Risk Assessment in the Netherlands

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discussion paper

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Summary

The Dutch **approach to risk assessment** is defined in the National Plan for Environmental Protection Policy (NMP) of 1988. The goal is the present and future protection of humans, animals, plants, the ecosystem, and property through measures designed to provide for a sustainable development. The safety goals are defined in "Premises for Risk Management," an annex to the NMP, in 1989.

Safety goals are determined with quantitative values. Maximum permitted risks are differentiated from negligible risks. Risks that fall between these two values must be reduced to a negligible level within one generation (ALARA-principle). The safety thresholds for existing and new hazards are also differentiated.

Hazards include stationary installations, transport systems (road, rail, water, and air transport), hazardous substances (chemical, radioactive), and genetically-altered organisms. The two **most important criteria** for risk assessment are the individual probability of death and the probability of death for groups. Although quantitative safety goals have been defined for other criteria such as ecosystems, noise pollution, and odor nuisance, they have little effect in practice. **Criteria which are deliberately left out** include injured persons, financial-economic damages, damages to plants by radioactivity, and different reductions in activities.

The **assessment process** begins with the observation that a plant may potentially be very hazardous. An external safety report (ESR) must be prepared as a basis for the risk assessment. The ESR contains the results of the quantitative risk analysis. In this analysis, the maximum permitted individual risks are illustrated with risk isolines on a geographical map, and group risks are entered onto a frequency/number of deaths (F/N) diagram. The agencies of implementation then appraise the ESR. If the ESR for

existing plants is accepted and the risks are too great, then the hazard must be reduced at its source, or use must be restricted, which can lead to the demolition of housing. Building and operational permits for new plants are only granted if safety goals are met. To date, eighty of the approximately 160 stationary plants required to file an ESR have done so.

This quantitative approach to the definition of protective goals is **justified** by the ease of implementation. The processes of risk analysis and assessment have also been simplified with the development of standard software packets. The Ministry of Housing, Physical Planning and Environment (VROM) is essentially satisfied with the implementation of risk assessment in the Netherlands.

Everyday **experiences** are quite different. Representatives of communities and industry have voiced sharp criticisms. This criticism is directed first and foremost at the definition and implementation of safety goals for groups and at the ALARA-principle. Other ministries as well as parliament have also found fault with the quantitative approach because it does not coordinate safety goals with spatial and emergency planning.

Recommendations for **alternative approaches** to risk assessment include (1) a risk discourse about the methods of risk analysis and assessment among all stakeholders; (2) a scenario-oriented definition of safety goals for individual and collective risks and consideration of financial-economic criteria; (3) replacement of the concept of group risk by a consideration of collective risks; (4) risk aversion (subjective perception of risk) and the technical aspects of risk assessment should be granted equal attention; (5) more cooperation between the stakeholders at all stages of risk assessment and implementation; (6) an active information policy.

1. Development of the Risk Debate and Legal Measures

1.1 The Dutch Risk Debate

The Dutch have a long history of dealing with risks because of their own constant battle against the sea. The collapse of the Zuiderzee dike in 1916 led to the construction of higher and stronger dikes. The modern risk debate was set off in 1953 by a disaster in the province of Zeeland, where the collapse of dikes resulted in 1700 deaths. During the initial debate, the main concern was to increase the heights of the dikes and thus improve their protective functions. The perpetual confrontation with the risks of flooding resulted in a pragmatic approach to the risk debate. Not only potential damages, but also the probability of their occurrence was taken into account from the very beginning.

The Dutch debate about the systematic evaluation of industrial and technological risks, known as external safety management, is about twenty years old. The various driving forces behind this debate can be categorized as negative experiences, technological developments, and legal measures.

The negative experiences which have stimulated the Dutch risk debate include the following accidents:

-1971: Butane explosion at *Marbon Europe* in Amsterdam, NL (10 deaths)

-1975: Explosion at *Naftakraker DSM* in Beck, NL (14 deaths)

-1976: Seveso accident

-1984: Accidents at Mexico City and Bhopal

-1991: Explosion at a fireworks factory in *Culemborg*, NL (2 deaths)

-1992: Explosion at a chemical plant *Cindu* in Uithoorn, NL (3 deaths)

During the 1970s, the environmental division of the Ministry for Housing, Physical Planning, and Environment (VROM) took on the leading role in the risk debate. This period was characterized by the search for a uniform way of measuring different types of risks. The comparative study of risk analyses in the Netherlands during the years 1977-1987 by Van Eijndhoven and van Ravenzwaaij (1989) point out a definite trend toward the standardization of risk analysis. The authors identify and describe a striking change in the definition of consequences, risks limits, and safety goals during the period under consideration.

As indicated above, the ministry explicitly chose a technical-quantitative approach to the formulation of relevant risk indicators and safety goals. The current risk debate emerged out of this formulation of safety goals for external safety.

1.2 Legal Measures

The use of liquefied petroleum gas (LPG) as a fuel following the energy crisis of the 1970s triggered important developments in the risk debate. Detailed risk analyses of LPG-transport chains represent a milestone in the treatment of risks in the Netherlands [Stallen and Smit, 1993]. In the early 1980s, the focus on LPG risk analysis prompted the Dutch parliament to pass two important measures: the LPG-Policy-Decree (1980) and the integral LPG-Decree (1984). Subsequent legal measures which prepared the way for present methods of risk analysis and risk assessment are summarized in the following.

1982 Post-Seveso Directive of the European Community (81/501.EG)

Following the dioxin disaster at Seveso (Italy, 1976), the European Community issued a directive to all member states known as the Post-Seveso directive (1982). It states that all Seveso-plants must provide risk information to their governments. The Netherlands have implemented the directive by means of two general rulings: the alteration of the Nuisance Act and the establishment of the decision "Heavy Accident Risks" (1986). This latter decision requires plants to carry out an External Safety Report (ESR) that includes a quantitative risk analysis. The Post-Seveso directive does not actually require this kind of quantitative risk analysis; it merely called for the plants to map risks and to inform their governments about these risks. The reason which led to this emphasis in the Netherlands on a *quantitative* approach was the belief that *qualitative* reports and expert opinions no longer provided an adequate basis for making decisions about safety.

1984 Integral LPG-Decree (VROM, EZ, V&W)

The Dutch government came to view the newly developed methods for quantitative risk analysis and the results that were obtained by these methods as a useful instrument to support decision-making about industrial activities. Subsequently, the government decided to make more use of these methods.

After the LPG-Policy-Decree (1980) came into effect, the environmental division of VROM commissioned a detailed study about the standardization and simplification of risk analyses in the process industry. The result of this study was the development of the computer model SAFETI, a program designed to simplify and standardize the process of risk analysis. SAFETI provides straightforward methods for performing a risk analysis and for appraising the results. The computer program enables industrial plants to assess risks in a more objective manner and also to avoid unnecessary expenses. After the LPG-Policy-Decree was passed, efforts to improve the methods of quantitative risk analysis received continued support so that this type of risk analysis could be better integrated into the policy-making process.

1985: Environmental Planning Decree (IMP-M) 1986-1990 (VROM)

The most influential legal basis for the current debate is probably the Environmental Planning Decree (IMP-M), which was enacted in 1985. With this decree, the Dutch government introduced risk analysis as a policy framework. Further, the decree explains the philosophy behind safety goals for external safety for the first time. It is evident that the ministry (VROM) wanted to promote the quantitative method by providing the computerized process SAFETI, which was designed to reduce the costs of risk analysis. At present, approximately half of the 160 plants affected by the post-Seveso directives have performed a risk analysis. However only ten of them have used the computer program SAFETI.

1988: Resolution on "Risks of Serious Accidents" (VROM)

This resolution is the Dutch implementation of the Post-Seveso directive of the EC; it is derived directly from the Environmental Planning Decree (IMP-M). All Post-Seveso plants are required to prepare an external safety report (ESR) every five years. The plants must provide a quantitative risk analysis even though the Post-Seveso directive does not require it.

1988: National Plan for Environmental Protection Policy (NMP, 1988-1989, 21137)

The National Plan for Environmental Protection Policy (NMP) was the first strategic long-term environmental plan in the Netherlands; it contains environmental goals for the years 2000 and 2010. The main goal of the policy is to maintain the resilience of the environment by providing for sustainable development. The resilience of the environment is affected negatively when certain environmental influences are not eliminated within one generation. To avoid this, the NMP is aimed at protecting humans, animals, plants, the ecological system (ecosystem) and property. A supplement to the NMP (OMR) specifies how these subjects are to be protected.

1989: "Dealing with Risks" (OMR, VROM)

In 1989, the ministry VROM introduced the annex to the National Plan for Environmental Protection Policy (NMP), "Premises for Risk Management" (OMR).

The risk analysis strategy of the Dutch government was developed further in the OMR. The annex is seen as one of the pillars of environmental policy in the Netherlands. In the OMR, a quantitative method of risk analysis is applied as an instrument to specify safety goals for "modern risks" such as chemical installations, nuclear power plants, transports of hazardous goods, and air transport. The OMR specifies that quantitative methods should be used to assess the safety of a given current system and also, in combination with other aspects, to optimize environmental planning.

The risks taken into account by the OMR include involuntary risks to humans, animals, plants, and ecosystems (major accidents, hazardous chemical substances, and radioactivity). The annex covers both risks resulting from hazard sources as well as the risks of pollution.

1990: Dealing with the Risks of Radioactivity (Norms for ionizing radiation for the protection of the environment and the work place) (OMRS)

The annex "Dealing with the Risks of Radioactivity" (OMRS) was drawn up in order to convert the safety goals defined in "Dealing with Risks" into a workable form for the area of radioactivity [UmSR, 1990]. The OMRS takes a position in this annex on the risk criteria "individual risks" and "group risks," saying that these criteria should do more than protect against deaths due to accidents related to technological activities. Group risk and its standardization should also aim at minimizing the likelihood of social disruptions after large-scale accidents at technological installations.

It must be noted that "Premises for Risk Management" (OMR) does not have the legal status of a decree, meaning that it is not legally binding in any direct way. Despite this legal position, the ministry VROM has nonetheless tried to implement the safety goals which are defined in the OMR. Thus far, these efforts appear to have paid off, as the ministry has achieved many of its goals for quantitative risk analysis prior to the enactment of more formal legislation.

2. Risk Analysis as a Basis for Risk Assessment

2.1 Essential Information Provided by Risk Analysis for Risk Assessment

Risk is viewed as a combination of damages and their probability. Every hazard source can cause varying extents of damage. The extent of potential damage and the probability of its occurrence can thus be determined for all possible scenarios.

This means that the only information required for a risk assessment is a single pair of numbers: the extent of damage and its probability. During the assessment process, the expected extent of damage and its probability are estimated for various selected scenarios.

Probability is represented as a quantitative value between zero and one. The extent of damage to humans and the ecosystem is also quantified. The following indicators are derived from the study of relevant hazards to humans and the ecosystem; they must be examined during risk analysis and utilized for risk assessment:

Humans:	-Probability of death
	-Noise pollution
	-Odor nuisance
Ecosystem:	-Impact of chemical substances
	-Noise impact
Microorganisms:	-Genetically-altered organisms

The factors which play a role in the determination of risks include both the duration of exposure for endangered persons, living organisms, and objects as well as the concentration of hazardous substances and the type and extent of potential damage.

The risk of death for short-term exposures following accidents is calculated within the framework of external safety. The risks for chronic hazards, however, are dependent on factors like wind direction and the elevation of the hazard source. In such cases, the degree of exposure is of fundamental importance for risk analysis and assessment.

2.1.1 Hazards to Humans

In general, only the probability of death is taken into account in the description of risks to humans. One differentiates between those persons within (participants) and those on the outside (non-participants) of the plant. Although deaths are the most important criteria for measuring harm caused to humans, noise pollution and odor nuisance are also considered.

-Individual probability of death: The probability of death for individuals and groups is the most decisive criteria for the assessment of risks. Other types of harm, such as injured persons or material losses, are not directly taken into account. Injured persons are implicitly taken into consideration with the assumption that every death is likely to be accompanied by ten injured persons. Material damages are not taken into account because, it is argued, they do not have any influence on risk assessment.

The actual manner of death is not distinguished in the assessment of risks. Similarly, no distinction is made between short- and long-term damages. Therefore a death resulting directly from an explosion is treated statistically the same as a death caused by long-term effects. Only involuntary risks are considered. Voluntary risks, such as those incurred while participating in sports, are not a concern of environmental protection policy.

The following measurements are relevant for various types of risk analysis: for radiation hazards, sievert values (Sv); for thermal hazards, the density of the energy current; for pressure hazards, the force of pressure; and for the spread of poisonous gas, the concentration.

Although the maintenance of industrial health and safety standards (worker protection) is covered by labor policy and not by environmental protection policy, the annex "Dealing with Risks" (OMR) stresses that certain labor conditions may produce circumstances that place particular organs of the body at risk.

-Noise pollution: Noise pollution is measured in decibels (dB). It refers to both chronic disturbances and to short-term high noise levels. Noise within buildings is differentiated from noise outside. Noise pollution can cause sleep disturbances and hearing damage.

-Odor nuisance: Odor nuisance is a significant local problem in the densely-settled Netherlands. Unpleasant odors in existing industries are differentiated from those in new industries. Odor nuisance is measured in units per cubic meter.

2.1.2. Hazards to the Environment

Information about ecological impact is not as relevant to risk assessment as information about hazards to humans. This is attributable in part to a deficiency of relevant scientific knowledge. The lack of emphasis on ecological impact is often explained with the argument that if humans are adequately protected, then the environment will be sufficiently protected as well. It is recognized, however, that more research is necessary in this area in order to provide for a sustainable development which takes environmental protection adequately into account.

-Impact of chemical substances on the ecosystem: Populations, not individual organisms, are of importance to ecosystems. The intensity and the duration of chemical impact must be determined in order to assess risks. The effects of chemical substances on plants and animals is represented in EC50 or LC50 values.

-Noise pollution for ecosystems: Natural noise levels for ecosystems must be taken into account. Noise levels are, however, highly dependent on time and location.

-Microorganisms: Because organisms reproduce themselves, two questions must be answered by a risk analysis: (1) Does the genetically altered organism take on properties that make it more hazardous than the unaltered organism? (2) Can another organism take on harmful properties by transmitting genetically altered material? If at least one of these questions can be answered in the positive, then the potential damage must be appraised.

2.1.3 Types of Damage Explicitly Not Taken Into Account

In addition to the indicators listed above, additional factors could potentially be considered in the realm of a risk analysis and assessment. A few of the indicators which are not explicitly taken into account in the Netherlands are considered in other countries, including:

-Financial-economic damages: Financial-economic damages are not considered crucial to risk analysis. It is conceded, however, that financial-economic aspects play a role in socio-political decisions.

-Exposure of plants to radioactivity: It is assumed that the protection of individual humans against radioactivity also provides adequate protection for plant and animal populations. Prudence is however necessary whenever plants and animals are subject to extremely hazardous situations.

-Profit and benefits: The risks examined under the heading of external safety are caused by human activities. Such activities normally provide the affected persons with a particular profit or benefit. Measures to reduce risk tend to reduce total profit, due to either the costs of risk reduction measures and/or to the resulting reduction of productivity. It is therefore judicious to take financial considerations into account in the analysis of risks deemed as "not all too great." This is not, however, done in the Netherlands. In addition to material costs, other types of benefits such as recreational values, agriculture, and operational losses might also be calculated into a risk analysis.

The methods for the practical implementation of risk analysis are described in the *red book* (Methods for Determining the Probability of Occurrence), in the *green book* (Methods for Determining the Potential Extent of Damage), and in the *yellow book* (Methods for Determining Physical Effects) [DGA, 1990].

2.2 Risk Criteria and Safety Goals

Suitable criteria for risk assessment and for the definition of safety goals can be derived from the types of damage described in section 2.1. In the Netherlands, the implementation of risk analysis and its results has been standardized through the prescription of a quantitative approach. According to this approach, the expected extent of damage and its probability are the two decisive risk criteria. These two criteria also define the risk value used to carry out the final risk assessment.

2.2.1 The Dutch Concept of Risk Assessment

The Dutch concept of risk differentiates various steps in dealing with risks; this series of steps comprises the process of risk management. They include:

(1) Identification of hazards for humans and the environment

(2) Estimation or quantification of the potential extent of damage and its probability

(3) Assessment of the risks

(4) Avoidance of risks when possible; if this proves difficult, then protective measures must be directed at the source or at the extent of potential damage.

(5) Achievement of an acceptable risk level and reduction of risks down to a negligible level.

Risk analysis focuses on individuals, groups, and collective ecosystems. Short- and long-term damages are taken into account. These forms of damage, together with the probability of their occurrence, form the basis for risk assessment. In the process of risk assessment, the risks, comprised of extent of damage and its probability, are divided into the following three classes:

(1) Negligible risks

(2) As low as reasonably achievable risks (ALARA)

(3) Unacceptable risks

2.2.2 Criteria for the Assessment of Risks to Humans

The criteria used for the assessment of human risks take primarily the risk of individual deaths and group risks into account. The hazards of radioactivity at the work place are specified separately and compared with risks in other occupational fields such as the construction and heavy metal industries. Limits for noise pollution and odor nuisance are also defined.

-Probability of death: Individual safety goals for new hazards are fixed at a probability of death of 10^{-6} annually. The risk level deemed as negligible for the individual is set at 1% of the safety goal, or at a probability of death of 10^{-8} annually. These values refer to a person who is (hypothetically) present at a given location at all times. If this person is exposed to multiple external (new) risks, then the safety goals are set at levels which are 10% higher, between 10^{-5} and 10^{-7}. The limit of 10^{-6} annually corresponds to a dosage equivalent to 0.4 mSv annually. The risk of injury is implicitly taken into account in the selection of the risk indicator *incidences of death*. It is assumed that ten injured persons accompany every death.

LPG-policy is consulted for the determination of safety goals for individuals exposed to existing hazards. Plants in which the individual risk exceeds 10^{-5} annually are required to undertake clean-up measures. This value is presently used for the assessment of risks in existing plants.

The situation is similar with regard to hazardous substances. The maximum permitted individual risk for a hazardous substance is 10^{-6} annually; the risk considered as negligible is 1% of this figure. The maximum allowable and the negligible individual risk for all hazardous material is 10% higher than the corresponding values for individual substances. The maximum level for substances with limits is reached when the concentration of a substance reaches the "no-effect" concentration, as determined by the Dutch Council on Health. The negligible value is 1% of this limit.

-Groups: Group safety goals for new hazards are illustrated in the accompanying diagram. The vertical coordinates represent probability values or the expected frequency (F). The horizontal coordinates indicate the number of deaths or damages (N). Each F/N-point signifies that the frequency F is accompanied by the minimum number of deaths or damages N. The curves on the F/N diagram represent the limits for permitted and negligible risks. The fact that a single large accident is perceived as being worse than several small accidents of the same extent was taken into consideration in the construction of these curves (the so-called n^2-aversion effect).

In the course of a risk analysis, a curve is produced on the F/N diagram for every hazard source (e.g chemical installation). The risks of an installation are considered to be negligibly small if the F/N curve lies entirely within the negligible area. If a part of the curve lies in the transitional area, then risk reduction is required. If a part of the curve lies in the unacceptable area, then significant measures must be taken immediately to reduce the risk.

Specific measures to be taken against existing hazards are described in the annex "Dealing with the Risks of Severe Accidents" [UmR, 1989].

Insert chart "Group Safety Goals"

from English summary (with corrections) here

-Injuries at the work place: Safety goals for specific organs are determined by organ dosage limits. The highest permitted equivalent dosages in the work area may not exceed 20 mSv annually. The highest dosage for the remainder of the work force is 2 mSv annually [UmSR, 1990].

-Noise pollution: The negligible level of noise pollution is generally set at 10% of the ideal noise level. The ideal noise level for individual noise sources is in most cases 50 dB. Limits for air traffic are represented in so-called cost units (CU). This value can be converted into dB. The ideal CU value is 35 CU, and the maximum permitted value for new noise sources is 45 CU.

-Odor nuisance: The limit in new industrial installations is 99.5 quantile per odor unit/m^3. The limit for existing installation is 98 quantile per odor unit/m^3. Further investigations into the determination of odor limits are still in process.

2.2.3 Criteria for the Assessment of Transport Risks

Safety goals for transport routes correspond to those for hazard sources. The safety threshold for individual risks is the same for both transport routes and stationary installations. In order to compare the group risk of a transport with the group risk of a stationary installation, a unit length for the transport route must be arbitrarily determined. The risks for this unit length can then be compared with stationary hazard sources. A team of specialists has been working on setting safety goals for transport routes for the past year. Lengths of either one or ten kilometers are currently being considered; ten kilometers will probably be chosen as the standard unit.

In the area of rail transport, one must keep in mind that a moving train causes less risk than a train standing in a station. This phenomenon has particular consequences for freight depots, which are normally surrounded by relatively dense settlement. Safety goals may lead to moratoriums on the construction of new homes or to orders to demolish existing dwellings.

In the Netherlands, the transport of hazardous substances via the waterways is an important subject and a particular challenge for the makers of safety goals. A reasonable adaptation of safety goals for inland waterway transport is being investigated in part by participants in the project "Safer Water Traffic."

In the area of air transport, the only safety thresholds that have been set thus far are those for individual risks. Safety thresholds for collective risks are still being considered. In principle, the individual threshold for the probability of death for air transport is also 10^{-6} annually. Installations with values up to $5x10^{-5}$ are permitted to continue operating, but they may not be replaced. Installations with larger risk values must cease operating.

2.2.4 Criteria for the Assessment of Risks to Ecosystems

Protective goals for ecosystems focus on the preservation of the structure (species) and functioning of ecosystems. In the case of aquatic and terrestrial ecosystems, it is assumed that the preservation of structure automatically protects its functioning. Protection is geared chiefly toward populations and not toward individual organisms. Protective goals are limited to substances with safety thresholds. In the case of substances without threshold values, it is assumed that protective (safety) goals set for humans also adequately protect the ecosystem.

Protective goals for ecosystems are based on tests of the ecosystems as well as on observations. The safety threshold for harmful effects on an ecosystem equals the concentration of a substance which still provides protection to 95% of the species in the ecosystem. This threshold is referred to as the collective risk of a substance. The negligible value is 1% of this limit. Whenever possible, the negligible value for noise pollution in an ecosystem is established at a level equivalent to the background noise level of the ecosystem.

2.2.5 Criteria for the Assessment of Risks to Microorganisms

If a genetically altered organism takes on properties that make it more hazardous than the unaltered organism, or if another organism takes on harmful properties by transmitting genetically altered material, then a risk analysis must be performed. The probability of these hazards must be quantified. In addition, the following mechanisms must be assessed: (1) the transmission of genetic material; (2) the phenotype of the altered material; (3) the probability of its onset; (4) the properties of the new substances; (5) the interaction of the new substances with the environment.

3. Risk Assessment Methodology

3.1 Why Quantitative Safety and Protective Goals?

A quantitative approach to risk assessment was chosen in the Netherlands for various reasons. The most important of these is that clear and objective criteria were sought for the assessment of risks. This is easiest if all risks are represented quantitatively and in the same units. The quantitative approach was also chosen because it makes it possible to standardize risk analysis, thus making the practical work of enforcement agencies easier.

3.1.1 Objective Criteria for Risk Assessment

Risks are of course much more complex than can be described by a single pair of numbers (extent of damage and its probability). Extent alone has many more facets than assumed by the Dutch risk concept. The neglect of these additional aspects is justified, however, by the fact that the probability of death is the most decisive factor for measuring risks. If necessary, other important aspects are allowed for in the calculation of the probability of death. This means that in practice, the Dutch concept of risk analysis is based solely on two criteria: individual probability of death and group risk as depicted on an F/N diagram.

Three aspects require further explanation: the risk aversion, the neglect of certain types of hazards, and the combination of hazard types. Group risk refers to persons outside of the plant grounds. The safety goals for groups help to avoid social catastrophes, that is, the possibility that an entire group of humans is affected at one time. If risk had been defined as a product of probability and extent, and the damage extent of a still permissible risk were *x*-times greater, then the probability would have to be *x*-times smaller in order to fall within acceptable limits. These calculations have been deemed inappropriate. It was assumed instead that a damage extent x-times greater must have a probability of occurrence x^2-times smaller in order to fall within acceptable limits. This means that rare but greater damages are perceived as being more severe than more likely occurrences which are accompanied by a lesser extent of damage.

This quadratic term was more or less arbitrarily chosen. How well this formula actually describes public risk aversion has not yet been investigated. The choice of an arbitrary formula stands in contrast to the time and effort invested in the creation of a realistic physical-chemical model for risk analysis. The determination of the probability of occurrence, the spread of damages, and the sensitivity of humans and the environment were empirically investigated and theoretically derived from a number of experiments. It is thus not surprising that representatives of industry and the public express opposition to group risk assessments, for subjective aspects hardly come into play in the assessment process.

One might also question the validity of viewing individual and group risks as representative of all other types of damage. In addition to financial-economic damages and the exposure of plants to radioactivity, there are potentially other types of damage worthy of consideration, including: injuries and psychic influences on humans, economic damages (e.g. loss of material assets, living space, jobs) damages to social institutions, ecological damages (e.g. water pollution) and affect on quality of life.

Van Ravenzwaaij stresses that a comprehensive description of risk must include more that just individual and collective probability of death [Van Ravenzwaaij, 1994]. In order to describe risk more completely, he recommends expanding risk criteria to the following five groups: individual risk, group risk, group risk for injured persons, risk of housing loss, and collective risk for the ecosystem.

But the selection of several damage types of varying nature leads to questions about the comparability of damage types. It is thus difficult, for example, to compare x km^2 of polluted water surface with y dead large animals. The suitability of the Dutch approach to risk assessment could be confirmed if it were determined that the loss of human life is both the dominant and the most representative damage type.

3.1.2 Aids to Practical Implementation

Efforts were undertaken in the 1980s to make risk analysis easier and less expensive. From the very beginning, the environmental division of the VROM invested time and energy in developing computer systems which would simplify the process of risk analysis. These systems were used to further develop methods of risk analysis, to carry out case studies, and of course to support consulting offices in their work.

VROM made the software packet SAFETI available. Additional software systems which came into use are Riskcalc, SAVE II, and the model "Effects and Risk Curves," developed by TNO [Groot, 1991].

The Environmental Planning Decree of 1985 describes measures designed to provide assistance in the consuming tasks of risk analysis and assessment. The decree states [Van Ravenzwaij, 1994]:

> *In order to keep the labor and material resources required for a risk analysis and assessment at an absolute minimum, a comprehensive computer program (SAFETI) has been developed to simplify the risk appraisal of industrial installations. . . . The following measures should be taken in order to simplify the practical process of risk analysis: (1) Consulting agencies which carry out risk analyses for*

the individual plants should be provided with training programs; (2) Enforcement agencies should be informed about the current state of affairs; and (3) The VROM should offer technical and scientific assistance.

As Van Ravenzwaaij remarks, these developments have led to the standardization of risk analysis [Van Ravenzwaij, 1994]. While risk analysis in the early 1980s focussed primarily on providing information about safe distances and accident scenarios, the second half of the 1980s brought a concentration on the determination of individual and group risks.

However even the VROM has some reservations about the computer program SAFETI. SAFETI may be very comprehensive, but it is not easy to use. Further, plants are not legally required to use the program for risk analysis. Only ten of eighty external safety reports made to date have utilized the SAFETI program. In addition to SAFETI and the computer programs mentioned in the preceding, various other programs have also been employed [Beroggi and Kröger]. In order to further support the plants, the ministry has issued additional directives about how to prepare an external safety report.

3.1.3 Selection of Methods

The selection of the methodological approach used by risk analysis largely determines the approach to risk assessment. The choice of a quantitative approach to risk analysis does not necessarily require that safety and protective goals be expressed in quantitative values; theoretically, risk assessment could still be carried out in a qualitative, descriptive way. The selection of a qualitative approach to risk analysis, however, requires the choice of a qualitative approach to risk assessment.

Hence the choice for a particular methodological approach can not be made by risk experts alone. The authorities responsible for enforcement as well as representatives from the public should also be allowed to play an active role in the selection of methods for risk analysis.

In the Netherlands, the procedure for risk analysis was drawn up by a group of experts. All environmental quality norms and protective goals are examined by a group of specialists from the Public Health Council. After this examination, the experts formulate a "concept-policy-position" which is then presented to all involved authorities and parties as well as to the Lower House. After the "concept-policy-position" has been discussed in the Lower House, objections may be filed by the public during a fixed period.

Yet despite the various commissions and independent reviewing authorities involved in the complex process of risk analysis, individuals may nevertheless be able to exercise decisive influence over the choice of basic methods. This phenomenon has been observed in the Netherlands. If experts in responsible positions at the Ministry of the Environment had not taken control of matters in time, the Netherlands would not have adopted the quantitative protective goals which are now recognized as pragmatic measures.

3.2 The Risk Decision

Risk assessment is concerned primarily with determining whether or not a particular installation is safe. One speaks in this context of a risk decision. However according to the Dutch approach, risk is just one aspect of spatial and environmental planning. The goal of the National Plan for Environmental Policy is the present and future protection of humans, animals, plants, ecosystems, and property through measures which are intended to assure sustainable development. In order to achieve this goal, it is important to change the one-way flow of various substances into a circulation, to use energy more rationally and efficiently, and to improve the quality of the environment. If these goals are to be achieved, structural changes must be promoted without losing sight for measures which limit negative developments.

The measurement of risk as a combination of damage probability and extent as defined in the preceding thus provides only one component of a sustainable spatial and environmental planning process. It is therefore legitimate to question the necessity of decisions which isolate the question of risk, for since environmental policy tries to provide for a sustainable development, isolated risk decisions are not possible. If this environmental policy is to be workable, then protective goals should not be defined by risk criteria alone. However most protective goals are based on aspects of risk. An exception is the safety threshold for group risks, which takes an aversion figure into account. The ALARA-principle (as low as reasonably achievable risks) calls for risks to be brought down to a negligible level within one generation. The possibility of measuring risks according to other criteria, such as costs expressed as marginal costs, has not yet been considered.

3.2.1 Comparing Different Kinds of Risks

In addition to the determination of safety thresholds, other problems encountered in risk assessment are related to the type of risk. The difficulty lies in comparing different kinds of risks (chemical risks and radiation risks) and in comparing risks with different consequences (chronic disturbances and acute hazards).

The writers of "Dealing with Risks" [OMR, 1989] concentrate above all on acute hazards resulting from accidents. Because these safety goals are generally applicable, they can also be applied to chronic disturbances. Air and noise pollution, odor nuisances, and radioactivity are among the most important chronic disturbances.

Because protective goals must first be defined independently of hazard types and damage forms (as death risks), it has always been clear that risks of different natures can be compared with one another. The comparability of risks was an important reason behind the decision for a quantitative approach to risk analysis. Only during implementation did it become clear that this approach merely shifted the problem from risk analysis to risk assessment.

Practical experience will reveal the advantages and disadvantages of a quantitative approach to risk assessment that has been simplified by assuming the comparability of risks. At this point, at least certain areas of quantitative risk analysis are taken seriously by all involved parties. These parties have also, however, voiced serious reservations.

3.2.2 New and Existing Hazard Sources

The National Plan for Environmental Protection Policy (NMP) specifies that new hazard sources must immediately meet safety goals. If they do not, then construction or production permits are not issued. Therefore attempts are made to maintain the lowest possible risks on the borders of industrial zones so that the use of adjacent zones is not significantly affected.

The situation is somewhat more complex when previously existing hazard sources come into play. Safety goals are just one of many aspects to be considered. Realization of safety goals is more costly and time-consuming than in existing plants. Social aspects must also be considered in the assessment of existing plants whenever various developmental goals, including those related to the environment, agriculture, traffic and transport, economics, housing construction, and employment possibilities, are being pursued. If all these factors are to be considered, then choices must be made about how quickly and at what price final decisions will be made.

The National Plan for Environmental Protection Policy lists the consequences of reaching defined thresholds for certain substances. This was not done in other cases because the risks are not yet known. A systematic analysis of these risks is still in process. An estimation of the pace at which the set goals should be reached can only be made after a systematic analysis of the risks.

This policy can of course lead to problems, especially where previously planned buildings do not meet safety goals. Yet it is difficult to intervene in the spatial planning process before the exact risks are known. In the case of existing installations, spatial planning problems are handled by regional environmental offices and local developmental agencies. A conservative approach is normally taken. An attempt is made to reduce existing sources of hazards before construction permit procedures begin.

3.2.3 Superimposition of Risks

The environment is polluted by many different substances simultaneously. If it cannot be proved that a combination of substances has a negative effect on the environment, it is assumed that no additional risks arise as long as limits are not exceeded. Combinations of substances which produce negative effects do however exist. Individual substances which border on acceptable safety thresholds can exceed these values when combined. This potential was taken into account by setting the negligible risk per substance at 1% of the threshold value.

Radioactivity risks are calculated in a similar manner. The safety threshold of 0.4 mSv for individual risks was set under the assumption that an individual is affected by ten hazard sources simultaneously. The highest permissible individual risk per radiation source is therefore 0.04 mSv [UmSR, 1990].

The superimposition of risks is of equal importance to exposed persons, industry, and spatial planning. In order to avoid conflicts with neighboring zones, industry tries as much as possible to locate lesser risks on the borders of industrial zones whenever possible. This is however not always feasible, especially with regard to hazardous material transports. The question for industry is: which of the existing plants must contribute to risk reduction and how much? The question for new plants whenever several plants want to build at the same time is: which plants have what construction priority?

A confusing situation arises when a single plant which fulfils safety goals wants to divide itself into two independent plants. In such a case, the division may not be permitted out of technical safety considerations because the new plant would be located within the risk zone of the old one.

3.2.4 From Consideration of Hazards to Consideration of Damages

The Dutch concept of risk assessment is derived from the National Plan for Environmental Protection Policy (NMP). This document specifies that environmental planning should be oriented toward sustainable development. The goal is not to pursue sustainable development by taking selected measures (reductionistic approach), but to attain environmental goals with sustainable development in mind (holistic approach). The former approach concentrates on hazards, for if the potential for every hazard falls below a defined limit, then the risk for the entire system is also limited. The latter approach is based on predominant damage potentials, which are limited by means of safety goals.

The second approach appears to be more rational because it does not require that safety goals be adapted according to the growth or disappearance of hazard sources. This approach is however very difficult to apply, for ultimately individual plants must be singled out for risk reduction.

The NMP recognizes this problem and specifically states that the damage-oriented approach can by no means completely replace the hazard-oriented approach. The Dutch concept of risk assessment can thus be viewed as a kind of provisional solution. Defined as individual and collective risk, safety goals are damage-oriented and hence (almost) independent of individual hazard sources. Enforcement is carried out in a hazard-oriented manner, as each individual plant must satisfy the determined safety goals.

3.3 Risk Communication

3.3.1 Passive Distribution of Information

Risk communication refers to the exchange of information about risks between authorities, plants, and the public. Three separate parties participate in risk assessment: plants, the responsible authorities (communities and provinces), and citizens [Weterings, 1991]. The main emphasis of risk communication is placed on accidents. The history of risk communication in the Netherlands has developed simultaneously to the implementation of the post-Seveso directives. These directives require that the public be informed about industrial risks. In addition, persons exposed to risks must be informed about the risk situation and appropriate measures must be taken.

The first step taken toward regulating the distribution of relevant technical risk information among the public is described in "General Policy Rules" (AMP) for accidents. Only a passive distribution of information is involved here, for the affected parties are faced with two obstacles: they must seek out the information themselves (from ESR), and the information is usually difficult or impossible for laypeople to comprehend [Van Eijndhoven and Worell, 1989].

Because the post-Seveso directives of 1982 do not specify how information should be distributed, its dispersal in the public was initially passive. In 1988, an appendix was added to the directives specifying that all persons affected by the risks of accidents must be informed. This requirement was also adopted by the Netherlands.

Brochures which explain basic information about the risk concept in everyday language are available at the VROM. However interested persons must pick up the information themselves, and the brochures are of course only of interest to persons confronted with the risk problem in one way or another.

3.3.2 Active Distribution of Information

Investigations at two separate locations tried to determine how chemical plants worked together with communities to spread information among the surrounding population. The content of the distributed risk information differed in each case. Quantitative, probability-related facts were the focus in one case, while a qualitative description of the potential results of an accident was provided in the other case. This difference is attributable in part to the content of available risk information, and in part to differing degrees of readiness on the part of the communities and plants to invest time, money, and effort in the risk communication process. Since there are no specifications about the quality of risk information to be made available, communities and plants normally keep their efforts at a minimum.

The investigations revealed that the population was indifferent toward the distribution of information. This indifference can be explained by the background of the investigated cases: the plants were not particularly problematic, and the population had long been accustomed to living with these risks. In addition, the existing risks did not have consequences for spatial planning [Van Eindhoven, 1990].

As a consequence of these investigations, emergency planning was integrated into the communities in order to increase risk consciousness. A recent national campaign about risk information was directed at informing citizens not only about what to do in the event of an accident, but also about the existing risk situation. The emergency ordinance requires communities to inform the public about existing risks.

3.4 Implementation and Enforcement

3.4.1 Creation of the external safety report

To date, about half of the 160 plants required to prepare an external safety report (ESR) every five years have submitted their first report. Performance of the risk analysis is the responsibility of the plants, which usually engage consulting offices for this task.

Because the type and amount of hazardous substances present can change, the number of plants required to file a report varies. A plant which must submit an ESR can later be released from this requirement if the amount of hazardous substances present is reduced. A plant may also be added suddenly to the list of plants required to submit a report if it begins to work with hazardous substances.

The ESR is public. Therefore it must be comprehensible for anyone "reasonably trained and informed." The report should not be directed exclusively at experts, but it must also not necessarily be capable of being comprehended by the lay public. The ESR is made up of four parts. Part 1 contains a general description of the installation and existing hazardous substances along with their properties. The situation is represented by geographical maps on which the relevant facilities are marked. Chemical, physical, and toxicological properties of the substances must be described.

Part 2 provides a general description of the processes which are carried out in the installation. This may be depicted by means of a block diagram. Part 3 describes potential undesired occurrences. Measures taken to reduce the chances and extent of such occurrences must also be described. This information must be provided for every installation which contains hazardous substances. Measures taken to reduce the chances and extent of damages include regular inspections, the installation of alarms and signals at various points in the production process, the issuance of warnings in the event of production interruptions, minimization of processing units, and remote-controlled regulation mechanisms. Part 3 also requires a description of all measures taken to combat serious accidents. These measures include the emergency plan, the alarm system, plans for sprinkler systems, and a description of communication procedures.

Part 4 encompasses the quantitative risk analysis. The most hazardous installations are singled out with the help of a selection system. A quantitative risk analysis of these installations is then performed. Part 4 also includes a list of identified potential accidents, their consequences, and their probability. Quantitative individual risks are represented by isolines on a geographical map; group risks are entered onto a frequency/number of damages (F/N) diagram.

3.4.2 Tasks of Enforcement Authorities

All plants which surpass critical levels of hazardous substances must submit an external safety report (ESR) to the enforcement authorities. If a plant falls under the Air Pollution Law (LWR), then regional authorities are responsible for enforcement. The community is responsible if the plant falls under the Hazardous Incident Ordinance. Since communities often have limited means, they often receive financial and material support from VROM.

Enforcement authorities are assigned with various tasks related to the appraisal of risks. They must assist plants in determining the appropriate degree of detail of the ESR, in defining accident scenarios, and in finding the most appropriate calculation model. These duties apply to both new and existing plants.

After the ESR is submitted, enforcement authorities test it by means of a formal procedure in order to determine whether it meets the required specifications. The ESR is rejected if it does not meet requirements. If the ESR is sufficient, then copies are distributed to the appropriate authorities including the fire department and factory safety and health control officials, who then draw up emergency plans.

The actual content of the ESR is not evaluated until this point. The assumptions and calculations contained in the report are now examined. This caution has nothing to do with distrust toward the authors of the ESR's; quantitative risk analysis is a very complex procedure, and the assumptions adopted can influence the results considerably.

A careful examination of the quantitative risk analysis is of fundamental importance because serious decisions are based on the ESR. Such decisions include the granting of building permits and decisions about spatial and emergency planning. If the examination of the contents results in serious misgivings about the ESR, then the officials who have already received copies must be notified. The plant must then resolve these inconsistencies. While the formal test of the ESR takes two to three days, an expert must spend ten to fifteen work days evaluating the contents.

3.4.3 Priorities and Scope of Risk Assessment

As indicated above, the external safety report (ESR) has several functions. The ESR indicates to the plant submitting the report which scenarios create the most risks, and how these risks are appraised by enforcement authorities. The plant often ends up altering certain processes in order to achieve a lesser total risk. If the risks in an existing plant exceed defined safety thresholds, then the plant must develop a clean-up plan; planned plants are denied a building permit if their risks exceed thresholds.

The ESR is also employed for spatial planning. A new apartment building may be built near a plant only if it does not raise the risks of the plant above safety thresholds. Similarly, the use of an industrial zone may not be increased so greatly that risks rise above defined threshold values.

Since the ESR is public, it is also made available to the public during building permit processes. In practice, practically no formal objections are filed as a result of the ESR. The significance of the ESR for spatial planning is much smaller than one would expect.

The ESR is also employed for emergency planning, although the ESR is an instrument of little use in its present form. Emergency planners are interested in maximum safe distances within which serious consequences are expected for humans. These distances are determined by the range of the hazard (e.g. heat radiation or spread of harmful substances). This deficit is supposed to be corrected in the near future.

A final consideration is the priority in which plants should be investigated. In general, new plants have priority over existing plants so that the building permit process will not be slowed down any more than necessary.

4. Experiences with Risk Assessment

4.1 Reactions of the Stakeholders

4.1.1 Reactions from the Public

Reactions from the public are most clear in cases of persons directly affected by accident risks. This is especially true for group risks for transport routes. Residents who are still permitted to live near transport routes have trouble understanding why they are not permitted to add onto their homes or why additional residents are not allowed to move into the area. This phenomenon occurs when group risk nears its threshold value.

The comparable situation is in the case of the largest airport in the Netherlands, Schiphol near Amsterdam. Two years ago, building permits were still granted for construction near the airport, and the government subsidized the renovation of homes in this area, but today some residents who live near the airport must leave their homes and no other building near the airport can be built.

Because the regulations appear incomprehensible to them, residents have joined together in various organizations. They often argue that everyday risks are much greater for them than the flight risks they have grown up with. While the public accepts hazards well-known to them, they often react with adamant opposition to unknown or undesired hazards. This behavior can be observed in the case of environmental organizations which protest against the transport of hazardous material by road and by rail.

The public has the most influence on risk policy when the community itself is responsible for enforcement. If however regional authorities are responsible, as in the case of the Dutch train system's chlorine route, then the community's hands are tied. Not only will risk along the rail route be raised, but the affected communities must adapt their spatial planing to the risk situation. An often tried method in such cases is to initiate a discussion about the problem through information panels.

In a letter to the Ministries of Transportation and the Environment, the Union of Dutch Communities (VNG) made the following four points: (1) Only individual risk should be considered in the setting of safety goals; (2) Safety goals for group risks should be dropped except in cases in which alternatives must be weighed against each other; (3) A concrete program of operation for the transport of hazardous materials should be established; (4) The demolition of housing for the purposes of risk reduction should not be permitted.

Public attitudes about external safety has been systematically investigated for the region Rotterdam [Stallen and Tomas, 1988]. Three questions made up the focus of the study: (1) Does the public feel threatened by its technical and industrial surroundings, and if so, to what degree?; (2) In what ways do affected persons deal with these feelings of endangerment?; and (3) Does the presence of specific technical hazards represent a daily source of stress?. The study determined that people who think they can control hazards that suddenly appear are also more likely to accept chronic exposures to industrial risks.

The study also determined that people are better able to deal with feelings of endangerment by industrial risks if a possibility exists to find a more healthy alternative. It also showed that women are put under more stress and feel more threatened by technical installations than men. This is not because women are more apprehensive, but because they value health and other values more than men. The authors conclude their study by stating that risk communication with the public should receive at least as much attention as quantitative risk analysis.

4.1.2 Reactions from Industry

Dutch industry is organized in the Union of Dutch Entrepreneurs (VN0). As one might expect, it was the VNO that reacted most vehemently to the environmental directives, including safety goals. The representatives of industry agree in principle that environmental norms are necessary. Their criticism is directed chiefly at overly strict norms which lawmakers are eventually forced to scale back.

An often cited example is the safety threshold for radioactivity. In the Netherlands, the natural radiation value (from the earth or the atmosphere) is 1 mSv annually. Added to this value is the figure of 0.5 mSv annually from medical diagnosis. The use of building materials constitutes an additional value of 0.5 mSv annually. This makes for a total of 2 mSv per person and year. In the Netherlands, the threshold value for external safety in each installation is 0.04 mSv per person annually. This means that the threshold value per plant is 2% of the natural value. This leads to situations in which natural radiation is several levels higher than the radiation permitted from industrial activity. The VNO feels that this disproportion is too large.

The problem with safety thresholds is also illustrated with regard to other hazards such as PVC, carbon dioxide emissions, and soil clean-ups. More than anything else, the VNO criticizes that threshold values are often prematurely defined without adequate considerations of the consequences. These hasty decisions are usually corrected in the long run, but this kind of policy is hardly conducive to acceptance on the part of industry. The VNO thus recommends that better "game rules" be developed for the setting of environmental norms [Kan, 1993].

The VNO suggests that when norms are set, independent experts should be engaged in order (1) to investigate whether the norm is useful, (2) to determine whether the environmental problem is effectively combatted or merely shifted elsewhere, and (3) to appraise the practical results of the norm. The organ of enforcement should be the

Council on Health, not the Ministry of Housing, Physical Planning, and the Environment (VROM).

Industry finds fault not only with the norms, but also with the requirement to submit external safety reports (ESR). The ministry has often pointed out that an ESR should help the individual plants by providing them with a useful information basis. In practice, however, the plants already have their own inventory procedures and their own approaches to risk appraisal. After major catastrophes like Seveso, Sandoz, and Bhopal, most plants realized what consequences a catastrophe can have for the environment as well as for the plant itself. While internal measures toward risk reduction are normally coordinated with the remaining aspects of production planning, the ESR is seen as an unnecessary administrative formality and is resisted by the plants.

Finally, industry also criticizes the selected risk indicators, especially group risk. Group risk is seen as difficult to understand and properly apply. Industry only sees a use for group risk only in situations in which several alternatives are present. Yet even in these cases, industry views groups risk as merely one factor in addition to economic aspects.

A further point of contention for industry is the plant-oriented application of safety goals. It is possible that a plant which meets all safety goals cannot divide itself into two independent plants because of safety norms, as in the case Hoogovens. In the case of a division, the second plant would be located in the risk zone of the first plant, which is not permitted.

4.2 Governmental Experiences

4.2.1 Reactions from Parliament

Parliamentary risk discourse takes place in the Lower House. It must be recalled that the quantitative definition of safety goals for dealing with risks has been treated as a directive and not as a decree. This means that the binding force of the safety goals can and has been called into doubt. The goals would be legally binding if they had been issued in the form of decrees.

Two important aspects come to the fore repeatedly in the Lower House: the choice of risk criteria (probability of death) and the setting of safety thresholds, above all the ALARA-principle (as low as reasonably achievable risks). In the course of discussions about the problem of radiation, various motions were made to abolish thresholds for negligible risks (ALARA). Decisive changes will be made only in coordination with other European activities.

There is a tendency in the Dutch parliament away from a view of thresholds for negligible risks as inviolable safety goals. Risks in the ALARA-realm are no longer interpreted as "acceptable, but to be reduced as much as possible," but rather as a cue to "examine risk reductions and coordinate them with other aspects." These "other aspects" include various types of use, available evacuation routes, and possible ways to manage catastrophes [VNCI, 1994].

4.2.2 Reactions from the Ministries

Officials in the Ministry of the Environment realize that their internally developed risk assessment methods have both advantages and limitations for safety planning. For example, to date these methods have only been applied to hazard sources and not yet to hazardous situations (e.g. pollution).

In addition, up until now, only direct hazards have been registered. Also, risk assessment is only one of many methods employed in spatial and environmental planning. Additional aspects such as energy diversification and the development and use of ecological products must also be considered. Finally, the same procedure cannot be used to treat voluntary risks (e.g. smoking) and natural risks (e.g. cosmic radiation).

The VROM also realizes that the affected parties, above all industry, must have clearly defined tasks and goals. However the ministry also expects industry to take the initiative in realizing an environmental policy aimed at prevention. The ministry acknowledges that because the procedure for defining safety goals is so painstaking, it is very time-consuming as well.

All in all, the VROM is satisfied with the definition of safety goals, risk assessment, and enforcement. It does not view frequent criticism from industry and the public nor the occasional need to readapt safety goals as a drawbacks of the adopted methods.

The situation at the Ministry of the Interior is quite different, in part because it is responsible for emergency planning. Officials at this ministry openly admit that the safety goals for group risk cannot be effectively implemented with regard to spatial or emergency planning. The Ministry of the Interior is thus thinking out loud about developing alternative instruments for risk analysis and, as much as legally possible, for risk assessment. Not surprisingly, these thoughts indicate a tendency to completely remove probability from consideration and concentrate instead on damage scenarios and possible consequences. The goal of the Ministry of the Interior is to develop a simple, workable instrument that will be useful to local authorities and emergency units for emergency and spatial planning. Conflicts between the VROM and the Ministry of the Interior and challenges to the practical enforcement of safety goals are likely in the near future.

4.2.3 Reactions from the Agencies of Enforcement

The standardization of risk analysis with the software packet SAFETI has made it easier and less expensive for industry to engage in risk analysis. Yet this standardization, combined with quantitative safety goals, can also have disadvantages. Van Ravenzwaaij (1994) points out that the risk analysis procedure may be misused by varying the parameters until the desired results are achieved. This point was also made by a representative of industry who stated that because the safety threshold of 10^{-6} annually was too strict, industrial plants would manipulate risk data to achieve the prescribed value [Van Ravenzwaaij, 1994].

Officials at the Ministry of the Environment realized from the start that problems could arise out of the quantitative approach to risk analysis. In order to recognize these problems as soon as possible and to support the agencies of enforcement, two case studies about the creation of external safety reports were conducted. ESRs meeting all official specifications were conducted for *General Electric Plastics* (Bergen of Zoom) and *Akzo Salt and Basic Chemicals* (Rotterdam) [Blokker, 1990].

Yet even after these model studies, serious problems with ESRs persisted. Two commissions were set up to take action. The Administrative Commission was assigned with legal questions and administrative aspects, while the Technical Commission was made responsible for technical and practical problems. Representatives from the responsible administrations, from the agencies of enforcement, and from industry participated in both commissions.

The findings of these two commissions cannot be viewed as direct recommendations, but the agencies of enforcement did integrate them into the assessment of the external safety report. Important areas touched on by the Technical Commission include risk analysis for shipping, the use of toxicity values, the frequency of failure for pressure tanks, and the description of accident-related risks for the environment.

4.3 Risk Analysis: Elements for Contemplation

Although risk analysis, especially quantitative risk analysis (QRA), has taken on considerable importance in various fields, the application of the concept is not without restrictions. A number of limitations and caveats regarding the application of risk analysis, particularly in the field of transportation, have been the subject of discussion.

The application of risk analysis has gradually shifted during the course of its development in the Netherlands. Risk analysis was developed as a decision-support tool for the comparative assessment of various risk-inducing steps related to the chain of production and transport of dangerous goods [TNO]. However over the years, risk analysis has evolved into a decision-support tool for policy-making in the area of urban and industrial planning involving hazardous activities, for recommending mitigation possibilities, and for providing the public with risk communication. Such a shift in application raises questions about the general applicability of the risk concept, the nature of the questions to be answered, the basic assumptions of risk analysis, the inputs used, and the required outputs. The four principal criticisms elaborated in the following include: (1) limitations of the risk concept; (2) methodological uncertainties; (3) practical application; and (4) changes in the needs of policy analysis input.

4.3.1 Limitations of the Risk Concept

There are three main limitations of QRA-application in the area of transportation. First, risk analysis, in particular QRA, was developed in the process industry under two assumptions: it was supposed that the dominant hazard could be defined as toxic and that lethal effects were caused by exposure to chemical substances. Of course chemical installation are stationary; they consist of many standardized parts and components and operate in a well-defined and controllable configuration. When risk analysis was transferred to the transportation sector, it understandably focused on hazardous goods because the transported substances were the same hazardous substances present in chemical installations. Yet although the presence of this type of risk is most prevalent, it is by no means the *only* relevant hazard or necessarily the *dominant* hazard in the transportation industry.

The present definition of risk does not take into account a number of mechanical hazards which may inflict serious risks on the exposed individuals. In road and railway safety hazards, for example, the kinetic energy involved in collisions - attributable to high speeds and masses - is a serious mechanical hazard which is responsible for the majority of damages and injuries. In aviation, high speed and the presence of a large amount of fuel pose major hazards, while in shipping, the hazard of drowning is most imminent.

Second, in the area of policy planning, the risk estimate focuses primarily on the impact of hazards on what is defined as external risk - the so-called "third party risks." This definition assumes that the "first party" - the vehicle operators - and the "second party" - the passengers - voluntarily submit to the hazard, thereby eliminating them from the risk balance as "internal risk." This restricted way of defining risk appears to deny that the Harald of Free Enterprise or the Estonia shipping disaster were major accidents, which is of course an unrealistic assumption when one considers the impact that these accidents have had on the social acceptance of transportation safety and on policy-making in this area. Moreover, the application of a restricted definition of "third party" risk theoretically excludes external safety as an issue for consideration in the environmental impact statement concerning the High Speed Train in the Netherlands because the train is not intended for the transport of hazardous goods.

Third, the nature of transportation systems differs from stationary installations, which involve a confined site with hierarchically-structured command and control processes. The autonomous role of "the human factor" in critical situations, which has been formalized by legislation on "good airmanship" and "good seamanship," the variety of vehicles underway, the number of autonomous actors involved, as well as the ambiguous and multi-functional role of government cause a wide margin of uncertainty with regard to the outcome of risk calculations. Mitigating measures may also influence the results of such calculations, in particular with respect to the effects of these measure on the ultimate level of safety.

4.3.2 Methodological Uncertainties

Most illustrative in the debate about methodological uncertainties in the application of QRA is the Consensus Report on the Risk of Transporting Dangerous Goods [Solway, 1992]. This report formulates basic questions about the role and limits of QRA and about practical issues related to contracting for and conducting QRA from a user's point of view. The report also discusses the implications of its findings for risk analysis methodology. In the view of experts, QRA must move beyond merely providing senior government and corporate policy-makers with risk estimates; it should also offer recommendations for mitigation and assist with public risk communication by providing a readily understandable interpretation of its findings. Experts agree that although quantification may be useful in assigning priorities to mitigation options, mathematical precision might suggest greater certainty about risk issues than is warranted.

Further, the report recommends the introduction of a code of practice which would include elements such as assumptions, risk measures, documentation, internal consistency, uncertainties, sensitivity analysis, and recommendations for mitigation and communication.

The report also proposes the development of standard values, because risk experts must agree on the expertise supplied by specialists in other disciplines such as toxicologists, meteorologists, planners of infrastructure, and experts on disaster management and other contingent areas.

4.3.3 Practical Applications

In the Netherlands, risk analysis is frequently incorporated into environmental impact statements (EIS's) which refer to the issue of external risk. An evaluation of the way such EIS's are applied reveals several methodological caveats [De Valk and De Vries, 1994]. Ten statements were reviewed on the basis of methodological criteria that deal with ambiguity, level of bias, exactness, validity, accuracy, sensitivity, and applicability of the statements. None of the ten statements fulfilled all the criteria. Each statement bore inconsistencies which can be explained by a number of factors. First, differing legislation and regulations gave rise to differences in measuring techniques for a number of physical parameters such as noise. Second, the working style of the specialists was often careless, resulting in errors and discrepancies between the quantitative data presented in the reports and the data that appeared in the summaries.

This carelessness and the resulting negligence appear to have been caused by inherent conflicts of interest between a number of functions which must be fulfilled by EIS's. For example, there is a tension between the desire to achieve scientific correctness in the formulation of statements and the need to make the statements broadly understandable. There is also a conflict between providing globally-formulated outlines to aid decision-making and supplying more detailed information. Another conflict is related to the aim at exactness vs. uncertainty in the data and their interpretation. Moreover, the specialists are under constant pressure to deliver their reports according to a tight time schedule. The allocation of weighting factors is also a cause for dispute, and a conflict exists between the use of strategic arguments and the supply of information. Because of these various limitations of operational practice, EIS's tend to fulfil the needs of the actors who initiate particular projects instead of giving rise to well-deliberated changes in the planning process or encouraging the selection of a better alternative to the original project.

4.3.4 Changes in the Needs of Policy Analysis Input

Experiences demonstrate that in a broader perspective, a traditional approach to policy analysis has been less beneficial than expected [Thissen, 1983]. Recommendations generated by rationally-based analyses were often not followed. The reasons behind this failure to follow recommendations include the inadequate theoretical basis for explaining the functioning of social systems and the presence of many other factors that could not be integrated into a rational model. In particular, factors such as the political context, the social acceptance of the policy, and the nature of the message played a major role [Thiessen 1983]. Recent developments in water management policy indicate that policy analysis instruments depend on the availability of expertise, data, and models to describe the system and to integrate expertise.

Concepts about the policy-making process change as well. This process is increasingly perceived in terms of a network of actors who each strive to achieve their individual goals; the process is aimed at intervening in a network of relations. This concept makes it possible to apply a broader approach to policy analysis. Any attempt to balance between environmental, societal, and economic interests must also deal with policy aspects such as feasibility, long-term developments, sustainable development, etc. This balancing approach tends to put less emphasis on quantitative modeling based on "objective" data.

In the area of transportation policy analysis, a development similar to that which has taken place in water management may occur. A number of long-term strategic decisions including a shift in the transport of hazardous materials exclusively to inland shipping and pipelines, separation of passenger and freight traffic, and the use of underground infrastructures, may influence safety significantly, but risk analysis does not yet take them into account. Hence although public debate often focuses on such decisions, their impact cannot yet be estimated by QRA because no ex-post information is available and because quantitative analysis does not have the capacity to assess the impact of new technologies.

In the area of transportation, political preferences for certain options have influenced the policy-making process, excluding certain aspects from the flow of information and disrupting formal procedures [Frissen, 1993]. In particular, the development of new infrastructure and transportation networks are a response to the "NIMBY" syndrome, in which methodological aspects of traditional QRA are criticized in the course of the political and public debate.

5. Recommendations for Alternative Approaches to Risk Assessment

The complexity of risk issues justifies the call for consistent and efficient methods for performing risk assessment. Practitioners of risk assessment need instruments which are based on transparent procedures and lead to understandable results that can be used to communicate results to the appropriate decision-makers. No single proposed analytic procedure can ever completely eliminate either the ambiguities inherent in risk assessments or the uncertainties and controversies over the results. Nonetheless, clear results and transparent methods provide the basis for a discursive approach to risk management.

The following recommendations concerning alternative approaches to risk assessment do not represent an official Dutch point of view. They have been derived from the discussions carried out during the completion of this report and are complemented with the personal conclusions of the authors. The recommendations are divided into four main categories: methodological approach, definition of safety goals, enforcement, and risk communication.

5.1 Methodological Approach to Risk Assessment

5.1.1 Selection of a Risk Assessment Method

Many controversies in the risk assessment debate stem from the approach chosen for risk assessment. Often, reservation about a risk assessment study are related more to the chosen assessment procedure than to the results themselves. In particular, controversies about low-chance/high-consequence (LC/HC) risks may turn out to be disputes about quantitative vs. qualitative approaches to risk assessment. Recently proposed risk assessment procedures focus more on managemental and organizational aspects such as training, safety culture, and active prevention measures.

To date, a large variety of risk assessment methods have been proposed and implemented. The selection of one risk assessment approach or the combination of several approaches for licensing technological installations or for evaluating operational safety must therefore be carefully addressed. The fundamental concepts of the different approaches can and should be comprehensible to less technically-inclined decision-makers. All stakeholders in risk decisions should hence be involved in the process of selecting the appropriate method of risk assessment from the very beginning. The stakeholders include experts and governmental decision-makers as well as representatives of industry, public and private organizations, and environmental organizations.

The pluses and minuses of qualitative and quantitative methods, of process-oriented and management-oriented approaches, and of probabilistic and deterministic methods should be carefully discussed with reference to the problem at hand. The most promising methods for risk assessment must then be tested in representative pilot studies. These pilot studies should include both critical and less critical technological systems. A technological system would be defined as critical if the potential consequences are rather high (i.e. LC/HC) or if the method chosen is not appropriate for that particular kind of system. The results of these pilot studies would provide insights into the most promising methods, which should then be discussed with the stakeholders. At the conclusion of this evaluation process, the most appropriate approach to risk assessment could be chosen .

5.1.2 Identification of Relevant Scenarios

A risk assessment study should represent a reasonable compromise between accuracy and required effort; that is, risk assessment should be economically viable. The results of risk studies are inherently uncertain. Risks consist of sequences of events which include initiating events (e.g. explosion), dispersion of the hazardous material (e.g. in the air), presence of sensitive objects (e.g. humans), absorption (e.g. inhalation), and damage (e.g. poisoning). The outcome of these events is uncertain. Hence many different scenarios can be identified by combining the possible outcomes of each event. Even in the case of risk chains which consist of a small number of events, the number of possible scenarios is too expansive to be fully considered in a risk assessment study.

Guidelines for risk assessment should therefore assist the risk analyst in the identification of the most relevant scenarios. These scenarios must be tailored to the relevant risk criteria.

5.1.3 Definition of Risk Criteria

The specific risk criteria under consideration determine the units in which the risks are expressed. For example, when risks to human lives are the subject of analysis, the results are given in expected deaths per year. Hence the choice of relevant risk criteria must take the perspectives of the various stakeholders into account. Individual death risks and injuries are most relevant from the government's point of view; loss of image and economic considerations play a crucial role for industry; impacts on natural resources are critical for sustainable development; and the functioning of the infrastructure is a major concern of the communities.

Methods of risk assessment should not only identify the most relevant criteria, but they should also support the analysts and decision-makers in making trade-offs between the various criteria. Trade-offs might be defined in terms of priorities, numerical weights, or descriptive rules.

5.1.4 Collective Risk vs. Group Risk

The problems associated with the safety threshold for group risk, including the ALARA-principle, have been addressed in previous chapters. Essentially all stakeholders criticize the concept of group risk for one reason or another. In addition, there are also technical difficulties with the assessment of group risk. Group risk, expressed as the F/N-curve (frequency vs. number of deaths or number or damages) is a stochastic concept: it represents the frequency of accidents exceeding a certain value. The frequency is derived from the histogram of accidents. If the F/N-curve of a particular system lies completely below the acceptable safety threshold, then that system is safe. The concept of the F/N diagram is very useful for evaluating systems for which a large amount of accident data is available; this data can be used to determine the accident histogram and to derive the F/N-curve. However if accident data are not available, the analyst must define a large number of scenarios for increasing numbers of potential accidents or damages. This task is obviously too cumbersome to be feasible.

Thus the concept of group risk should be replaced by the concept of collective risks. The collective risk is the sum of individual risks, which, like individual risk, is determined only for selected scenarios. If all individual risks are below the acceptable individual risk level, then the acceptability of the collective risk must be traded-off or balanced against other criteria, chiefly economic aspects. Collective risks are determined for different types of individuals, e.g., persons who are directly involved in hazardous operations and persons who are not aware of the operations. The trade-off values therefore depend on the type of damage.

5.1.5 Risk Aversion

Risk aversion, which expresses the perceived or subjective risk as compared to the computed collective risk, should be assessed with the same analytic depth as the technical aspects of risk assessment. The risk aversion factor currently used in the Netherlands - the n^2-factor - was chosen rather arbitrarily. In reality, the attitude toward a technological hazard as well as the computed collective risk depend on a number of factors. These factors must be identified and assessed as part of the risk evaluation procedure. One source of differing risk attitudes lies in discrepancies in risk perception among the stakeholders. The public is more sensitive towards human risks; representatives of industry may even be sensitive in the face of smaller events that can affect their image.

The risk aversion factor also accounts for the fact that one spectacular accident is likely to cause a larger public reaction than many small accidents with the same overall consequences. Such effects are incorporated into the analytic risk model by "correcting" the objectively computed risk to the "perceived" risk. This perceived risk is then considered alongside the individual risk as a basis for decision-making. Hence the accuracy of risk aversion figures should be of the same order of magnitude as the accuracy of the computed collective risk. This implies that the attempt to assess the risk attitude of the stakeholders should entail just as much effort as is extended for the technical risk assessment. Guidelines for risk assessment should incorporate a description of procedures for assessing the risk attitude.

5.2 Safety Goals

5.2.1 Quantitative Safety Goals

Despite all the controversies surrounding quantitative measures in risk management, their workability outweighs their limitations. Quantitative values are determined by means of an analytic model. Even when the numerical results are uncertain, analytic models provide a basis for a systematic and standardized approach to risk assessment. Differing results of risk analysis can be compared with each other and with quantitative safety goals. The numbers themselves may be uncertain, but the decisions made on the basis of numerical models are objective. However it is always the responsibility of the analyst to point out the limitations of any numerical result, for numbers convey the impression of precision even when the exact relationship among the elements of the system may not be completely understood.

The definition and acceptance of numerical safety goals always implies the acceptance of certain models and procedures of risk assessment. Hence the selection of risk assessment models should be included in the definition of numerical safety goals (see 5.1.1); in other words, models and results go hand in hand. Nonetheless, quantitative risk values should always be accompanied by an indication of the numerical uncertainties and a qualitative interpretation of these results.

5.2.2 Safety Thresholds

Absolute safety thresholds for individual risks are appropriate. These thresholds can vary according to several factors such as the voluntary and willing engagement of individuals in an operation, their knowledge about the hazard, and the actual control such persons have over the hazard. Safety thresholds should therefore be flexible and incorporate the attitude of the risk-takers (risk aversion).

Collective risks should not be limited with thresholds if the individual risks are already below individual risk thresholds. Even if all individuals are adequately safe, industry or public organizations might nonetheless judge the collective risk (sum of the individual risks) as too high. However the limits for collective risks should be traded-off against other criteria such as the economic concerns of public policy or of industry. In addition to the risks to human life, risks of injuries, pollution, and environmental degradation could also be limited. These limits should likewise be traded-off against other criteria such as the reversibility of damage, willingness to accept the risks, and economic considerations.

5.2.3 Damage-Oriented Safety Goals

Ideally, safety goals should not be source-, but rather impact-oriented; in other words, they should be defined from the perspective of damage, or, even better, from the perspective of sustainable development. Hence the purpose of safety goals is not to restrict industry in its operations, but to protect the environment from the negative effects of industrial activities. Limitations must be placed on the sum of damages that may result from any number of risk sources and not on individual risk sources.

However in practice, it is difficult to define safety goals from a damage-specific point of view. Therefore source-specific approaches are often used. In such cases, enforcement authorities must take this difficulty into account and show flexibility whenever the situation allows it.

5.2.4 Prevention, Mitigation, and Safety Measures

Safety goals must also take any prevention and mitigation measures explicitly into account. The total damage is not determined solely by what can happen, but also by what can be prevented and mitigated. Moreover, prevention and mitigation activities also cost money and resources; these expenses should appear in the final risk-cost balance.

5.2.5 Spatial and Emergency Planning

Safety goals have consequences for industry. However not only safety considerations, but also spatial and contingency planning put constraints on industrial activities. These various constraints should not be superimposed over one another, but rather coordinated with each other. This approach would lead to a more efficient use of land and resources as well as to better cooperation with industry. Moreover, risk issues should be integrated with societal issues wherever they occur. Hence risk should not be seen as an isolated issue, but as a component of activities deemed as useful or desirable to society. These activities include land use, recreation, industrial production, transportation, and energy production. Risks must thus be addressed in a broader context and not in an isolated risk debate. In addition, it must be emphasized that the system under investigation is not necessarily limited by political or topographical borders. The system's borders are defined by the content of the risk problem, which may potentially extend beyond national territory.

5.2.6 Transport Activities

Safety goals for the transport of hazardous materials should aim at reducing the volume of transports instead of restricting exposure. Another alternative is to consider a modal split where appropriate. Limiting exposure for growing transport volumes often entails the abandonment of inhabited housing. Such a policy leads to heavy opposition and is difficult to enforce. In addition, hazardous materials should be made harmless prior to their transport; measures to achieve this should be promoted.

5.2.7 Concentration of Risks

Risk sources should be grouped and located in special industrial areas. Such grouping improves all stages of risk management: mitigation planning, preparedness, response, and recovery. Specialized response units (e.g. fire fighters, chemical response teams) can be stationed close to the area and housing can be kept at a reasonably safe distance. This approach presumes that the different risk sources cannot cause a so-called domino effect, which occurs when one hazard source initiates another one. An additional advantage of the grouping of risk sources is that transportation distances between processing units can be kept at a minimum.

5.3 Implementation and Enforcement

5.3.1 Responsibility of the Communities

The communities should bear responsibility for the implementation and enforcement of safety regulations. Communities can help implement regulations by promoting safe activities and infrastructure and by cooperating with industry and public organizations. The purpose of this proposal is not only to involve the communities in risk discourse, but also to allow them to coordinate safety issues with other planning efforts such as spatial and emergency planning. All parties that are interested in the issues can thus gain insights into the relevant facts and figures.

5.3.2 Flexibility of Enforcement

Enforcement should be flexible and not arbitrary. This refers to both the time frame and the individual measures chosen to reduce risks. In the Netherlands, the ALARA-principle was originally interpreted as a call to reduce risks to a negligible value within one generation. This rather vague safety goal proved to be unworkable and has consequently been dropped. However, the Dutch interpretation of the ALARA-principle did leave room for some flexibility because it did not explicitly define the length of one generation. The possibility of a flexible interpretation of enforcement measures can be useful when improving technology opens the way for solutions that were not foreseeable when the measure was first formulated.

5.3.3 Coordination with the Efforts of Industry

Implementation and enforcement should be coordinated with parallel efforts made by industry. This coordination motivates industry to cooperate and, consequently, to supply data and information about its operations. Safety issues can then become an integral part of a particular company's management and marketing activities. In addition, enforcement should be updated periodically. The intervals between such updates should be determined on a flexible basis, thus further stimulating closer collaboration between industry and communities.

5.4 Risk Communication

5.4.1 Active Risk Communication

Communities and industry should have a risk information and communication policy in order to assure that the public gets involved in the risk debate at an early stage. In this way, all stakeholders have a chance to participate actively in the decision-making process and to take responsibility for the outcomes. This kind of cooperation is possible in the definition of safety goals, the setting of standards for risk assessment, the selection of risk criteria and trade-off values, and the identification of risk measures.

The early involvement of the relevant actors avoids the negative consequences of late consultation, which can result in costly and time-consuming alterations of planned activities. Information thus means participation, i.e., the parties affected by risk issues should not only be informed, but they should also be given the opportunity to participate in the planning and decision-making process.

The information policy should focus not only on retrospective facts (e.g. after an accident), but also on prospective aspects (e.g. before an accident occurs). Risk management is hence largely a prospective activity complemented by responsive measures.

5.4.2 Risk Discourse at the Level of Decision-Makers

There should be an active risk discourse at the level of decision-makers that involves communities, industry, representatives of the public, and safety experts. Ideally, an effective risk discourse can open up the hidden agendas of the various interest groups. These hidden agendas often force the individual stakeholders to balance risks against other criteria. A dialogue in which hidden agendas are openly discussed can make it possible to coordinate safety measures and trade them off against other activities. Such trade-offs can be made with respect to both prospective (planning) and retrospective (response) activities. Moreover, planners and emergency managers must coordinate their activities with one another.

5.4.3 Risk Discourse in the Policy Domain

Decision-makers in the policy domain should be prepared to discuss safety goals periodically. Decision-makers must realize that standards such as safety goals are dynamic and change over time. There are various reasons for these fluctuations, including changes in the value system and experiences gained through the practice of risk assessment. Hence decision-makers in the policy domain must be involved in the early stages of the definition of safety goals and also in adjustments which become necessary because of experiences gained during implementation.

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