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RAILWAY SAFETY: RISK ASSESSMENT TECHNIQUES

The concept of risk management based on quantitative risk analysis

Transmitted by the Government of the Netherlands

Note: the Working Party, at its fifty-second session, examined the information provided by different Governments on the application of risk assessment techniques to railway safety. It also asked the representative of the Netherlands to provide a copy of the guidelines applied for risk assessment policy, which might be taken as a basis for further work in this area.

The Working Party may wish to consider the document transmitted by the Government of the Netherlands, which is reproduced below.

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The concept of risk managenment based on Quantitative Risk Analysis.

The contribution gives an overview of the use of risk analysis as an instrument for risk management policy. The Dutch approach is described; examples are given. There are roughly 3 different applications: The (first) "quick and dirty" analysis, the (ultimate) question if risks are acceptable and (if not) the decision making on measures or alternatives.

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1 INTRODUCTION

1.1 Riskful industrial activities

Some chemicals processes, handled or used in our industrialised society are hazardous or even extremely dangerous for people. Industrial activities cause certain risks to the surrounding population because of the possibility of accidents with such substances. From major accident investigations we learn tough lessons that special safety measures are necessary and that in some cases separation of hazardous industrial activities and poulation areas is necessary. In many countries it has been concluded that an external safety policy is necessary to deal with problems in this field.

1.2 Lack of space

It is in many cases not possible to reduce the mentioned risks in densely populated and highly industrialised countries to zero. Safety measures, when relevant, are often expensive and have limitations. Furthermore there will often be a lack of space for a safe zoning between industrial activities and living areas. It can be concluded that a kind of decision support system is useful in order to manage risks and to set risk acceptability criteria in order to answer the question: "how safe is safe enough?"

1.3 The contents of this contribution

The contribution describes the external safety policy developed and used in the Netherlands and some other countries. The contribution includes methods on how to use risk analysis depending on decisions that have to be made.

2 EXTERNAL SAFETY POLICY IN THE NETHERLANDS

2.1 Dealing with risks

The development of the external safety policy in its current form in the Netherlands originated when it became clear that the use of LPG would increase considerably. Obviously the occurrence of a number of major hazards - e.g. Flixborough, Beek, and Los Alfaques - catalysed the process of developing policies aimed at improved prevention of accidents.
Quantitative risk assessment (QRA) is used in the Netherlands as a tool to 'measure' the risks. A dangerous activity is analyzed with respect to all the systems in a plant or storage and/or transportsystems which contain dangerous chemicals. For each system, the release of these chemicals is modelled and the risk contribution is calculated.

2.2 History

Twelve years ago, in 1982, two large studies were undertaken aimed as a basis at finding ways of managing risks connected with dangerous activities:

* The LPG integral study which determined risks of all LPG activities in quantitative terms.
* The COVO study, which covered six industrial activities in the Rijnmond area and which showed the viability of quantitative risk assessments for determining the extent of hazards in activities with dangerous chemicals.

Quantitative assessment of risks was found to be the most effective instrument to understand the risks caused by possible accidents. However it became also clear that it was important to find consensus about the techniques, computerprograms and inputfigures used.

The LPG integral study resulted in a report (1984) of 24 volumes on all the safety aspects of the storage, transport and use of LPG and liquid automotive fuels. This study formed the basis for the LPG Integral Memorandum that was accepted by Parliament in 1984 and which laid down essentially three important elements for the Dutch external safety policy:

1 The use of quantitative risk assessment to determine risks.
2 The adoption of two risk-determining parameters:
   - individual risk
   - societal risk
3 Acceptability criteria for both the individual risk and the societal risk.

In fact it enabled to arrive at an effective policy to control (major) hazards. First a policy for industrial sides was implemented, afterwards a policy for transportactivities was added, including airports.

2.3 Introduction of risk criteria

In the external safety policy, dangerous activities are evaluated with respect to their risks, both in terms of individual risk and societal risk. For activities identified as dangerous, these risks are compared with acceptability criteria. If risks are found to be unacceptable, risk reducing measures or zoning (or both) are applied to bring the risk to an acceptable level.

The acceptability criteria used in the Netherlands were originally based on the results of risk analyses compared with general figures of the probabiltiy of death given a certain age. As a criterion for individual risk it was found out that one additional percent of increased probabillity of death for the less vulnerable group in society (people between twelve and fift een years old) fitted best. However it must be stressed that given the definition of individual risk, figures cannot be compared "one by one" with the probability of death used in such health statistics. The individual risk figures given the standardized assumptions in the calculation, are pessimistic compared with figures of this probability of death.

For societal risk one of the main topics in the discussion was the relation to be used between probability and consequences. It was decided that increased conseqences should be compensated by a more than linear decrease of probability, given the increased societal (and therefore political) attention to large scale accidents.

Apart from the more "scientific" discussion about risk criteria, it would not have been possible to introduce such criteria without knowing the consequences. Although the consequences (costs and constraints for physical planning) were not investigated comprehensively, decisionmakers were quite sure that it would be possible to work with the risk criteria proposed.

Subsequently, over several years there have been discussions in Parliament about the use of risk criteria, not only for industrial accidents caused by stationary activities, but also for transport and airports and, although not within the scope of this paper, also for risks caused by radiation, continuous exposure to substances and environmental risks.
After the primary introduction of risk criteria the concept of using individual risk and societal risk has not been changed.

There is an intention to formalise the criteria for individual risk by a pertinent Decree. Acceptability criteria for societal risk, which will be regulated by the same decree, will have a somewhat different status in that permitting authorities will be enabled to accept higher risk situations, provided that the decision is properly motivated and a thorough balancing of interests has taken place.

2.4 To a practical approach
It has never been the intention to develop a decision support system where it would be necessary to calculate risks for every hazardous industrial activity. In fact, one of the principal objectives is to avoid such a costly, time consuming process.
For several categories of industrial activities, covering more than 80 % of all activities, general analyses form the basis for a policy, described in specific degrees by which risks and additional measures are compared with safety distances.

- Most LPG activities (e.g. filling stations)
- Pipeline transport of natural gas
- Pipeline transport of K1, K2, K3 liquids
- Pipeline transport of other dangerous chemicals
- Storage of pesticides in warehouses
- Storage of chemicals in warehouses
- Use of ammonia in cooling installations
- Railroad yard activities involving dangerous chemicals
- Transport of dangerous chemicals by road or by railroad cars
- Transport of dangerous chemicals over inland waterways

The way to control the risk of these activities is dependent upon the type of risk involved, though the criteria for acceptability are the same for all cases.

2.5 Current situation and further developments

Table 1.
Overview (indication) of safety zoning in the Netherlands in relation with various dangerous activities.

Dangerous activity	Safety zoning: no living areas allowed [m]	Area with attention for safety [m]
General goals	> max tolerable Individual risk	to meet target value Societal risk
Seveso industries **max.**		
- Ammonia liquef. 500 t	ca. 500	
- Hydrogenfluoride ,, 600 t	600	
- Ethylene oxide 800 t	800	
- Chlorine liquef. 2000 t	800	ca. 2500
- Flamm. gas liquef. 10000 t	800	
- Flamm. gas cooled 80000 t	600	
- flamm. liquids 300000 t	500	
Railroadyards	200	2500
Categ.of stat.act. **max.**		
LPG stations 50 t	80	80
Ammonia refrigerators 1 t	30	30
Ammonia refrigerators 5 t	70	70
Ammonia refrigerators 50 t	150	150
Chem. storages 100 m²	20	20
Chem. storages 600 m²	40	40
Pest. storages 100 m²	20	20
Pest. storages 500 m²	40	40
Transport		
Pipeline natural gas	60	120
Pipeline LPG	125	400
Pipeline Toxic gas	400	2000
Road	50	120
Railroad	50	200
Water	40	800
Water (sea vessels)	1000	2000

Plants, storages, LPG stations etc.
For a number of dangerous activities, specific legislation and specific guidelines have been adopted. In a number of these cases, risk assessment forms the basis of the decision on acceptability of an activity in a specific situation. In other cases, in particular for most LPG activities, this is achieved by using pre calculated safety distances based on the same (maximum) risk acceptability criteria.

Ammonia refrigeration units are another class of possibly hazardous activities. For these activities, a specific guideline is already available as a basis for the safety aspects of licenses. This guideline will be improved in 1996 in order to provide a better tool for managing the pertinent risks. In addition, it will be considered whether a system of safety distances can be introdocuced for these types of in-stallatons.

In table 2 a summary of the risk situation is presented for 66 of the main industrial companies and 85 railroad yards in the Netherlands.

Table 2
Summary of risk situation of main industrial companies and marshalling yards in the Netherlands: number of sites involved in the indicated risk situation.

Stationary activities	Number of situations	> MTR. Ind.risk	> target value societal risk
PLANTS	66	12	8
RAILROAD YARDS	95	7	9

b Transport of hazardous substances
Risks associated with transport of dangerous chemicals by rail, road, water and through pipelines are considered within the external safety policy
For pipelines only there are already safety distances available based on the same (maximum) risk acceptability criteria.

In table 3 a summary of the risk situation is presented for the 3000 most relevant locations near transportroutes in the Netherlands.

Table 3
Summary of risk situation Transportroutes (road, rails, water and pipeline) for locations of 1 km. Number of situations involved in the indicated risk situation.

Mode of transport	Number of locations	> MTR Ind. risk.	> target value societal risk
ROAD	2505	0 - 5	10 - 20
RAILROAD	304	0 - 5	5 - 10
WATERWAYS	238	5 - 10	0 - 5
PIPELINE	39	0 - 5	0 - 5

c Airports
The national airport, Schiphol (Amsterdam) has in the past few years been the object of extensive safety studies within the framework of plans to expand the airport. In 1993 a report on the external safety around Schiphol (related to civil airplane movements) was prepared. On the basis of this report an action plan aimed at improving the safety around Schiphol was presented to Parliament. In addition to this, in a study safety zones have been determined to limit the risk for people living around Schiphol. Within the 10^{-5} risk zone new construction of housing as well as other dwellings is prohibited. Within the $5x10^{5}$ risk zone, existing housing will even be 'closed down' on the longer term. Within the 10^{-6} contour area an overall risk policy is adopted, aimed at a stand-still in the development of the risk in the contour area. In an even larger area the construction of dwellings is restricted to a certain extent. This also involves a policy with respect to societal risk. However, it can be concluded that the risk policy for the airport differs from the policy being used for, for instance, chemical plants.

3 RISK ANALYSIS AS A DECISION SUPPORT SYSTEM

An instrument often used when dealing with risks is risk analysis. By assessing risks of industrial activities it is possible to compare results of such analyses between each other and to compare the calculated risks with acceptability criteria established by the politicians.

Risk policy using QRA as an instrument is effect-oriented. This means that the necessity of risk reducing measures are related to the (possible) effects of hazardous industrial activities to the outside polulation. However the policy used to reduce risks can also be based on the so called source oriented policy. In the case of the here described external safety policy this source oriented policy means the application of the so called ALARA principle (As Low As Reasonably Achievable). Working with the ALARA priciple means that normally the best practical means are used; but the best technical means are first asked for.

3.1 Applications

In the various risk management policies adopted in different countries one can distinguish in principle between 3 levels of application of risk assessment

1 *Rapid ranking methods*
Risk assessment can be used for strategy purposes: setting priorities. The methods used are often "quick and dirty'. The objective of this approach is to get a broad view of a large number of different industrial activities and situations, without any detail.

2 *Detailed analyses*
Risk assessment can be used to evaluate on a quantitative basis whether the risk due to a certain hazardous activitry is acceptable or not. The problem of risk acceptability criteria can be solved only by decisions on the suitability and applicability of such criteria at a political level. The objective should be to maintain a general level of safety and next to focus on those situations that are serious enough to require decision making at a more detailed level. The risk assessment techniques used are often quite complex, and it has proven necessary to achieve beforehand consensus about assumptions and models deemed suitable, because of the possible (financial) consequences of the decisions.

3 *Analysis of specific measures/alternatives.*
Risk assessment can be used to decide on the effectiveness of risk reducing measures or to decide on alternative production, storage-, or transport strategies.
The analysis is often quite detailed for one or two parameters out of parameters which may influence the risk. The objective of this approach is either to get a basis for deciding whether a specific measure is cost-effective or to select one from several strategy alternatives based on risk minimisation. In this context risk assessment is often used as the input for a cost benefit analysis.

3.2 Possible approaches to problems.
Risk management policies are only adopted and implemented if there is political concern for the risks caused by industrial activities in the first place.
Maor hazards have caused such concern in the past, and have as a consequence, initiated the development of risk management policies prevailing in many countries.
One could, however, also consider safety situations by carrying out a quick survey. Such a general and broad analysis gives the opportunity to determine whether a more detailed risk management policy is actually necessary or desirable. If this were confirmed, the next step is then to carry out a detailed risk assessment for selected activities.

Apart from these analyses methods it is necessary to start a discussion about risk criteria. When comparing results of risk assessments with established risk acceptability criteria, one inevitably should consider the possibilities for risk reducing measures and for safety zoning.

The application of risk assessment to go into detail for one specific parameter gives the opportunity to analyse kinds of risk reduction that are possible. It is possible to consider the feasibility of risk reduction with respect to "the costs": financial and economical costs and land use planning.

It is often not possible to reduce risks to zero. In particular the first application of risk analysis methods described, the rapid ranking methods, give decisionmakers also the possibility to prioritize for industrial activities the preparation of emergency situations. The second application, the detailed analysis of one particular hazardous industrial activity, provides the opportunity to make a detailed emergency plan based on possible events that may occur.

Results of the analyses carried out during the whole process can be useful to communicate risk to the public.

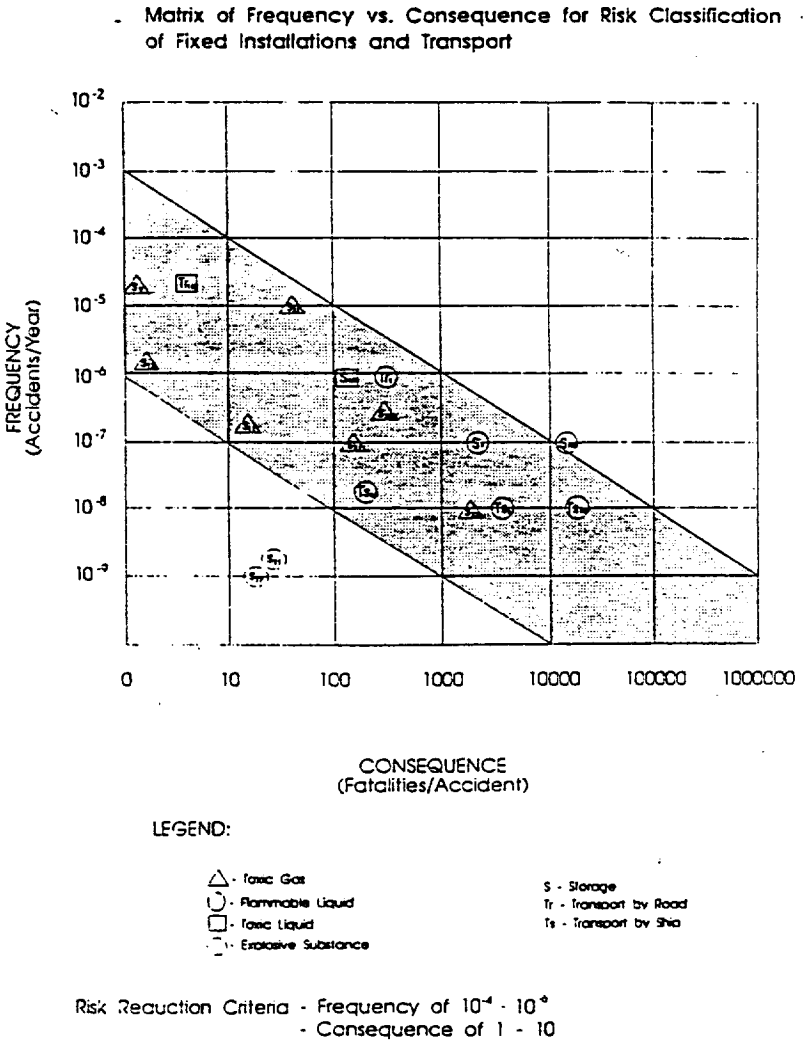
4 RAPID RISK ASSESSMENT METHODS (RRAM)
As desribed in the preceding paragraphs these kinds of risk analysis methods are important to policies of dealing with risks.

One available method is the "manual for claasification and prioritization of risks due to major accidents to process and related industries" (which is distributed by the UN (IAEA) and available in several languages:including English, Russian and Chinese). This manual described methods for both stationary industrial activities and transport activities.

The most serious problem when developing such a method is to compromise between the different objectives. Such a manual must be conenient to work with and has to include all possible

riskful activities which are conflicting objectives with how representative and scientific the results should be.
In the RRAM, a step by step approach is described. First the user must decide if there are any relevant industrial activities. Secondly by using basic information on the kind of activities and on substances handled one can determine the kind of average effect that can occur in the case of an accident. Thirdly by comparing the possible affected area with actual, or planned, population living in that area, it is possible to estimate the consequences. The following step is to assess the likely probability of such an event. This can be calculated by using general probability numbers for different kinds of industrial activities and "to correct" these numbers by using correction factors based on the specific circumstances.
Both consequence and probability numbers are displayed in the form of risk levels in a graph. The graph shown below gives the result of a survey carried out with this manual for the Laguna de Bay area in the Philippines.
It is possible to draw a line in this graph to set a criterion for decisionmaking. It is obvious that risks are most relevant in the upper right corner of the graph.

FIG 1 The result of using the RRAM in the Philippines.



5 DETAILED RISK ANALYSIS.

One of the advantages of quantified risk analysis is its integral approach, which accounts for all important issues of risk to people and environment. The risk assessment as an instrument for decisionmaking not only gives the opportunity to discuss the acceptability of calculated risk levels, but also gives an understanding of factors important to the risks calculated.

5.1 Risk analysis

The main steps of a quantitative risk analysis are;

1 Identification of the causes of possible accident sequences.
It should be emphasised that this part of the analysis can never be 100%. It is not possible to foresee all accident scenario's.

2 Assessment of probabillities of possible accidents.
It must be stressed that it is often difficult to find proper probability figures. Different techniques are used. Amongst others the use of casuïstics (historic accident data). Furthermore one may consider the probability of accidents to be a chain of different independent causes, giving the opportunity to assess probability figures, for each link in the chain.

3 Calculation of effects.
Typical of risk analysis is the large number of possible events to be considered, the various amounts of chemicals released, the various possible wind directions etc. All these possible parameter values should be handled in the quantitative assessment. This implies that many calculations have to be performed and combined in the end result. For each identified case, calculations of possible physical effects are performed. Standard models are used to account for different physical phases, consequential release rates, evaporation rate, dispersion effects, fire impact, explosion impact, etc.

4 Determination the consequences of the effects calculated.
The consequences for toxic compounds are calculated using probit functions, which give lethality probability when people are exposed to a certain dose (concentration during a certain exposure time). The parameter values in these probit functions are derived from data on past accidents and from animal experiments.

5.2 Consensus

To establish criteria for risk tolerability it is very important that a committee is formed with participants from all authorities involved in the proces of analysis. The magic word here is consensus.It means that all parties involved will accept the results of calculations to avoid arguments about results of calculations at a later stage. There is another more practical reason to involve all authorities. Though usually a consultant specialised in risk analysis is commissioned to carry out such a study, the expertise about specific installations or routes often is only available through the responsible authorities.

5.3 Risk definitions

Risk definitions used for managing external risks to populated areas relating to industrial and otheractivities, are based on the conditional probability of being killed as a direct consequence of a major hazard. In practice a time frame of two weeks is used to deal with the small-delay lethal effects. Injuries and other lethal effects of major hazards on people are not accounted for in this modelling.
The practical reason for this is that it is considerably more difficult to assess the consequences for all the substances causing risks in terms of various injuries. In addition, fot preventative policies it proves to be generally sufficient to limit the risk modelling to a consideration of lethal effects. In the risk modelling, two risk parameter risk definitions are usedin a complimentary way.

Individual risk

The probability per year that any member of the general public staying 24 hours a day unprotected on a certain location near a riskful industrial activity, may be killed as a result of exposure to a lethal effect due to an accident occurring because of this activity.
The individual risk calculated is independent of the population near the industrial activity. The level of the calculated risk can be drawn on a map as so called iso-risk contours (lines around an industrial activity with the same level of risk) like the height lines on a topograpic map. The individual risk normally has a negative relationship with the distance.

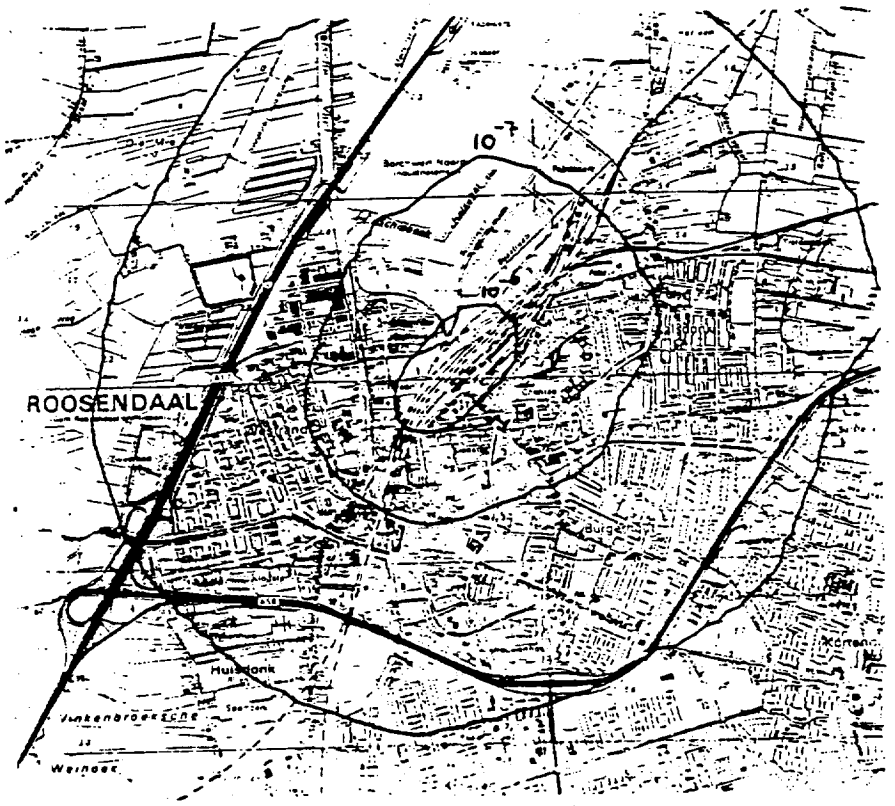
Individual risk levels can be used to establish a certain distance to industrial activities and so maintain a certain minimum safety level for every individual person living around it.

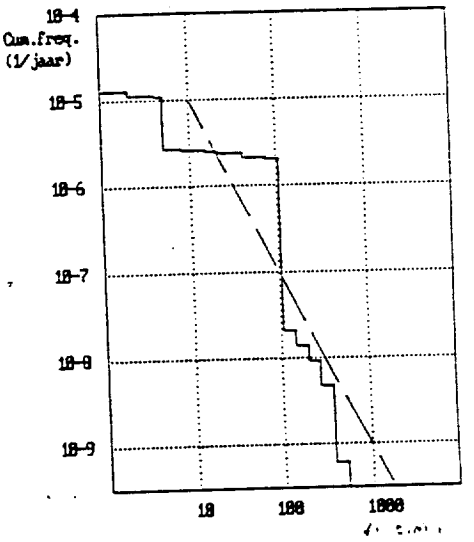
Societal risk

The number of people killed by accidents which are possible because of a certain industrial activity, as a function of the probability that this number will be exceeded. The societal risk is expressed as a curve in a graph where the Y axis gives the probability and the x axis the number of people killed.
The societal risk is largely dependent on the distribution of the people living near the industrial activity. In the calculation as much as possible represensitive mitigation factors are taken into account.

Societal risk can be used to get an idea of the impact of possible accidents. The societal risk describes in an appropriate way risks which may be of concern to politicians. Societal risk can be used to compare alternatives. Furthermore societal risk can be used for (priority setting by) disaster planning and ofcourse to maintain a certain level of risk for a given situation (an industrial activity and its surroundings).

FIG 2 Example of individual risk contours (a) and societal risk (b) of a shunting yard.





5.4 Risk criteria

A relative instrument

The chosen level of the risk as the acceptance criteria can be related to a certain percentage of natural risk of human life. However, the figures used are ofcourse political decisions in which acomparison is made between the costs of such a policy and the safety standard politicians wanted to maintain.

Risk criteria may have a different status. In the Netherlands the individual risk criterium is used as a definite threshold value. The societal risk criterium is used more as a goal, an objective, which should be reached (but not necessarily at any cost). One can call the societal risk criteria used target values.

The risk criteria can be used both for stationary industrial activities, a plant, a storage etc., and for transport activities.

In the case of calculations made to compare stationary activities and transportation routes all the relevant activities on a plant and all the transports of kinds of substances on a

route per year are taken into account. Furthermore in the calculation of societal risk for a route to compare to the risk criterion, the route is divided in standard practical segments, as if each segment is an industrial activity on its own.
It is important to understand that risk criteria work like a carpenter's bench. The decision on the exact adjustment of the plane iron makes the difference between proper planing or no planing at all.

The criteria used in the Netherlands are:

*** Individual risk:**
10^{-6} per year
limit value for new situations
Target value for existing situations
- In vulnerable areas
- For transport and stationary activities

*** Societal risk:**
10^{-4} per year: > 10 people killed
10^{-6} per year: > 100 people killed
10^{-8} per year: > 1000 people killed
Target value
- In vulnerable areas
- For transportroutes of 1 km lenght

10^{-5} per year: > 10 people killed
10^{-7} per year: > 100 people killed
10^{-9} per year: > 1000 people killed
Target value
- In vulnerable areas
- For stationary activities

For the airport Schiphol different (less tough) criteria are used, based on specific political discussions.

Relationship between calculations and setting criteria.
The risk criteria used have a strong relationship with the way risks are being calculated.
It must be stressed that every country using or developing national accepted risk criteria has to set its own standards based on risk definitions used and based on the costs of such a policy. Furthermore neither the calculations nor the risk criteria are an objective on its own, only the possibility to use risk calculations and risk criteria as a decision support instrument to reduce risks in an objective way.

6 ANALYSIS OF SPECIFIC MEASURES/ALTERNATIVES.

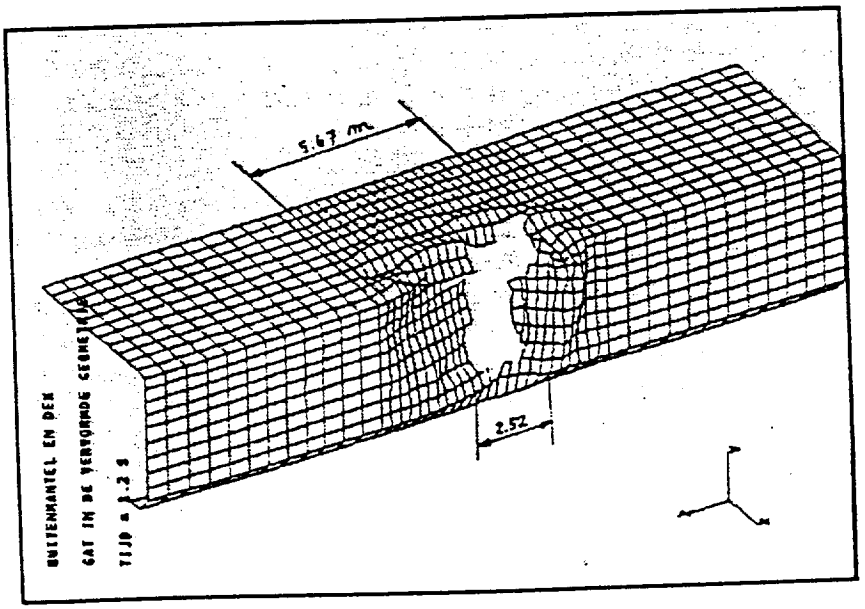
Such analyses are carried out to find an answer to the question: what is the most appropriate way to reduce risks? This part is in fact the most practical of the process of dealing with risks. The results of the process promises risk reduction which is of course the ultimate goal.
The feeling of unacceptable risk triggers the question of how to reduce risks. It is advisable to go through the process of risk reduction analysis as a standard approach as part of the ALARA principle already described in chapter 2.

In essence there are two different kinds of questions.

1 In a given (existing) situation: what kind of measures are possible and (still) achievable?
2 In a planned situation; are there alternatives and what is the influence of the alternatives on the risks?

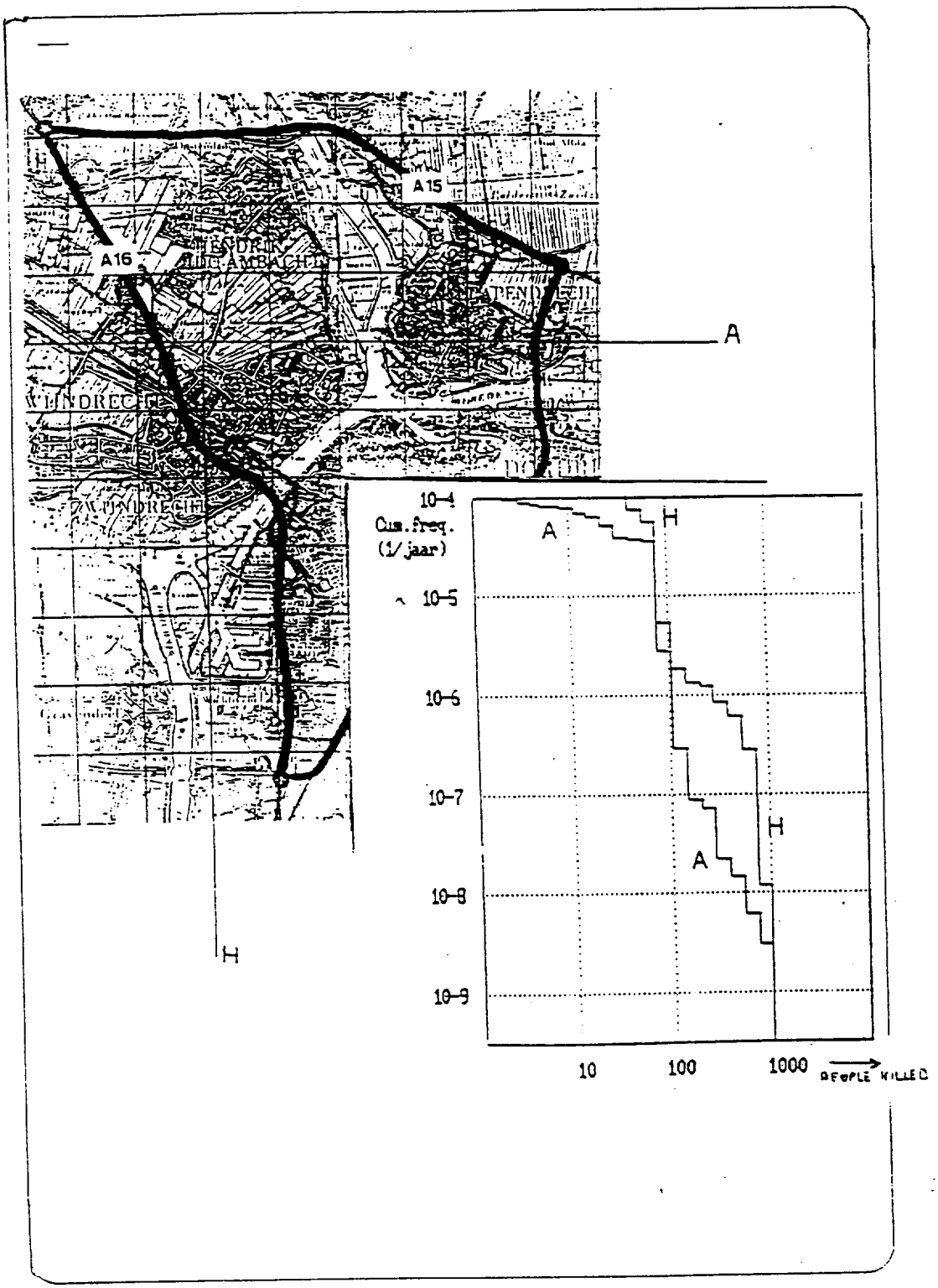
The first question is often found as part of the decision making by legislation. The decision about additional safety valves, to have storage of gas under pressure or cooled, the question of single or double hull vessels in the case of transport of liquids, loading/unloading facilities over the top or from the bottom of storages are some of the many examples.
These kinds of questions have in common that it is not necessary to go through all the steps of risk calculation again. It is not necessary to realculate individual and/or societal risk, however the analysis is focused on one or a few factors that influence the risks.
For instance the question of using single or double hull vessels is the question of the different probability of a leakage of liquid in the case of a collision. Depending on the consequences of the result of such an analysis, a lot of money can be spent in investigating certain measures to be able to answer such a question.

FIg 3 Calculations on the penetration possibility of a double hull vessel.



An example of the second question are certain possible routing alternatives for the transport of dangerous substances. Here the principal factors that make the difference between alternatives are traffic safety, the length of the route and the characteristics of the possible affected area.

FIG 4 Comparing route alternatives.



7 CONCLUSIONS.

Risk analysis can be an effective instrument for decision making.

Different approaches to analyse risk are available. The approach chosen depends on the kind of decision that has to be made.

It is recommended to start risk policy with a "quick and dirty" analysis. As a basis to find out if there is political support for a risk policy and as a first step to communicate about risks and in the second place to find out on which industrial activities to focus.

All parties involved in the risk policy process should work together to reach consensus about risk analysis techniques used, to combine specific knowledge and to give the results of risk analysis common status for decisionmaking.

It is not advisable to compare risk criteria of one country with the criteria of another country without knowledge of the risk analysis models and the (exact) risk definitions used in other countries.

APPENDIX: AN EXAMPLE

1 SYSTEM DESCRIPTION.

The Westerschelde: a river

The Westerschelde is one of the main rivers in the Netherlands. The most important harbours are those of Flushing and Antwerp. The latter is the main port of Belgium.
On the Westerschelde a lot of traffic of both sea-vessels and inland waterway-vessels takes place. At one particular place, near the city of Flushing, traffic safety is of major concern. Statistics of the last ten years show an average frequency rate of 5 **serious** collisions a year.
A large amount of all kinds of dangerous goods are transported from and to the mentioned harbours. In the past also accidents occurred with these kinds of vessels.

Local concerns and interests

Politicians in the area are concerned about the risks for people living on the borders of this part of the Westerschelde. On the other hand the same politicians have intentions to build new (vulnerable) dwellings on both borders which can be explained by looking at the profits which can be made by selling luxury appartments with an excellent view of the river....

A national political discussion

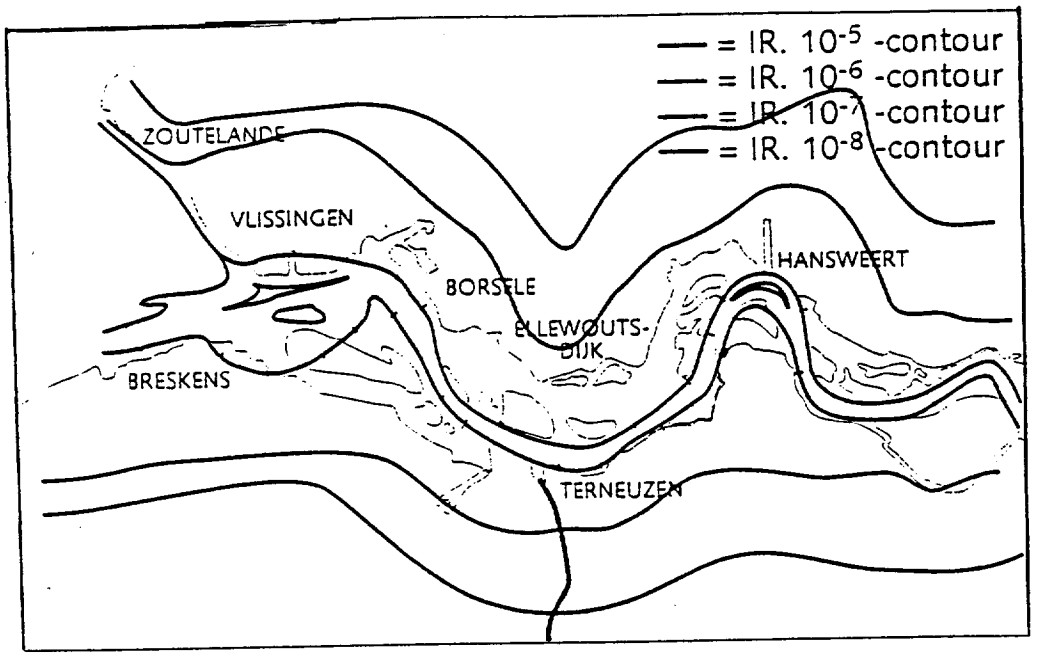
The debate about the above-mentioned different views of interest: transport, external safety and physical planning, became a matter of concern on national level. Both the Minister of transport and the Minister of Environmental Affairs, went to court to ask for a moratorium on developments in the area and to wait until more knowledge for a sustainable development of the area was available, which was the start to carry out a risk analysis.

2 THE RISK ANALYSIS.

Consensus

It is very important that a steering committee is formed with participants of all authorities involved in the decision making process. The "magic word" here is **consensus**: which means that all parties involved will accept the results of the analysis, to avoid arguing about figures after doing the analysis.
There is another practical reason to involve all authorities: although most of the time a contractor specialised in such risk analyses, is ordered to carry out such a survey, the expertise about the river (issues about the number of different vessels, navigation, traffic safety etc.) is most of the time only available by the responsible authorities.

FIG 5 Individual risk contours Westerschelde



Problems
It took quite a lot of time (almost 2 years) to finalise the study. The main reasons were:
It was difficult to get a good picture of the number of different vessels in relation to the hazardous cargo they transported, which can be explained by the fact that a substantial number of these vessels sail to Belgium, which do not register the vessels properly.
There was a fundamental discussion within the steering committee about the probability of a release of a dangerous gas or liquid after a (defined) collision.
The models used to calculate the dispersion of toxics on such a large scale (for instance releases of 10000 tons ammonia or more) needed adaptation.

3 RESULTS AND CONSEQUENCES.
During the study already some recommendations led to measures on the river, recommendations related to the transport of ammonia and the anchor places used. However the risk levels in certain areas on the borders remain high. The most important risks calculated are those of the transport of cooled and liquefied ammonia gas by sea vessels and (less important) the risks of the transport of LPG. The risks caused by inland waterway vessels are of minor importance on this (broad) river.

As a result of the study it has been concluded that additional measures on the river are necessary. Priority is given to decrease the probability of accidents. The main goal is to avoid a (large) safety-zone around parts of the Westerschelde.

By carrying out the study it is already clear that specific issues will be the subject of discussion, also with the Belgian politicians.

a Changing pilots near the harbour of Flushing, a place with a lot of passing vessels.

b The anchor places already mentioned, in the same area of the river.

c The procedures of guiding vessels through the Westerschelde.

d The necessity to make emergency plans in case a serious accident on the river takes place.

e At some places on the border a safety zone.