve have the highest SR. 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 SR. Using the experimental mapping at first it was concluded that flammable gasses (like LPG) contribute the most to the SR. However, after taking into account the full population -instead of just the population in the first 500m- it was concluded that the influence of toxic liquids is much larger than estimated in the first approach. Even at 1350m the toxic liquids still have a large influence. Main conclusion was that the normal approach of taking into account the population up to 500m, 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 no spatial limitations can be made beyond 200m (Houdijk 2014). It's very striking that changing the scope of the analysis -but using the same prescribed methodology- the outcome is so very different. Instead of a focus on preventive measures for BLEVE scenarios around the station area, the alternative analysis suggests a focus on preventive measures for toxic scenarios in the whole city. So the question is not only were to spend each Euro most wisely, but also on which kinds of effects. Effect and vulnerability reducing measures for pool fire or BLEVE are after all quite different from those for toxic scenarios.

Surprisingly the QRA method remains solidly embedded in the Dutch legislation, despite the numerous and serious problems and drawbacks. Uijt de Haag et al. (2013) conclude that the QRA fulfils its most important goals of transparency and verifiability, even reducing the "discussions between the competent authorities and the operators [of establishments handling, processing or storing dangerous substances]". Although a common ground and shared understanding between government and industries in itself is a huge benefit, the lack of discussion does not make society safer per se, nor is it proof of acceptable or accountable risk management.

The municipality of Dordrecht makes an effort to use the QRA approach as wisely as possible. For example in the development of the Leerpark area, the land-use has been optimized by using the areas closest to the railway (and a road with similar transport) as parking spaces and by smart repositioning of planned schools and residential homes. However, the method makes it inevitable that for very specific zones quite expensive safety measures have to be taken. This has been the case for the redesigning of an elderly home, which for political reasons could not be moved outside of the area. At the same time the remainder of the buildings stays without specific safety measures because by Law this cannot be demanded. This obstructs an effective implementation of a cheap and potentially lifesaving prevention measure like the aforementioned automated closing of 'mechanical ventilation' in buildings by the operator of the 112 emergency room.

7. Conclusion: towards a process and dialogue oriented 'all impact' approach

For the local participants the PRISMA test case seems to validate the focus of the MiSRaR handbook on the risk management process, rather than simply relying on technocratic assessments. As Van Xanten et al. (2013) state, the relevance of risk analysis outcomes might improve if they are used in a more relative sense and aimed to help decision makers and relevant stakeholders to reach a balanced understanding of their shared problems. This is exactly the aim of the alternative 'all hazard' methodology of the regional risk profiles. Moreover, this methodology makes a clear distinction between probability and impact assessment, presenting both dimensions separately on a risk diagram instead of combining them into one single risk figure. This provides more insight to the political decision makers on the specific characteristics of the risk, so they can decide upon either probability and/or impact reducing strategies for the different scenarios, making the assessment much more safety relevant than only the quantification of IR and SR (Van Xanten et al. 2013).
The overall vision of the stakeholders in the project is that safety and spatial planning should 'meet' as early as possible and should find a "shared rhythm to dance" (Seabra 2014) 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 and finding win-win between safety and spatial development. The stakeholders therefore concluded there is the wish and need for a framework or assessment tool to incorporate safety issues more easily into spatial planning. This 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'. This framework should include different kinds of tools to gain insight in the nature of risk (Houdijk 2014). An integration of QRA methods, all hazard methods and risk mapping seems the most promising. In this way an 'area-oriented approach' (Van Xanten et al. 2013) -which corresponds with the EU and UN objectives of integral risk management- might come more into view in the near future.

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