

**Lowering risks concerning the transport of hazardous materials by rail:
an institutional approach**

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Samenvatting

*Verlagen van risico's ten aanzien van het transport van gevaarlijke stoffen per spoor:
een institutionele benadering*

In Nederland worden veel gevaarlijke stoffen getransporteerd. Een relatief klein deel hiervan wordt over het spoor vervoerd. Desondanks levert dit toch de nodige problemen op ten aanzien van risico's. Dit paper bekijkt risico's vanuit een institutioneel perspectief en of binnen die instituties een mogelijkheid is om risico's te verlagen. Dit wordt gedaan door te beschouwen hoe het zogeheten externe veiligheid beleid is opgebouwd en of hierbinnen verbeteringen mogelijk zijn. In dit paper wordt een aanzet gemaakt tot een nieuwe manier van het analyseren van en het denken over risico's.

1 Conflicts of interest between spatial planning and rail transport

A shortage of land across the Netherlands has led to the development of design and construction techniques that enables intensive use of the limited space. In the last decade, the space available adjacent to and above the transport infrastructure - particularly railway tracks - has been used at a growing rate in city centres. In addition, line infrastructure for transport of hazardous materials is mostly also in use for passenger transport and therefore often crosses densely populated urban areas. The new development strategies of the Dutch Ministry of Housing, Spatial Planning and Environment regarding space in urban areas pay special attention to these issues. However, the Dutch spatial planning policy, which aims to intensify the use of space (Ministerie van VROM, 2001), may come into conflict with the intentions set out in the Fourth National Environmental Policy Plan, which states that additional (open) space is sometimes necessary to guarantee external safety (Raad voor Verkeer en Waterstaat & Vromraad, 2003).

In the Netherlands, regulations for land-use planning in the vicinity of major industrial hazards are explicitly risk-based. This implies that potential adverse physical effects of incident scenarios are considered along with their probability of occurrence and their possible impacts. One of the main reasons for implementing the risk policy is a shortage of space, as a result of which the optimal space according to the effect distance of a worst case scenario between a risk generating activity and urban development cannot be achieved. Three main elements constitute the Dutch regulatory risk framework. These elements are: (i) quantitative risk assessment, (ii) the adoption of individual and group risk as risk-determining parameters and (iii) acceptability criteria for individual and group risk. Basically, risk consists of three components: the scenario, the probability of this scenario and the consequence of the scenario (Kaplan & Garrick, 1981). Risk is described in the Dutch policy practice as the formula: the probability of an accident multiplied by its effect. This is therefore the most frequently used definition in Dutch risk analysis.

In order to reduce the risks concerning the transport of hazardous materials by rail within the boundaries of the risk criteria, technical measures are generally taken. For example, if the risk exceeds the norm on a certain location, measures taken are for example the decreasing the maximum speed, removing track-changes from a certain part of the railway track or preventing the dispersion of hazardous substances (Wiersma *et al.*, 2004). These technical

measures then reduce the risk of transport with respect to urban planning, due to the fact that either the probability variable or the effect variable (or, of course, both) are lowered. In practice, however, still problems occur with this more technical approach as the norms that are set for this so-called External Safety Policy are exceeded in several cases (see for example Raad voor Verkeer en Waterstaat & Vromraad, 2003; AVIV & Royal Haskoning, 2005).

In this article the authors try to handle a 'Popperian view' on external safety, after the famous scientist Karl Popper. The basic idea behind his view is that scientific knowledge is not distinguished by empirical verification, but by falsifiability (see for example Leezenberg & De Vries, 2001). It is the opinion of the authors that this is also accountable for institutional frameworks. As there is no guarantee that the present institutional framework is the best way of looking at risks, the authors try to create a new way of looking at risks by means of a different institutional framework.

In the following sections, we will unfold a possible new way of managing risks in the Netherlands by matter of philosophizing on risks and deducting possibilities for a new or different institutional framework. The purpose of this article is to show what might happen if new ideas on risk management and risk analysis are implemented into the decision-making on external safety. For this to occur, we will start by looking briefly at the role of institutions in a policy field (section two). The present framework for risk management in The Netherlands will be explained in the third section. In section four we will present new ideas for a possible new institutional framework. In the fifth section, we will show what this new framework could look like. Hereafter, in section six, we will discuss what this could mean for an urban plan of a randomly picked Dutch city and how the framework could help to shape the ideas of policy makers. In the final section, we will discuss our findings and conclusions.

2 Institutions and risk management

Every policy is based on a set of basic assumptions. In the social sciences these policy assumptions are often referred to with the concept of 'policy theory'. A policy theory can be defined as the whole of hypotheses and assumptions combined that underlie a certain policy (Leeuw, 1989, p.91). These policy theories are something different than scientific theories on policy, and involve the reconstruction of the assumptions of policy makers. These assumptions of policy makers could even regard to social aspects - such as the behavior of persons or groups-, but also to the functioning of organizations or to economical aspects of

policy. These assumptions often concern causal relations (cause and effect relations) and final relations (goal and means relations). Apart from these relations, normative relations are also important in policy theories. These relations are based on (political) principles, norms and values on the one hand and expected, existing or intended situations on the other and are also called institutions. According to North: “*Institutions are the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions and codes of conduct), and formal rules (constitutions, laws, property rights)*” (North, 1991, p.97).

Daily interactions between policy actors are assumed to gradually develop into more or less stable patterns, which may also include the substantive delineation of the problem at stake and its possible solutions. This could also involve, however, the processes between the actors and the formal and informal rules according to which these processes take place. These processes are usually referred to as institutionalism (Liefferink, 2006, p.47).

More in relation to risks and risk management, safety measures are implemented to increase safety levels to a certain level. There are several measures that can be implemented against critical scenarios in such projects. Risk assessment consists of the use of all available information to estimate the risk to individuals or populations, the environment or property from identified hazards and compares this with targets and search for solutions (Vrouwenvelder, 2001). In risk assessment, generally some effort is made regarding scenario development, whereas most emphasis is put on frequency analysis and risk calculation (Rosmuller, 2001). In this respect, risk management is the application of risk information as an integrated part of the management process, including interaction with external bodies (Høj & Kröger, 2002). The relation between these aspects can be schematically visualized as shown in Figure 1.

This figure shows the relation between several aspects of risks. Moreover, it also shows the relations between (possible) formal and informal rules in order to lower risks, which will be explained after the figure has been presented.

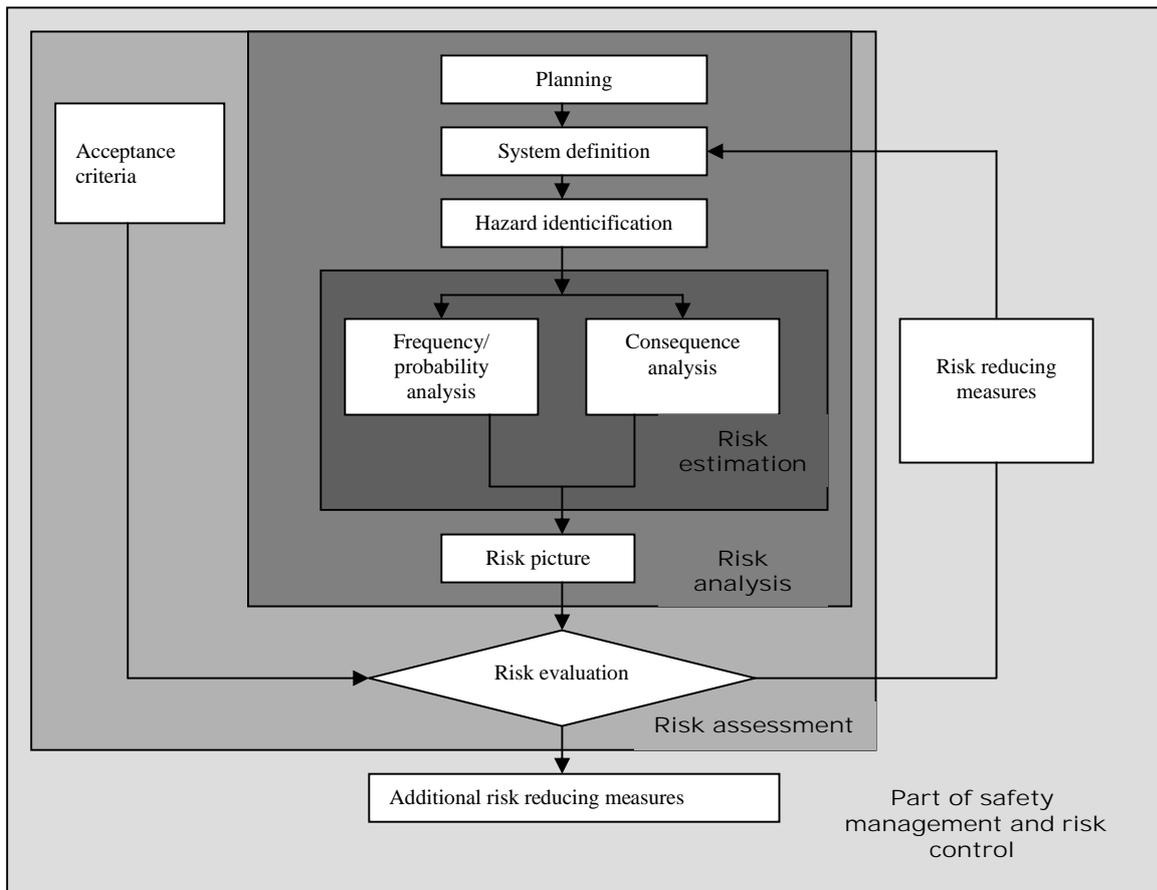


Figure 1: The risk management process (Høj & Kröger, 2002)

Risk estimation and risk analysis

In the Dutch practice concerning external safety and its institutions, transport risks of hazardous materials are estimated with several mathematical Quantitative Risk Assessment (QRA) models, resulting in a presentation of the so-called risk picture. One of these QRA models used in the Netherlands is the so-called RBMII model (Ministerie van Verkeer en Waterstaat, 2006a). This standardized model is free of use and distributed by the Dutch Ministry of Transport, Public Works and Water Management. This is done to satisfy a need for a relatively simplified, standardized and validated method to calculate relevant risk values (Ministerie van Verkeer en Waterstaat, 2006b). This model is assumed to be the benchmark model for all risk analyses to be made regarding transport of hazardous materials, except for highly complex non-standard situations, such as risk calculations in case of a building realized above the infrastructure (Ministerie van Verkeer en Waterstaat, 2006a; Suddle, 2004).

The RBMII model uses many more assumptions in its calculations than just probability and effect, but it basically boils down to the standard formula of risk of Kaplan & Garrick (1981). The model considers input parameters such as accident frequencies, the speed of the train on the considered rail track, the amount of level crossings, the amount of track switches et cetera. The effect of a possible derailment is calculated by such variables as the amount and the type of hazardous materials released, resulting in physical effects on people, which depends on the amount and duration of people living in the adjacent area and the distance between the center of the track and the built up area.

The calculations made for the IR and the GR are based on all possible scenarios. These scenarios are based on imaginary incidents with different types of transported hazardous materials. The effect of the transport of category C3 materials (flammable liquids) is dominant for the IR contours. Sometimes the effects of toxic liquids or flammable gasses are dominating (AVIV & Saxxion, 2005). Since the influence of the C3 category is dominant for IR-contours, the 10^{-6} contour appears to be hardly more than 30 meters from the centre of the railway track. The theory behind this is that a leaking tank generally cannot create a pool (fire) with a diameter of more than 30 meters. Moreover, a minimum amount of more than 3000 tanks per year is needed to create a 10^{-6} contour outside the railway track. For the calculation of the GR, the worst case scenario is a BLEVE (Boiling Liquid Expanding Vapor Explosion). A BLEVE is the consequence of the failure of a pressure vessel containing a liquefied, mostly flammable, gas. The quick change of the liquid phase to the vapor phase goes hand in hand with a big volume increase, causing the explosion-effect. In the most cases, the evaporated gas is ignited, resulting in a fireball with an effect diameter of possibly more than 300 meters causing large number of fatalities (Berg & Weerheijm, 2004). This scenario influences the GR value by more than 90%.

Risk assessment

In the Dutch practice there are two acceptance criteria. The first one is called Individual Risk (IR). This is the probability that an unprotected person dies due to an accident with hazardous materials per year on a certain spot when this person resides here a full year. The individual risk depends on the geographical position and is displayed in the form of iso-risk contours on a geographical map. The individual risk is thus not characteristic for any person, but only for the location for which it is calculated. Thus, the individual risk contour maps give information

on the risk of a location, regardless of whether people are present at that location or not (see Figure 2). The maximum allowed risk as laid down in Dutch law, is $1 \cdot 10^{-6}$. This means that an additional involuntary risk which is lower than once every million years is found acceptable according to Dutch policy. The second risk indicator generally applied in the Netherlands is Group Risk (GR). GR is defined as the probability per year that in an accident more than a certain number of people are killed. Group risk is usually represented as a graph in which the cumulative frequency of more than n fatalities is given as a function of N , the number of people killed. This graph is called the fN curve (see Figure 3).

In the Dutch risk policy, the risk acceptance standards for the IR are included in binding rules. Therefore, vulnerable objects cannot be built within the 10^{-6} contour. However, the GR is rather an indication criterion with a so-called orientation value as decision standard. Figure 2 shows two diagonal curves which represent the orientation value for GR installations (below) and transportation risk. When a calculated GR exceeds the orientation value, the acceptance of the GR must be motivated by local authorities. Economic aspects and repressive measures are widely considered in such a motivation. So, the orientation value is not binding by law and acts more as a guideline for policy makers and planners to review their plans including safety aspects. Moreover, the decision-makers - mostly the local municipality - can weigh the risk (qualitatively) with e.g. economic or environmental aspects. It should be noticed that the decision-makers are juridical responsible for accepting the exceeded risk. In practice, the GR orientation values are generally taken into account when deciding upon new projects or large urban adjustments in a consisting project with relation to urban planning adjacent to or above infrastructure with hazardous materials transport (Van der Heijden & Van der Vlies, 2005; BEVI, 2005).

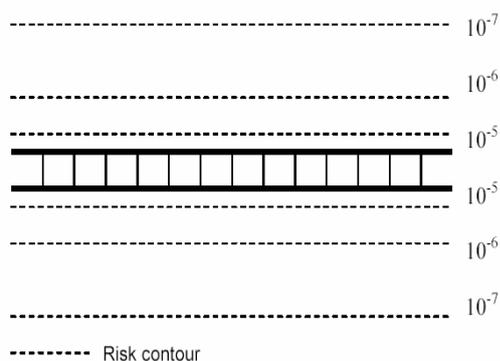


Figure 2: Schematic visualization of Individual Risk near a railroad.

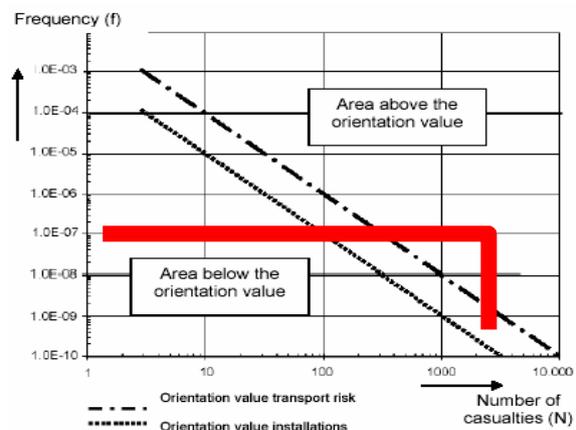


Figure 3: Schematic reproduction of an exceeding of the Group Risk criterion.

Safety management and risk control

Unfortunately a number of locations (40 to 50 spots) where current risk acceptance criteria for the group risk are already exceeded (AVIV & Royal Haskoning, 2005), such as nodes for the transport of hazardous materials, are also the locations for which the Fifth National Policy Document on Spatial Planning of the Netherlands desires intensification, combination and transformation (encircled in figure 4). One could say that in these cases risks are not as low as they should be according to Dutch policy.

To summarize the preceding, in the node *estimation of risks*, frequency and the potential consequences in numbers of fatalities along with possible scenarios is analyzed with software, e.g. RBMII. The node *Risk analysis* provides the calculated and quantified risks for the considered area in which the potentially vulnerable vicinity, including people along with the risk generating activity (transport of hazardous materials) are located. During risk assessment process, the calculated risks are evaluated with the risk acceptance criteria. In case of exceeding the norm, it can be considered if the exceeded risk is acceptable and whether risk reduction is necessary. However, there is still a large number of locations where risks are exceeded.

3 Objections to these institutions

From a command and control perspective, Dutch policy standards which relate to environmental issues are a common good. De Roo (2003) points out that the Dutch government has set out strict quantitative standards for human activities in favor of protecting the environment for more than thirty years. When the policy is made, norms effect regional and local authorities by means of generic norms which sets limits for other types of policy relating to the living environment. These norms include such environmental areas as to prevent air pollution, noise or to control soil pollution.

A calculated norm however, could provoke objections regarding the method of calculating risks. Several authors, such as Fischer (2003) and Healy (2001) object to these calculations since they consider it as a technocratic rational way of risk management and design of risk policy. In their opinion this way of managing risks is either a strategy designed to supply a technical rational basis for a centralized regulatory decision making (Fischer, 2003) or a scientific weakness to provide an instrumental, calculative and purposive rationality (Healy, 2001).

In the terms of quantitative risk analysis, Fischer (2003) and Healy (2001) object to the rational view on how to manage risks. This means that, in their opinion, risk is more than just a number based on which one can decide on whether something is acceptable or not. To come to a better understanding of risks Healy (2001) concludes that a more substantive dialogue between the natural and social sciences needs to be achieved. Fischer (2003) adds that it is also necessary to provide a framework for a more participatory approach due to which laymen can also speak out to risks. In addition, he notes that there is a lack of coordination between the technical and the social aspects of risk. This means there should be coordination between the quantified risk and the subjective side of the story, which is the opinion of the public on the question of what is acceptable.

Linnerooth (1984) argues that despite the increasing role of public institutions in the regulation of technological risks, the developing literature on risk assessment has had virtually no rooting in understanding organizational behavior or political progress. According to her, the rational decision-making model as a prescriptive tool, has been usefully applied to decisions at the level of the individual or firm, but is misleading and inappropriate when transplanted to the public arena, where decisions are not 'made' by a single individual, but are negotiated, not comprehensively, but sequentially, by competing groups and institutions.

Notions on the matter of acceptable risk is the notion that problems which stem from this matter are basically problems in decision making, which therefore require a choice amongst alternatives (Slovic et al., 1984). In addition, this choice depends on the set of options, consequences, values and facts invoked in the decision-making process. This means there cannot be a single panacea, or all-purpose number that expresses the acceptable risk for a society. Or: *'At best, one can hope to find the most acceptable alternative in a specific problem. Indeed, 'acceptable risk' may be a poor term if it connotes universality'* (Slovic et al., 1984, p.197).

However, it is not said that risk norms could not help decision makers to estimate the expected physical harm as they (could) provide the best available knowledge about actual damage that is logically or empirically linked with each possibility of action (see for example Renn, 1998). Furthermore, it should be noted that several risk analysts (e.g. Bedford & Cooke, (2001) say that the calculation of an fN-curve is just an estimation, rather than an exact presentation of risk results. In addition to that, the presented models and results are

simplified depictions of reality and should be in fact used to measure the effect on both human and economical risks regarding safety measures (Suddle, 2004).

This, of course, leaves the question unanswered: what would be a better way to deal with risks. Suppose the norms for external safety would not exist; what would happen then? On which base will decisions be made? Can this improve safety or is the system good as it is? The next section will explore the possible consequences of these ideas.

4 Some limiting conditions

It is possible to create new ideas on how to reduce the probability of an accident, and also the risk of a disaster, by creating design concepts that are the safest. However, such design concepts are both structurally and financially almost impossible to realize, because the theoretical dimensions of such measures are enormous. For that reason, the investments in concepts are extremely high and could even be higher than a single project budget (Suddle, 2004). Therefore, prohibiting transport of hazardous materials or prohibiting urban development are both controversial and almost impossible solutions. From this point of view, there is a strong need for design concepts that stimulate the continuity of both the transport of hazardous material and the urban development above or adjacent to those transport routes, if possible. Ideas such as tunneling all transport or a nation wide ban on the transport of hazardous materials are therefore not taken into account in this article. Also, even though external safety policy is a Dutch policy, there are fixed European institutions that have their influence on the Dutch external safety as well. The biggest influence is caused by the European directive on the free transport of goods (VNG, 2004). When transporting goods on the national level, quantitative limits can be set by the national government. The ideas for the basic network for example consist of such ideas. As a consequence, transporters may consider their own transport modality and may thus not be hindered in their operational management. This may result in differing transport flows of hazardous materials on transport routes. When comparing the transport numbers of 2003 and 2004 in the Netherlands, for example, the transport of flammable gasses shows an increase between 90% and 100% (Prorail, 2005; Prorail, 2006), resulting in an increase of the dominant group risk scenario with 90 to 100% as well. As the transport itself, in principle, is not to be influenced in a free market society, we will neither challenge nor discuss the amount of transported materials. Finally, it is necessary to accept the created present risk situations adjacent to railroads, particularly in areas where

the orientation value of the GR is exceeded. At some moment in time, there apparently was consensus on the created physical situation. We therefore accept this situation as given and do not debate this.

When we accept these three limiting factors, we can elaborate on new institutional principles for risk management and external safety. This is done through deduction of possibilities through conditional reasoning. Conditional reasoning is based on an ‘if A then B’ construct that posits B to be true if A is true.

If we take into account the objections to a quantitative approach to risk analysis and management and the fact that the GR criterion is not met in a large number of places, it might be a solution to use another way of dealing with risks in terms of acceptability. In the present situation, risks are acceptable when they do not exceed the orientation value in the fN curve.

When compared to the quite similar British situation for example, the Netherlands have a different interpretation in the acceptance of risk and what the term reasonability implies. Apparently, the Dutch interpretation is that reaching the norm also limits the discussion, whereas in the United Kingdom the limits have the aim of realizing ALARP (Ale, 2005). Melchers (2001) says that the ALARP (As Low As Reasonably Practical) approach shows an upper limit of risk that can be tolerated in any circumstances and a lower limit below which risk is of no practical interest. It is, however, also associated with quantitative levels of risk, which, in Figure 6, are used as an illustration only.

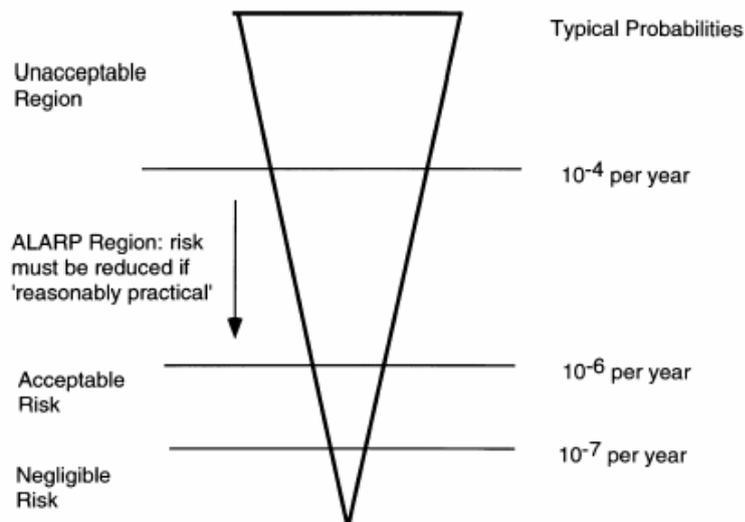


Figure 6: ALARP in relation to levels of risk, based on the experience in the UK. (Adopted from Melchers, 2001)

This means that the quantified numbers of transport of hazardous materials are taken as a starting point, instead of an end point. According to Ale (2005), however, the difference between the Dutch ‘Roman law’ and British ‘common law’ legislative systems implies that it is very difficult to implement such a criterion. The question to answer in the next section therefore is: how can we operationalize the ALARP criterion into Dutch practice and how can it be used as a potential risk reducing policy tool.

5 First steps towards a new institutional framework

Suppose if we would use the ALARP criterion, how should this be implemented and how would this influence risk management? If one talks about reasonability, this is often expressed in terms of costs and benefits. Bowles (2003) for example, talks about a disproportionality ratio, which, in his words, is a Cost/ Benefit ratio that includes both economic and life safety benefits. The advantages of this approach are (Bowles, 2003):

- An improved assurance that all reasonably foreseeable failure modes have been identified and adequately addressed;
- A stronger safety case for the risk reduction decision;
- A stronger business case for the risk reduction decision;
- A greater degree of defensibility for the risk reduction decision.

With respect to reducing risks as low as reasonably practical, Bowles (2003; 2007) has made a good effort to create a formula which expresses what reasonable costs are. In both articles, in which he calculates reasonability of costs to prevent dam failure, he presents the ‘Disproportionality Ratio’, R. R is equal to:

[Annualized Cost of Risk Reduction Measure - Annualized Economic Benefit of Risk Reduction Measure] divided by [Annualized Life Safety Benefit of Risk Reduction Measure].

As the equation is not applicable to rail transport, we will not get in too much detail how the calculation is made. It suffices, for now, to say that the calculation is a more sophisticated description of a standard cost / benefit analysis.

Suppose that a disproportionality ratio could also be applied to rail transport of hazardous materials, what might the consequences be? The RBMII model, in our opinion can still

function really well in relation to ALARP, but with a different basic assumption. It is therefore not necessary to get rid of the quantitative risk analysis tools or software. Instead of functioning as a more or less binding analytical tool it could function more as a decision supportive tool. Hereby, it is also possible to show in which project risks could be ALARP.

A way to explain this is to visualize this with the fN curve. Measures can be taken at the frequency variable (f) or the effect variable (N). Frequency is in that case is a derivative of the probability variable from the risk formula. Effect on the other hand is only expressed in terms of the number of fatalities in a certain area. Figures 7a and 7b give a schematic reproduction what this means in terms of the Group Risk criterion.

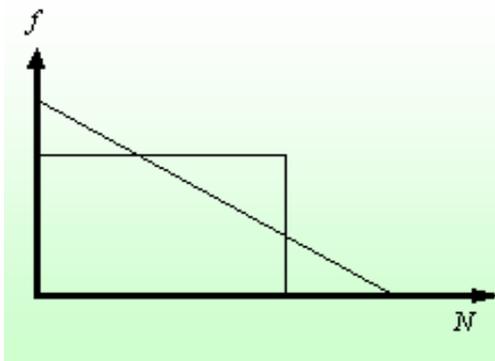


Figure 7a: A schematic reproduction of an exceeding of the Group risk criterion without the ALARP principle.

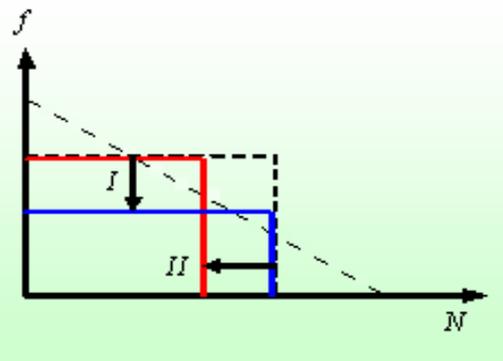


Figure 7b: A schematic reproduction of an exceeding of the Group Risk criterion with different possible calculated outcomes due to the ALARP principle.

Figure 7b implies that if the ALARP method is applied the norm for GR can still be exceeded. However, the measure taken (I) or (II) also imply that the overall risk is much smaller than in the previous situation as presented in figure 7a. It is remarkable that in a number of cases the risk in the present situation exceeds the norm with a factor of up to 90 times (AVIV & Royal Haskoning, 2005), there is no possibility that the norm will be reached, unless measures are taken that can cost more than the entire project. Hence, one may criticize the stringiness of the GR criterion.

It should also be noted that applying the ALARP criterion might reduce risks in present situations where the norm is *not* exceeded. In our view, using the ALARP criterion can continuously improve safety and reduce risks, which is also a policy goal for the Dutch Ministry of Transport, Public Works and Water Management (see for example Ministerie van Verkeer en Waterstaat, 2006a).

The possible, and also likely, implication of this idea is that by implementing ALARP, the present Dutch External Safety norms will not be met in all cases. When taking the preceding into account, it should be possible to combine all the previous notions into a new framework for decision-making on urban planning projects in relation to transport of hazardous materials by rail.

6 Conclusion

This article deals with risks surrounding the transport of hazardous materials and possible new institutions to control and to lower risks. Apparently, the present set of institutions is insufficient when it comes to controlling risks to acceptable levels. However, the meaning of such terms as acceptability, reasonability and practicality are, up to now, unclear.

In this article, we have intended to make a first initiative for a new way of looking at risks. This is done by discussing the possible positive consequences of using a formula to express ALARP. This article shows that a hypothetical change in Dutch external safety policy could evolve to a different set of institutions. Due to the fact that there is not one way of dealing with transport risks, there are also several ways these risks can be dealt with. Therefore, this is just *a way* and not *the way* a different institutional framework could look like.

Furthermore, risk problems are decision problems that require a choice among alternatives (Fischhoff et al., 1981). What is an acceptable or tolerable risk depends on the decision maker and how he or she deals with uncertainties and what is deemed acceptable. Besides this, they say that there are no universally acceptable options, risks, costs or benefits as they depend on the set of options, consequences, values and facts examined in the decision-making process (Fischhoff et al., 1981, p. 3). This means that there is no single criterion or solution for problems involving risks. When RBMII and a formula for ALARP are combined, this closely links to what Fischhoff et al. (1981) say, because this model does not limit solutions to a single standard or solution.

There are of course a number of objections or comments that can be made with our way of looking at risks. First of all, there are a number of uncertainties. The conditional reasoning does not give definitive answers to questions surrounding whether these thoughts also happen in practice. Secondly, there is no empirical research done (yet) to these matters. At this moment we agree that this article would be of more value when we could present such a formula in combination with empirical research. However, this has not been possible yet.

However, in order to come to other ways of managing risks and to explore alternatives in how to deal with risks that exceed the norm; this could be a useful option. In additional research, the authors hope to make a contribution and to test whether the statements made can be verified through empirical research.

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