# 3 Dealing 'sensibly' with environmental risk[i]

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***Abstract***

In this chapter we take a closer look at an important instrument of collective health protection, risk assessment and management. We establish that in principle any decent government should apply rights-based decision rules in environmental risk policy, guaranteeing every citizen an equal right to a certain level of protection. However, we have also seen that purely right-based policies may go beyond the bounds of efficiency or affordability. Vice versa, if maximisation of efficiency is the main target, there are inevitably distribution consequences: individuals or specific populations being treated unfair or even harmed in the name of efficient use of scarce resources: the traditional trade-off between 'equity' and 'efficiency' of welfare economics.

We discuss a number of 'sobering', complicating features of the concept of health risk, at least from the perspective of the average environmental engineer. The concept of risk consists not exclusively of 'objectively' measurable qualities of systems; but risk is also a social construct shared by our equals, in which qualitative, social-psychological attributes may be decisive in the acceptance of the dangers around us.

To deal with risk as a 'social construct', as well as with equity versus efficiency trade-offs, we tentatively propose a typology of risk problems with matching procedures of increasing comprehensiveness, comprising 1) 'business as usual', traditional, quantitative analysis and management, 2) appropriate and proportional use of 'scarce resources', 3) a way out when 'calculations are simply not the issue', or 4) wisdom, when 'ignorance' is recognised in time. Procedures involve decision rules, goals, solutions, strategies (discourses) and instruments.

[i] Chapter based on contributions as scientific secretary to reports of the Health Council of the Netherlands (1995, 1996, in co-operation with dr. W.F. Passchier) and a memorandum written at the request of the State Secretary of the Environment, published in Dutch by the Office of Environmental Policy Assessment (de Hollander & Hanemaaijer, 2003). To be submitted as Hollander AEM de, Brunekreef B, Woudenberg F, Hanemaaijer A. Dealing 'sensibly' with risk.

## 3.1 Introduction

### 3.1.1 The State Secretary's question

How should we deal with the deadly Legionella-bacteria, uninvited guest in every corner of our treasured drinking water systems? Can we really permit young children to visit schools in the sphere of extreme low frequency electromagnetic fields generated by high power lines? Should the expansion of our national pride, Schiphol Airport, be bridled, simply because safety standards with respect to aeroplane crashes can't be met completely, partly due to residential areas edging themselves towards every last acre of open (flying) space? Don't we like flying cheap; doesn't a large airport generate jobs and wealth?

Recently the State Secretary for the Environment, Mr Van Geel pleaded in several media for a more rational appraisal of the urgency of environmental health risks. A renewed attitude of sensibility would help us to spend available resources for risk reduction in a more proportionate manner, free from irrational fears or political correctness[1], and conscious of the simple truth that risks are a fact of life. Why do we bother so much about an extremely small additional chance of childhood leukaemia, if existent at all, while at the same time ostensibly we hardly worry about the many victims of daily traffic, or even worse, we carelessly light our next cigarette (see table 3-1). Do we have to spend billions of Euros to expel the Legionella-bacteria from drinking water systems throughout the Netherlands, while we know by doing this we will only prevent a limited fraction of all cases of legionnaire's disease? After all, as far as we know, more than half of the infections are caught abroad, e.g. on holidays around the Mediterranean[2]. In sum, is there reason to believe we are spending our limited resources for health risk management inefficiently, on the waves of emotions, however real (genuine) these emotions and concerns may be[ii]? This debate is going on for several decades now[3,4].

The State Secretary requested the National Institute of Public Health for a contribution to the debate on dealing 'sensibly' with risks[iii]. Assigned to deal with this request we defined two sides of the problem, the *why*-question and the *how*-question. Why do we (society and politics) respond so 'irrationally' and 'inconsistently' to emerging environmental risks? Or, don't we? How should we deal with 'real' risks, different perceptions and (ir)rationalities in a 'nuchter' manner?. With this request the State Secretary touches upon a sore spot in the field of risk assessment. Often, there is an 'unofficial' or at least an implicit policy makers urge behind these requests: the need for well-founded scientific algorithms to make a distinction between 'real' risks and 'perceived' risk, between scientific truth and just another issue (delusions) of the day or, in other words. "Please provide us with sobering numbers that tell us how to respond to (emerging) risk in a cost-effective way without running the risk of getting our political head chopped off!".

From the viewpoint of the average policy maker one risk measure to determine the seriousness of risks, preferably accepted by all parties would be a powerful tool to develop proportionate risk reducing strategies. However, the past 30 years have taught us such simple algorithm is probably best regarded as

[ii] In the last decade in the Netherlands we have seen a Boeing 747 digging itself into a block of flats, an exploding firework storage blowing away a complete neighbourhood, a whirlpool like machine spraying a fine mist of droplets of Legionella spec. among a large susceptible population of elderly people visiting a flora exhibition and so on. In all those cases the risks were supposed to be managed in a rational way.

[iii] He actually used the Dutch word 'nuchter' for which a series of translation can be found in dictionaries: 'rational', 'practical', 'sensible', commonsensical', 'down-to-earth', 'matter-of-fact', 'reasonable', 'non-emotional', 'sober', or 'sober-minded', probably the heart of the matter.

the unattainable Holy Grail, even if one restricts oneself to human health risks, as we do here. At the same time, that doesn't mean it wouldn't be fruitful to go on a quest.

### 3.1.2 Methods

Based on a comprehensive review of the literature we will analyse the *'why'-question*, discussing different approaches of the concept of risk, the aspects of risks that determine people's perception and acceptance, and how experts have tried to measure risks. We will outline aspects of complexity and uncertainty that are involved in scientific analysis of risks and how to deal with them. Finally, we investigate the perspective of risk as a social construct, not just as a set of quantifiable qualities of physical, spatial or social processes.

Based on this analyses we will deal with the *'how'-question* by constructing a typology of risk problems based on quantitative as well as qualitative aspects, such as probability and magnitude of the consequences, degree of uncertainty and complexity, and social stakes (societal benefit, appropriateness). Successively this typology will provide guidance on the manner in which risks are analysed (e.g. the choice of risk attributes, measures and criteria), the decision procedures and rules, and on the involvement of social groups and stakeholders.

The development of this framework has been guided by comprehensive consultation and discussions in working groups, workshops with participants from relevant disciplines within and in some cases outside the National Institute of Public Health and the Environment (RIVM).

## 3.2 Risk: a dragon with many heads

### 3.2.1 Risk: different definitions

If you look in Webster's Dictionary, 'risk' is defined as 'chance of injury, damage or loss'; in this definition danger is interpreted as 'evil chance': 'the possibility that something will go wrong'. Other authors claim that both 'evil' and 'good' chance come together in the word 'risk'. It is thought that the word 'risk' is derived from the Italian word 'rischiare' which in turn can be traced back to the Greek word 'rhiza', meaning root. On Crete the rocks jut out of the coast, often submerged like roots underneath sea level[5]. Sailing around these dangerous rocks of course requires helmsmanship, but the benevolence of the Gods as well. The possibility of damage or loss is directly linked to the expectancy of reaching one's goal as a reward of skilful effort: success and failure are two sides of the same coin[6,7]. Or, viewed from an even wider global historical perspective: exactly the ability to adopt new technologies, accepting the associated unknown risks is what has brought civilisations success and cultural dominance[8]. In the provocative words of hippy-writer Tom Robbins: "humanity has advanced, when it has advanced, not because it has been sober, responsible, and cautious, but because it has been playful, rebellious, and immature".

Within the domain of environmental risk management several committees of distinguished scientists sought to propose an appropriate, if not final definition of the risk concept, almost always from the viewpoint of 'evil chance'. In a report to the government the Health Council of the Netherlands proposed: 'the possibility, with a certain degree of probability, of damage to health, the environment and goods, in combination with the nature and the magnitude of the damage'[9]. In their definitions of risk other influential institutions such as the European Environmental Agency and the Environmental Protection Agency in the US also distinguish both the aspect of *probability* and *nature* and *severity* of undesired consequences[10].

*Table 3-1. Crude estimates of annual mortality and loss of health adjusted life-years attributable to a number of risk factors in the Netherlands[26,11].*

| Risk factor | Annual mortality | DALYs/year |
|---|---|---|
| smoking cigarettes | 20,000 | 440,000 |
| obesity | 8,000 | 170,000 |
| physical inactivity | 8,000 | 135,000 |
| unfavourable diet (saturated fat) | 7,000 | 137,000 |
| particulate air pollution (long term) | 2,500 | 32,000 |
| alcohol | 2,200 * | 195,000 |
| accidents at home | 2,200 | 52,500 |
| traffic accidents | 1,200 | 85,000 ** |
| air pollution (pm)*** | 1,300 | 1,800 |
| indoor radon | 800 | 7,900 |
| environmental tobacco smoke | 530 | 6,300 |
| Legionella drinking water systems | 80 | 560 **** |
| benzene (ambient air) | 3 | 140 |
| industrial accidents | 1 | 40 **** |
| lightening | 1,5 | 40 |

* traffic accidents excluded
** only permanent injury
*** based on time series analyses of daily mortality and air pollution
**** loss of life years only

### 3.2.2 Risk: causal chains in a traditional approach

Based on this type of probabilistic definitions traditional risk assessment approaches deal with risks as objective, measurable, countable, or even weighable phenomenon that can be unequivocally quantified by analysing physical, chemical, biological and sociological processes. Damage or loss is the result of processes that can be described by causal chains (see Figure 3-1)[12,13,14]. Moreover, analysis of these chains may identify the options for risk reducing measures, such as reducing emissions of toxic substances, changing human behaviour through public information campaigns or tax measures.

In formal system analysis often the DPSIR-cycle is applied, describing Driving forces, Pressure, State, Impact and societal Response. The DPSIR framework is often used to organise indicators, especially in the context of (international) environmental problems and sustainable development. As a result of driving forces such as industrial production, spatial planning or consumerism the human system puts pressure on the environmental system (e.g. through toxic emissions or noise), affecting the quality or state of the environment. This in return may affect human well-being or health. Responding to overt health damage or economic losses due to a poor state of the environment, the human system may decide to put more effort into cleaner technology or the spatial separation of transport and residential functions[15,16].

Furthermore, the concept of risk is characterised by uncertainty regarding how and when damage or loss will occur as a result of human activity, as well as the nature and extent of the consequences. One stage in the cause-effect sequence shown in figure 3-1 does not necessarily have to result in the next, or at least not to the same extent. This all depends on the processes within the sequence and on external factors, such as natural processes. Human activity will always yield small- or large-scale changes in substance and energy flows but these changes are not necessarily a threat to the health of humans or the environment. In this concept risk can be regarded as an attribute of processes in society, the possibility that things get out of control. Of course *Figure 3-1* is a simplification. In practice there will always be a web of causal sequences, including all kinds of feed back loops, counteracting or sometimes boosting changes[14].

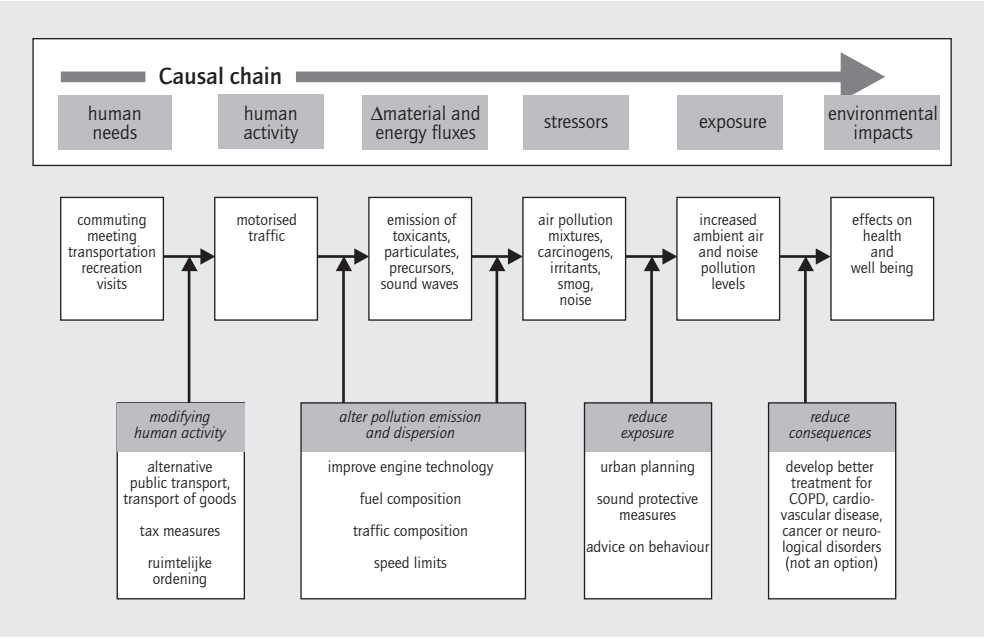


**Figure 3-1.** Relevance of causal chains for risk analysis and management; the example of traffic emissions

### 3.2.3 Risk: just a number, just another process attribute

Traditional risk management requires measures and numbers to express the 'magnitude' of risks. Expressed as a number risks can be handled, at least to a certain extent, risks can mutually be compared, and thus fair exposure standards for a range of risks can be established[17,12]. Often probability has been used to quantify risk, e.g. the probability that an undesired event, such as an increase in the number of (statistical) deaths, will take place in one year. In risk management of chemical carcinogens and radiation risk is often quantified as the number of additional cancer deaths among a large group of persons (often a million) exposed for one year. The magnitude of the consequence can also be part of risk quantification. In Dutch regulations with respect to large industrial accidents the accepted probability of an accident is a non-proportional function of the number of people simultaneously affected, to account for the social disruption that is associated with a sudden large number of deaths and/or wounded (high fatality counts in contrast to equally large, but the gradually and more diffuse incidence of for instance road casualties)[17].

A committee of the Health Council of the Netherlands stresses the fact that a variety of attributes is linked to the concept of risk. Like probability and number of immediate victims, some can be expressed in measures and numbers: attributable healthy life-expectancy or fertility reduction. Others are more qualitative in nature, such as the degree to which people (perceive they) are voluntarily exposed or perceive they can avoid or control the risk[12]. We will discuss these qualitative risk attributes later on.

### 3.2.4 Risk: a matter of delineation

Conscientious definition of the boundaries of a risk problem is an important part of risk assessment, often decisive for the outcome of quantitative analysis. What is part of the risk problem, and what is not? For

instance, while planning the site of an oil refinery, do we only bother about the emission of hazardous substances or do we include the probability of large accidents as well, within the premises and around the plant? And what about the possibility of accidents during transport of raw materials or end products? The establishment of an oil refinery will affect the local environmental quality, but should we also concern ourselves with the contribution of fossil fuel use to the greenhouse effect? Making an assessment of possible damage or loss, choices will have to be made on what we include in our scope: human health, ecological integrity, material goods, the local society, our nation, or even the world population? Or, one step further, do we always have to make our assessment from the perspective of global sustainability?

Analysis of past controversies shows that discrepancies in the assessment of risks and disagreement on management strategies are often caused by differences in the delineation of the risk generating system, the problem formulation that is implicitly or explicitly applied by experts as well as lay-people. Furthermore, this delineation of the system often depends on the societal perspective of the institution performing the risk assessment. Using the old case of the herbicide 'Alachlor', recently Hatfield and Hipel showed that to solve the controversy three different, influential institutions, primarily guided by normative, political values, defined different 'risk systems'. The decision whether this agricultural pesticide should be approved for the market, can be confined to possible unfavourable effects of the chemical on human health and ecological integrity of the candidate. However, one could also consider the unfavourable effects of competing, already permitted pesticides by way of comparison. One could even consider the economic advantages, such as the destruction of an undesired monopoly, or the advantages for public health, such as the availability of low-priced, healthy fruit and vegetables for the less thriving. Of course these 'extra-scientific' factors, or in other words value based decisions, are closely related to societal positions of the institutions (or the stakeholders they represent)[18,19,20,21]. In sum, an important step in environmental risk assessment is the definition of the system boundaries. This may involve the following questions:

which activities
what kind of damage and loss
what kind of benefits or gains (if any)
which causal chains
which geographical scale
what time scale (horizon)?

The report of the Health Council of the Netherlands on the health effects of large airports is a good example of explicit delineation of the 'airport system'. This system comprises a large area of many square kilometres surrounding the airport, including the economic activity and infrastructure to operate the airport, including the new housing development that is claiming the once empty Haarlemmermeer polder at the cost of extension potential[22]. Of course, this delineation is not a purely scientific matter as it involves social values. We will come back to this later.

### 3.2.5 Risk: uncertainty and complexity

In a pure, traditional scheme of risk management scientists analyse the probabilities of damage or loss in a quantitative, 'value free' and thus 'indisputable' manner. Successively, policy makers, after consultation with relevant stakeholders decide to what level risks are tolerable from a societal point of view, and where and at what pace risks should be reduced[23]. In more developed schemes there is also consultation between risk assessors and managers during the process for instance on problem formulation and risk characterisation[12]. However it has become obvious that these models fail to deal properly with the limitations of our scientific knowledge base. Every risk analysis, even when performed by a group of

excellent Nobel-prize winners, is limited by some degree of uncertainty. In some cases we are only dealing with lack of *exactness*. Only a limited number of measurements is available, so we don't know the precise value and variance of one of the parameters in our risk equation. The detail of the maps we apply is just a little bit too coarse, or we have to add up apples and oranges (and get a result for fruit). In other cases our risk analyses may lack *validity*. We don't really understand which are the relevant causal chains and how they function. We did model the scant data, but we can't be sure about the causality of the associations, and thus we can't be too sure about the truthfulness of our calculations. Very complicated statistical analysis tell us there is a positive association between daily mortality or cardiovascular hospital admission on the one hand and meteorology dependent air quality on the other, but we can't yet be sure that further reduction of traffic emission will really improve public health. Sometimes we are close to *ignorant*. We don't have a clue about how the system functions, where it starts or where it ends, or we can only identify and describe a number of specific elements in a much more extended system. We are in the dark whether it concerns the probability, the magnitude or the timing of exposure, whether it concerns the nature, the seriousness or the scale of the consequences. We don't even know what we don't know.

Funtowicz and Ravetz propose a very similar division into *technological, methodological* and *epistemological* uncertainty[24]. Other divisions are also applied, such as 'lack of knowledge' (inexactness, lack of observations, practically immeasurable) versus 'structural' or 'systematic' uncertainty (conflicting evidence, reducible ignorance, indeterminacy, irreducible ignorance) or 'criterion' versus 'construct' validity often applied in epidemiology[25,26]. It is important to note here, that with respect to uncertainty we tend to make careful, conservative assumptions, 'better safe than sorry' (or at least think we do). In sum, our values lie hidden in our policy analyses: 'you can't take politics out of analysis'[27]. We will come back to that issue later.

Complexity, another concept often applied in risk assessment, is closely associated with uncertainty, but far from synonymous to it. It refers to the extensiveness of the web of causal chains, discussed in a previous section, the extent of the total of relations that make up the risk system, and thus to the difficulty one may have to identify the relevant cause-effect sequences, feed back loops and interactions.

Climate change is the obvious example of an extremely complex (risk) system: a large scale (global), long term (centuries) phenomenon, multi-disciplinary by nature, concerning all economic sectors, taking place on different, interacting geographic scales, comprising a vast web of causal chains. On the other end of the spectrum of complexity are the simple exposure-response phenomena. For many chemicals there is sufficient toxicological data to model potential human health impacts in a reasonably reliable manner, one by one[iv]. However, in real life people are never exposed to one chemical after another, but to mixtures of many individual substances. Should we desire to make a similar toxicological assessment of the health effects of combinations of, let say, ten chemicals or more, then the necessary animal experiments data will soon reach astronomic numbers. So, relatively simple problems can be highly uncertain, due to lack of data (practically immeasurable). Calculations of the probability of large industrial accidents causing fatalities assume safety legislation is being implemented, enforced and inspected. However, evaluation studies of the plane crash of 1992 in the Bijlmer and the exploding fireworks storage facility in Enschede in 2000 have shown this assumption is often false[28].

One of the ways in which scientists deal with complexity is mathematical modelling, reducing reality into a system of essentially stocks and flows, states and transitions or actors, compartments and relations.

[iv] For the sake of simplicity here we disregard the many scientific controversies on extrapolation from animal assay to humans (see chapter 4).

From the moment Meadows and co-workers identified the 'limits to our growth' in the seventies, using a relatively simple world model, application of computer models and corresponding scenario techniques in environmental sciences has grown exponentially[29]. The old and trusted scientific method, requiring hypothesis formulation, testing and falsification under the controlled circumstances of the lab[30], is traded for the 'wondrous world' of mathematical models. Of course model output can be validated partly by comparison with historical data sets, but the forecasted behaviour of the world system cannot be tested in a classical experimental way. The complexity of large scale, irreversible issues, such as the greenhouse effect or globalisation, the necessary integration of time and geographic scales is far beyond the limited domain of traditional, empirical accumulation of knowledge. Of course, we wouldn't want to dissuade anybody from using models, on the contrary. However, it is a lot harder to present model results as science 'free of values', or beyond doubt, as we would from a positivistic perspective. After all, complexity has to be reduced one way or another, gaps in knowledge have to be bridged with assumptions, and huge uncertainties have to be accounted for. A myriad of decisions, some big, many small, will -often implicitly- be guarded by and founded on social values and ideology[31].

There are methods to deal with at least part of the uncertainties associated with risk assessment, if necessary making hidden values explicit in the process (see Figure 3-2). Uncertainties on the level of statistics (variance, measurement error) can be described by probabilistic techniques, such as Monte Carlo or sensitivity analysis. Model results are presented as probability distributions or ranges instead of single

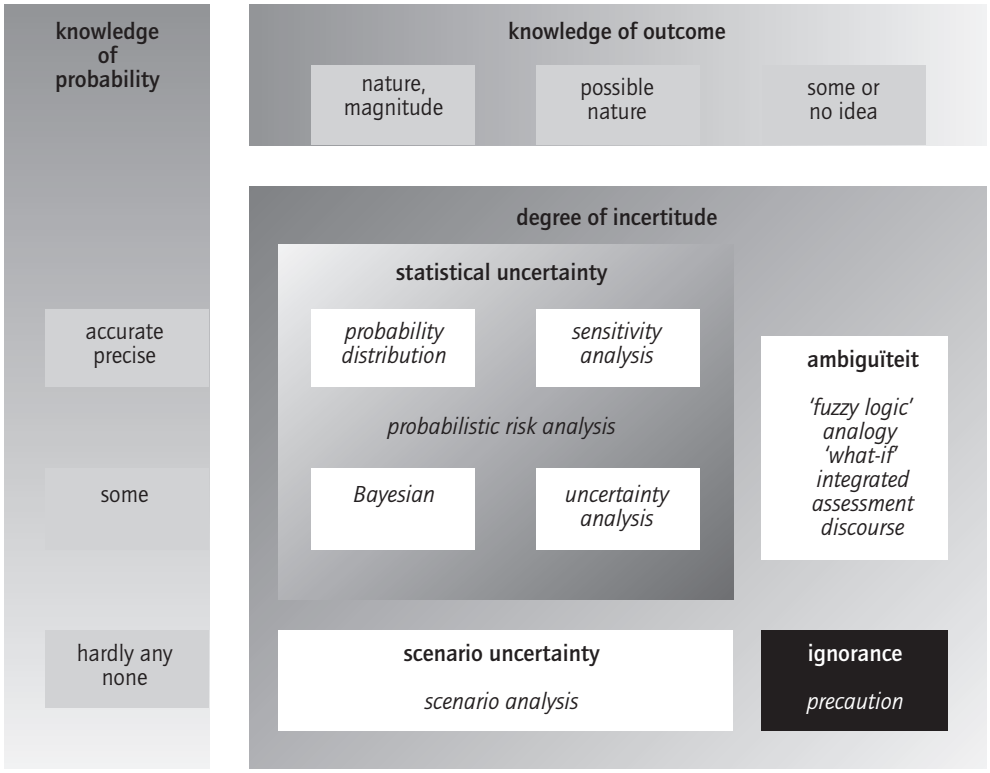


**Figure 3-2.** Dealing with different types of uncertainty (after 19).

values. When we are dealing with uncertainties on the level of models or constructs, we could apply uncertainty or scenario-analysis. We make our calculations under different assumptions or scenarios to get some sort of hunch of the range of probabilities, nature and magnitude of risk consequences. In case of structural uncertainty (indeterminacy, ambiguity or ignorance), assessment can only be based on analogies, formal logical reasoning, 'what-if' scenario-analysis, semi-quantitative frameworks to deal with vague problem definitions and inexactness ('fuzzy logic'), and of course reflective discussions with stakeholders (participatory sensitivity analysis, interactive uncertainty structuring). In case of ignorance, for scientists modesty would be an appropriate attitude. Here we are in the domain where risk problems cannot be properly described qualitatively, let alone quantitatively and precaution might be a good strategy.

### 3.2.6 Risk as a social construct: a broader approach

*Quality or construct*

In the traditional approach risk is conceived and measured as an objective and unequivocal phenomenon. According to this approach the fact that our knowledge is often limited and uncertainties may be huge does not rule out the existence of 'real' risk as quality of human and natural systems that can be objectively determined. More social-psychological or philosophically oriented scientists dismiss this notion of risk. They argue that risks do not lie on the street, around airports or industrial areas waiting for research institutions to get measured and assessed[31]. In this perspective the concept risk is rather a social construct than some sort of natural or physical quantity: a formula collectively put together in the long course of time that enables us to deal with everyday hazards and incertitude. During the larger part of human history we were obliged to arm ourselves against a multitude of threats. The acquirement of a well-developed risk feeling has turned out to be an important survival advantage[32,33]. Apart from knowledge of probabilities, nature and magnitude of undesired consequences these mental constructs comprise a variety of other, often social-psychological aspects: a rich mishmash of daily experience, values, convictions, and political preferences, negotiated and shared with like-minded and congenial groups. This more or less Darwinist view on human risk behaviour is supported by recent discussions on the validity of the rational behaviour model in economics. Do we really act on maximisation of our expected utility? Do we really calculate all possible consequences of all our possible choices, taking a range of uncertainties into account, before we decide? There is much reason to doubt this model is operating in everyday practice[34]. In recent publications persuasive evidence is presented that we confront emerging danger with two different systems: feelings and analysis. The first system is fast, associative, affective, automatic, emotional and is withdrawn from conscious control (similar to a reflex as a short-cut directly through our spinal chord); the second system works with rules for reasoning, algorithms, and formal logic, but is much slower, requires effort, learning ability, and consciousness[32,35,36]. Neurological research indicates both systems, emotional/affective and analytic, including their advantages and weaknesses, their biases and limitations, are necessary in making effective and rational decisions. Thus, the individual assessment of risk is the result of both affective (associative) and analytic processes. Furthermore, if they point in different directions, in most cases the 'feeling' will be decisive in our judgement[37,32,31,38]. Obviously, precisely our affective system is closely connected to typically qualitative risk attributes. Entirely consistent with this line of thought our judgement and perception of risk appears to be domain specific. Our assessment of qualitative attributes, such as voluntariness, perceived control, familiarity and equity differ whether it concerns health care, food or consumer safety, hazardous industry, financial matters, traffic or social safety issues.

So, risk is at least in part a social construct. Social scientists never get tired of pointing out that experts apply all kinds of qualitative and quantitative assumptions in modelling their 'objective' risk problems. And, of course, these assumption are as founded on values and subjective judgements as the 'models' lay-people use assessing the dangers of daily life[31]. However, we have to emphasise the fact the scientific context stands for a certain discipline of argument and is coded by good scientific practice[19].

The relevance of the debate between 'objectivists' and 'constructivists' -slightly accentuated here for clarity's sake- is well illustrated by the seemingly simple choice of risk measures. Even when mortality (rate) is concerned, surely one of the most unequivocal health endpoints we know, we will have to make choices with marked normative consequences. The health loss attributed to certain risk-bearing activities or situations, can be measured by annual mortality, annual loss of life expectancy, or loss of healthy life expectancy in an exposed group. Annual mortality is the most clear-cut measure and guarantees that everybody, young or old, rich or poor, healthy or sick, is regarded as equal and consequently is protected equally. However, at the same time that choice implies that 'acceleration' of death among the very ill with just a small number of days or weeks as it might result from an episode of smog, is of the same value as the accidental death of a father of a number of young children. If, on the other hand, we apply the number of life-years lost as a measure of risk, in principle we should profit from passing on the risk to the elderly, as they have a shorter life-expectancy to loose. From the utilitarian perspective this might be defensible, but surely not from the perspective of social justice. Expressing the health loss in terms of health adjusted life years has the advantage that non-lethal damage to health or well-being can be included in our measure, but it would imply at the same time that people with a chronic illness count for less, as their years are spent in reduced health. In sum, even ostensibly neutral measures are 'value-laden', whether we like it or not; the choice of risk measure can only be derived from normative choices we make as a starting point for risk management.

To highlight this somewhat more we may look at complicated, technological developments, such as the application of genetically modified organisms (GMO) in agriculture. Hazards and advantages regard human health (immune toxicity versus nutritional value), but concern ecological integrity (bio-diversity, 'escaping' genes versus reduced or more specific pesticide use), economy (advantages to producers versus consumers), agriculture (food security, sustainability), as well as ethics (animal well-being, playing God). In addition, several important risk attributes come up, such as indeterminacy, lack of control (in time and space), irreversibility, persistence, inequity, and the potential to cause societal commotion. Its is obvious that al these incomparable aspects will never be captured in one or even a few quantitative risk measures (incommensurability)[v,39]. It is not very likely that the question how society is going to deal with risks associated with agricultural GMO applications is going to be solved by a standard risk approach, applying only metrics and numbers.

*Qualitative risk attributes*

A large amount of psychosocial research, going back to the sixties, shows that when assessing risk generating activities, people tend to involve many aspects besides probabilities and magnitude of possible damage. Moreover, the latter quantitative aspects often appear to play only a minor role in public risk acceptance. In this the discrepancy in the perception of health risks between experts and lay-people may often originates. One assesses the same risk problems using a completely different set of risk attributes[31,40,41].

[v] Kenneth J Arrow won a Nobel-prize by formally proving that in a multiform society multidimensional preferences cannot be aggregated (and ordered) in a definite analytical way.

Most overviews will contain the following row of aspects.

spatial and time scale, potential magnitude of damage
catastrophic potential
lack of voluntariness ('free choice')
inequity ('who benefits, who runs the risk?')
(perceived) controllability of incidence or consequences (degree of personal influence)
lack of trust in authorities and others carrying responsibility, such as industry (often lack of openness)
unfamiliar, new technology (e.g. as opposed to 'natural threats')
hidden, delayed, and irreversible damage (e.g. cancer many years after exposure, or future generations)
indistinctness over societal benefits of risk generating activity
possibility of identification with victims
harmful intentions of persons of institutions producing risk (crime, terrorism, capitalist, sabotage).

After accidents have taken place, nowadays blameworthiness (e.g. negligence) appears to be an important aspect.

Psychometric research demonstrates that every risk problem has its own unique pattern of scores over the risk attributes[42]. Apart from that, these attributes are often correlated over a range of risk problems. Voluntariness, trust and controllability are associated, just as catastrophic potential, delayed hazards for future generations, and irreversibility. In their early publications Slovic and co-workers used the concept of (perception) factor 'space', a co-ordinate system, based on two higher-order factors: an axis 'dread' (fatal, global scale, catastrophic, irreversible, uncontrollable etc.) and an axis 'unknown' (unknown to science and exposed, not observable, delayed effects, new, etc.)[43]. Other authors propose two other categories of aspects that determine risk assessment and acceptance: 'deontological' and 'consequentialist' evaluation. On the one hand, aspects focused on causation: who is to blame, what ethical principles have been violated? (the past); on the other hand aspects that cover the consequences, what is the nature, what is the magnitude (the future)?[44].

*Social amplification?*

The risk attributes discussed here are also relevant to a phenomenon that is referred to as 'social amplification'[45]. Relatively innocent incidents provoke an enormous societal turmoil which, at least in terms of damage to public health, ecological integrity or material goods appears to be excessive. Although good scientific evidence is scarce, one mechanism forces itself upon us. Outwardly insignificant incidents are seen as the forerunners of huge, uncontrollable, and irreversible disaster, as an omen of doom[46]. Small incidents with fairly new, unfamiliar technologies, such as genetic modification, bio-industry provoke much more distress than a train calamity with many victims. In some cases the economic losses caused by these phenomena of societal distress and distrust are immense, in the form of reduced trade volumes or/and compensation. Recent examples are not hard to find: SARS (severe acute respiratory syndrome), anthrax spores in the mail, or Creuzfeldt-Jacob disease associated with BSE. Furthermore, this 'signal'-concept offers a good explanation for the success of present-day terrorism, being a poorly understood, unfamiliar, sinister form of danger that can easily be comprehended as an omen for an irrational, and ruthless, global outbreak of an uncontrollable series of catastrophes with exponentially increasing body counts. Relative small investments ('signals') cause enormous societal response[47,48].

*Mass media*

Of course the role of the (mass) media is important, if not crucial here. Although poorly understood, the

'asymmetry' of the coverage may contribute significantly to some sort acoustical feedback: 'bad news is good news, good news is no news'. It is apparent that the mass media cover risks selectively. Often risks that are rare or dramatic -that have 'story value'- receive disproportionate coverage, while more commonplace risks are downplayed[49].

Recently American researchers introduced the concept of stigma within the framework of social amplification. Amplified by the pervasive power of the media, public concern about health and ecological risks can develop into a new and very significant social phenomenon: 'technological stigma.' Stigmas are put on places, such as transport routes for nuclear waste, products, such as GMO ('Frankenstein') food or blood products, and new technological developments to tell us they should be avoided not just because it is dangerous, but because it destroys a positive condition. They 'signal' that what used to be something good or true is now blemished or tainted. "Stigmas represent a powerful force in our modern industrial society because science, technology, and communications media often interact with the idiosyncrasies of human cognition, perception, and emotion to produce extreme disruption in the lives of industries, products, communities, and people. In many instances the social and economic response is exaggerated, even unwarranted, leading to impacts far more serious than the initial threat"[50]. The resulting aversions can produce enormous economic impacts and social consequences, such as those experienced in recent years with British beef and cloning[51]. However, empirical evidence on the role of the media is often inconsistent. Media, including the Internet, do not only have the power to inflate concern over minor hazards, they may dull concern over serious ones as well[52,53].

### 3.2.7 Sobering answers to the why-question

The answer to the 'why-question posed in the introduction can be quite simple. We do *not* respond particularly irrationally or inconsistently to (emerging) environmental risks. We only tend to involve many other, often qualitative aspects of risk in our evaluation, such as freedom of choice to be exposed to a danger or not, the feeling we can personally control hazards, or at least the possible consequences, or our perception of societal utility justifying health risks being imposed on third-party bystanders. That may be one of the reasons we do not rank health risks in accordance with hard statistics such as 'annual attributable fatalities'. This juggling around with quantitative and qualitative aspects fits very well with indications from psycho-neurological research that two, sometimes antagonistic systems are operating when we make decisions, an *emotional*, *affective* and a *rational* system (see previous section). Apart from the fact sometimes people simply lack sufficient knowledge or are guided by misperceptions.

Of course, all this doesn't mean we are not prone to bias or a certain degree of subtle deception, even manipulation. Analysis of mass media coverage suggest the overall picture of health risks we get might be somewhat distorted, far from balanced. But then again, that is a fact of life we cope with in many instances or public domains. Or in the words of Baruch Fischhoff: "Attempts to change or adjust perceptions, evaluations or behaviours that technological 'stigma' may produce, presume a moral superiority on the part of those applying strategies to cope with them. This may not be a comfortable or appropriate role for scientists"[54,55].

Before we go on with the 'how-question' of dealing sensibly with risks, first a number of sobering interim conclusions.

The concept of risk consists not exclusively of objectively measurable qualities of systems

Risk is also a social construct; in which qualitative, social-psychological attributes may be decisive in our acceptance of health risks

There is no universal, unequivocal measure to quantify health risk; picking a measure always implicates a choice of normative points of departure for policy making

The result of (quantitative) risk assessment depends largely on the definition of the system boundaries

Therefore different risks can not be compared, just like that

Risk assessments are always uncertain to some extent; incertitude may range from statistical inexactness, construct or model uncertainty and indeterminacy, all the way to ignorance.

However, we still think risks can be adequately characterised, at least to a certain extent, applying a (limited) set of quantitative and qualitative attributes, such as probability, nature and magnitude of consequences, spatial and temporal scale, persistence, irreversibility, inequity, delayed consequences, and potential to provoke societal turmoil. The composition and extensiveness of the set will depend largely on the characteristics of the risk problem.

## 3.3 A proposition for sensible procedures

### 3.3.1 Where do we go from here?

#### *3.3.1.1 Both objective 'quality' and 'social construct'*

It is not very likely the debate between 'objectivists' and 'constructivists' about the essence of risk will ever be settled in a satisfactory manner. Here, maybe slightly spineless, we choose not the make a choice between both fundamental viewpoints.

If policy makers or authorities merely act on quantifiable measures, involved citizens might feel not understood, not taken seriously and irritated. They will not recognise themselves in a narrow technological definition of the risk problem, and thus will not commit themselves to the diagnosis, the assessment, the decision rule, nor to the proposed policies[56]. On the other hand, the prospect of complete replacement of positive, universal knowledge by democratisation of risk analysis and management isn't particularly attractive as well. "May I have your votes for the earth being flat". Nature and magnitude of health loss, and effectiveness and efficiency of risk reducing measures should always be part of dealing with risks in governmental policy, even if it concerns risks that for one reason or another do not appeal very much to the general public. The introduction of public health policies, involving sizeable programmes dealing with safe drinking water, sewage systems, and proper housing at the end of the 19$^{th}$ century[vi], extended life-expectancy with decades. It was initiated by the work of clever physicians and civil engineers with a scientific, public health orientation, not primarily by democratic views of general public[57]. We deliberately painted the picture in black and white. In practice it is rather a matter of a different emphasis put on quantitative or qualitative aspects of risk by various parties[vii,58].

#### *3.3.1.2 A new role for science*

After the sobering conclusions of the previous sections do we have to write of a decisive role of science (including social and gamma sciences) in dealing with risks? Of course not. Science can produce valid quantitative measures of probability and magnitude of undesired consequences. Furthermore in a slightly

[vi] Sometimes referred to as the Public Health Transition or Revolution

[vii] Of course there is no such thing as universal, objective, certain knowledge, but at the same time with stunning ease our 'post-normal philosopher' catches a plane, opens his laptop and starts working while flying at 10,000 feet, and after touch down checks his e-mail, just an hour before presenting a paper claiming that all knowledge is relative.

broader interpretation science stands for 'systematic analysis', a 'sceptical' attitude, 'peer review', 'independence', 'transparency', 'being answerable' and a 'capacity to learn' while doing the job. Not being right all the time in a value free manner, but precisely these, often more procedural attributes of science are of great value in the assessment and management of health risks.

Only science by itself is not enough. As the uncertainty become more substantial, as well as the social stakes and turmoil, the necessity of interaction with society increases as well. An open, critical, and pluralistic discourse with society is inevitable when it comes to the delineation, definition and modelling of the risk problem, the interpretation of uncertainties and dealing with them, and the choice of relevant risk attributes, criteria and decision rules[9,12].

#### *3.3.1.3 Structure of our propositions*

The remainder of this chapter will deal with procedures to be followed in 'sensible' risk management. We will first discuss the decision rules that are explicitly or sometimes implicitly used in dealing with risks, and the values behind them. Successively we will discuss their practical, and sometimes philosophical boundaries. Then, finally we will combine the information on risk attributes, and decision rules and propose a typology of risk based on several relevant aspects. Finally for 4 types of risks problems we propose 4 different procedures taking into account different challenges, different goals, different strategies and participation and instruments and decision rules to be applied.

### 3.3.2 Decision rules

If we want to develop procedures to deal with risk sensibly we will have to consider the rules or principle we have been using in the past to decide about risks. After all, even if we agree on how the risk is characterised, there are still many ways to come to a decision. Morgan identified three important rules in the domain of risk management: right-based, utility-based, technology-based (see below)[59]. Apart from these, the precautionary principle is increasingly prominent in environmental protection[60]. In practise often a mix of these principles is applied[viii].

In a right-based approach every citizen merits protection against risks above a certain level (for the benefit of one group risks cannot be imposed on others, at least to a certain extent). In a utilitarian approach one seeks to maximise utility for society as a whole; or in other words it is about the largest yield in terms of risk reduction (or public health) at the lowest costs (efficiency). A technology-based approach involves neither rights nor costs, but requires the best available technology, or demands a risk level 'as low as reasonably achievable' (ALARA[ix]). Therefore risk reduction is a moving target that parallels technological development. The precautionary principle is not exclusively based on quantification of risk. Often, here more qualitative risk attributes such as complexity, uncertainty and ignorance, a long time horizon, irreversibility (physical as well as socio-economical), uncontrollability, stock externalities, and future scientific progress have to be taken in account, as it deals with short-term strategies in the face of long-term uncertainties[61].

[viii] In the American literature two other principles can be found: 'innocent until proven guilty': we will not act until we are beyond reasonable doubt (in fact the counterpart of the precautionary principle), and 'non-interference': in the end citizens of non governmental organisations themselves will act, in court if necessary (liability rules).

[ix] This is a simplification: in many cases, including the Dutch and British regulations application of ALARA is guided by several social and economical conditions, including costs and benefit considerations, and therefore more than just a technological decision rule.

#### *3.3.2.1 Right-based rules*

The Dutch environmental risk policy of disregarding, accepting or prohibiting risk generating activities according to quantified risk criteria is a typical example of right-based decision rules for management. Basically Dutch policy distinguishes a level below which risks can be *neglected*[x] and a *maximal* level above which risks are *no longer tolerable*. In short this means that an activity (or source) is not allowed if one year of exposure increase anybody's probability of premature death with more than one in a million. If this additional probability is below one in a hundred million, it is disregarded[xi]. In between those *neglected* and *maximal tolerated* risk levels risk reducing measures are indicated[17]. Generally speaking in drinking water and food safety regulations similar decision rules are being applied. Residues, additives or genetic modifications may not significantly increase the health risk of consumers, irrespective of economic, social or even public health benefits. The right to protection of every citizen, regardless of age, income, gender, social status and so on is essential. Risks may not be passed on to certain societal groups however great the benefits may be. It is important to note that there is no scientific basis on which we can decide whether a certain risk level is tolerable or can even be neglected. Of course, a mortality risk of one in a million is low, virtually nil, compared to other daily hazards. The average annual mortality risk of a randomly chosen individual in the Netherlands is in the order of 0,01. Indeed, our life-expectancy is around 80 years[xii].

#### *3.3.2.2 Utility-based rules*

In a utilitarian tradition one is guided primarily by the trade-off between collective benefit and collective pain associated with policy measures[xiii,62]. What are the expected public health returns (risk reduction) and what are the costs, including opportunity costs? At the present juncture this motto is often interpreted as: 'are we not wasting the tax payer's money?' or 'are these policy measures really suitable (grasping the notion of efficiency as well)?'[63,64]. Especially in health care since the eighties a key-role is imputed on 'efficiency' in the battle against the health care cost getting rapidly out of hand. Economic evaluation research, by now a booming discipline within the public health sciences, is an important instrument supporting discussions on efficiency and suitability in health care. Roughly speaking, economic evaluation aims at proving insight in the relation between costs and health yields in health care and prevention[65]. As we are focussed on risk from a public health perspective in this chapter, we will zoom in a little on this field.

In Box 1 a number of cost-effectiveness assessments are collected of interventions in various domains of public health. Most striking is the enormous variation in cost per quality-adjusted life-year (QALY) saved. Disease prevention is often relatively cheap, just as health promotion and traffic safety. Cure interventions range all the way from cost saving interventions (medical costs that are prevented may be subtracted) to very costly life-years, saved with impressive (and impressively expensive) technology. In addition, several environmental interventions are expensive, at least per life-year saved. A paper that was published in the

[x] In most cases the negligible risk level never made it into practical Dutch risk regulation.

[xi] Of course there are many practical and theoretical problems associated with this approach, e.g. what is premature death? We will all die at sometime!

[xii] Even in the most favourable age group of 10-14 years the annual mortality risk is somewhere between 1 and 6 in ten thousand.

[xiii] Utilitarism was already defined around 1800 by the philosophers Jeremy Bentham and John Stuart Mill: activities are good when they yield more happiness than unhappiness, irrespective of the actor's intentions and motives; much later the utilitarism was shaped in the mathematical-economic form of the 'expected utility theory' (von Neumann and Morgenstern, 1944).

nineties suggested that the cost per life-year saved of a large number of environmental regulations was excessive, such as the reduction of benzene emission in the tire industries costing more than 20 billion dollar per life-year saved[66].

***Box 1.***

Table 3-2 shows a number of estimates of cost-effectiveness of interventions in different domains of public health. Use was made of a series of databases that have been made available on the Internet by various international organisations (HCRA; US Dept. HHS CDC; NHS EED; Office of Health Econommics HEED; SWOV). In addition, various, sometimes raw, calculations for the Dutch situation have been include. When making such comparisons account must be taken of considerable uncertainties in the calculation of both the costs and the benefits. Significant differences in the calculation method can be related to:

- the measurement of the benefits (clinical measures, life-years saved, possibly adjusted for health)
- the costs that are included (medical care: personnel, equipment, transport, medicines and devices, or also social: productivity, cost of care)
- the situation used as a reference (no intervention or conservative medical treatment)
- time horizon and discount rate.

Furthermore, the efficacy of (medical) technologies can improve rapidly. The statistics must therefore not be taken too literally. They will only provide an indication of the order of magnitude, purely by way of illustration.

Table 3-2. Overview of cost-effectiveness calculations for a series of interventions in different population health status domains (more concise).

| **Costs: euro/QALY[a]** | **Intervention** |
|---|---|
| < 0 (cost-saving) | National vaccination programme (DP)[b]<br>PKU test, neonatal heel prick (DP)<br>Screening of pregnant women for syphilis (DP)<br>Influenza vaccination for chronically ill elderly people (DP)<br>Smoke detector in the home (HPt)<br>Help with addiction to smoking (HP)<br>Removal of lead from petrol and paint, stripping lead-based paint coats (HPt) |
| 0-1,000 | Mandatory safety belt (HPt)<br>Disease coping training for asthma (MC)<br>Screening and treatment of chlamydia (DP)<br>Practical test for moped and autocycle (low-speed moped) riders (HPt) |
| 1,000-10,000 | Chlorination of drinking water (HPt)<br>Specific vaccinations, e.g. meningococcus C (DP)<br>Treatment of mild to moderate hypertension with beta blockers and anti-diuretics (DP)<br>HIV screening of visitors to sexually transmitted disease (STD) clinics (DP)<br>Influenza vaccination for all elderly people (DP)<br>Cholesterol test and dietary advice (DP)<br>Bypass operation (MC)<br>Stroke units (MC)<br>Viagra (MC)<br>Mammography population survey (DP) |
| 10,000-100,000 | Heart transplant (MC)<br>Controlling Legionella in (health) care facilities (HPt)<br>Pneumococcal vaccination for the elderly (DP)<br>Kidney replacing treatments (dialysis) (MC)<br>Smear and treatment for cervical cancer (DP)<br>Periodic automobile test (HPt)<br>Treatment for mild to moderate hypertension with ACE inhibitors, etc. (DP)<br>Airbags (HPt)<br>Ban on asbestos in brake blocks (HPt)<br>Helicopter trauma team (MC)<br>Lung transplant (MC) |

| Costs: euro/QALY[a] | Intervention |
|---|---|
| 100,000-1,000,000 | Reduction of radon in existing dwellings (HPt)<br>Neurosurgery for malignant brain tumours (MC)<br>EPO for anaemia in renal dialysis patients (MC)<br>General measures for controlling Legionella in water distribution systems (HPt) |
| >1,000,000 | Measures for reducing industrial benzene emission in the USA (HPt)<br>Measure to reduce dioxin emissions from waste incinerators (HPt)<br>General measures to reduce exposure to ELF associated with electric power lines (HPt)<br>Earthquake-proof dwellings in parts of the USA. (HPt) |

a. QALY: according to quality-adjusted life-year.
b. DP: disease prevention, HPt: health protection, HP: health promotion, MC: medical care.

It is important to note that environmental policies often have ancillary benefits in other domains as well, such as sustainable development, technological innovations, or ecological integrity. These benefits are not always taken into account in formal cost-effectiveness analysis[67]. The more qualitative aspects of health risk, as discussed in the previous paragraphs are also hard to implement in formal techniques of cost-benefit analysis. As we have learned, in the case of social amplification this shortcoming can have serious implications[33,47].

#### *3.3.2.3 Technology based rules*

Best available technology and as low as reasonably achievable (ALARA) are an important point of departure of Dutch environmental policy. Even when risk-generating activities are below the maximum tolerated risk level one is more or less expected to apply the ALARA-principle. In the Dutch situation the principle has been more or less extended in an utilitarian way to finding a balance between the benefits of risk reduction and the societal costs in an iterative process. The ALARA principle is not without controversy. Provocatively the acronym is sometimes translated into 'as large as regulators allow'. In everyday practise there is often a lack of hard criteria to evaluate the reasonableness or best availability of technology. The best guarantee clean and safe technology will be applied is often stringent regulations. In a limited number of years the automobile industry has accomplished impressive emission reductions, under the strain of societal pressure and strict regulations. The reverse situation applies to the energy sector in the United States: more or less outdated, inefficient technology, at least compared to Western Europe, producing high emissions associated with tolerant regulations[68].

#### *3.3.2.4 Precaution*

In this overview of decision rules, the precautionary principle (PP) cannot be overlooked. Since the seventies the principle has slowly gained importance and today it very nearly dominates the international discussions on the environment and sustainability. In the Rio Declaration the precautionary principle (15) is formulated as:

*"In order to protect the environment, the precautionary approach shall be widely applied by the States according to their capabilities. Where there are* ***threats*** *of* ***serious*** *or* ***irreversible*** *damage, lack of* ***full scientific certainty*** *shall not be used as a reason for postponing* ***cost-effective*** *measures to prevent environmental degradation" (Rio Declaration).*

The basic premise of the precautionary principle is that governments should not wait for conclusive evidence before considering measures to protect citizens, consumers or the environment. Thus, contrary to right-based and utility-based rules the PP is not based on any sort of quantification of risk. Despite the seemingly clear definition, its interpretation has been the source of endless controversy, especially between the United States and the European Committee, whether it concerns growth hormones in beef, the application of genetically modified organisms in foodstuffs or the existence or health effects of global warming. A nasty, critical editorial in the Wall Street Journal referred to the precautionary principle as 'an environmentalist neologism, invoked to trump scientific evidence and move directly to banning things they simply don't like: biotech, wireless technology, hydrocarbon emissions'. In spite of this all, the US is already acquainted with regulation based on precaution for a much longer period than the EU, since the Delaney Clause (1957, revoked in 1996) prohibited detectable levels of animal assay carcinogens in food. The United States were also much sooner in banning substances that are involved in the depletion of the ozone layer, regulations to control 'mad-cow' disease, just as prohibiting the application of DES as a growth hormone in cattle[69]. Nevertheless, contrary to the US administration, since the year 2000 the European Commission has officially accepted the precautionary principle as its point of departure for policy making[70]. A recent analysis shows that neither the European Union, nor the United States can claim to practise precaution more than the other. Furthermore, the fact that both economic superpowers from one risk to the next alternately apply a different degree of precaution cannot be traced back to fundamental transatlantic dissimilarities in politics and policy-making[71].

In its most extreme interpretation the precautionary principle requires absolute proof of safety before innovations can be adopted. On the one hand some authors doubt whether the precautionary principle can ever be a robust decision rule: When can something be marked as a threat, and what damage is serious or irreversible; how much scientific certainty is sufficient, and what is an appropriate or proportional intervention? Nonetheless, it seems precaution corresponds closely with our intuitively, maybe even evolutionary attitude towards risks as we are usually rather safe than sorry[32,72].

Key question is how to manage risk under conditions of imperfect knowledge. Intuitively one is inclined to postpone costly preventive measures until more and better science concerning health risks is available. Experience with climate change policies emphasizes the need to develop a *sequential* approach to decision-making. The choice between moderate or aggressive emission reductions is determined today by foreseen future improvements of scientific understanding of climate change and our ability or flexibility to switch to other energy sources[69].

An example of a very practical way in which the precautionary principle can be violated, was recently discussed by the European Environmental Agency. Analysing the methodological features of experimental and observational health risk research it was concluded that in trying to avoid false positives ('Whoops! It really isn't dangerous after all...'), 'sound science' appeared to be seriously biased towards producing false negatives ('Whoops! It really is dangerous after all....')[69].

#### *3.3.2.5 At the boundaries of the decision rules*

It is important to stress that decision rules, and the social objectives behind them, will at some point be conflicting. Most governments in the Western world are especially concerned with distribution issues, equity: everybody's right to a certain level of protection or health care. However, purely right-based policies may go beyond the bounds of affordability or efficiency. Vice versa, if maximisation of efficiency is the main target, that is, aiming for great benefit-cost scores, there are inevitably distribution consequences: individuals or specific populations being treated unfair of even harmed in the name of efficiency[73]. Here

we are confronted with the traditional trade-off between 'equity' and 'efficiency' within the realm of welfare economics[74]. This trade-off can be seen in many domains of public health and health care, for instance when priority is being given to younger recipients with better survival benefits given the short supply of donor organs at the cost of the total patient population. Another example is the choice of screening program coverage: do we aim efficiently at a limited high-risk group, or do choose for a fair inclusion of the total population[75]. Do we give all states or large municipalities a fair share of the federal HIV-prevention pie, proportional to reported AIDS-cases, do we distribute in accordance with cost-effectiveness considerations, or is there some middle ground to promote both objectives[76]. Environmental policies, such as clean air regulations are not primarily aimed at balancing marginal air pollution reductions and associated health gains with marginal social losses (e.g. as a result of opportunity costs). They are aimed at protecting the most susceptible individual, regardless of the costs[73]. But of course the final question is: can we afford this in the end?

In the Netherlands this trade-off between efficiency, equity, and perhaps even precaution is nicely illustrated by the recent political anxiety with respect to Legionella in drinking water systems. In 1999 more than 300 reported cases of this pneumonia-like disease, of which 29 died, were attributed to the improper operation of a number whirlpools and (probably) water atomising machines on a Flora exhibition in Bovenkarspel. Pressed by media and to a lesser extent the parliament, the Dutch government soon developed rather drastic measures to minimise the risk of Legionella infection in the general populations. Referring to the Precautionary Principle the Minister claimed that drinking water infections should not occur in a decent, civilised country. These 'temporary' measures forced local authorities, responsible for sport facilities, nursing and care institutions as well as private owners of sport, fitness and other public places to perform a risk analyses whenever there were hot water installations present. If necessary, technical installations had to be adjusted and every facility was obliged to make a water management plan. As it concerned hundreds of thousands individual facilities and institutions the economic costs of this policy were substantial; estimations ranged from less than one billion to several tens of billions of Euro. For several reasons the efficacy of these general measures was thought be rather limited. The number of reported and confirmed cases of Legionnaire's disease in the Netherlands is relatively modest, around 200 per year, although the true number can be several times higher. At least half of the infections are probably caught abroad (e.g. holidays around the Mediterranean). Furthermore, residential water systems could be a significant cause as well. Crude calculations indicated that, making conservative assumptions, the investments to save one health-adjusted life-year could easily exceed one million Euros. The Dutch Association of Municipalities claimed that the new Legionella control measures would cost 3 Euro per inhabitant, 1 Euro more than their total expenses on infectious disease control of 2 Euro per inhabitant[77].

After a fierce debate, involving several stakeholder parties, it was decided to focus policies on high-risk situations, such as nursing and care institutions with a susceptible population, yielding much better cost-effectiveness scores. Of course implicitly, this means abandoning a pure rights-based approach. A committee of the Health Council of the Netherlands stressed the importance of early diagnosis and treatment, and the necessity of proper focus of other high-risk systems, such as large-scale events where water atomisers are being used[2]. After all, that is where the 'Legionella-case' started in the first place. In *Box 2* a number of other environmental cases are presented.

***Box 2.*** *Cost-effectiveness of risk reducing measures*

For a number of cases here we briefly and crudely estimate the expected costs of risk reducing measures. The estimates are tentative, as they are based on contemporary knowledge and technological state of the art. Cost-effectiveness of technologies often improves with time as a result of 'learning' effects and economy of scale.

**Electric power lines**
In the Netherlands approximately 11,500 children (in 23,000 houses) are exposed to magnetic fields from power lines that may increase their leukaemia risk. Assuming there is a causal relation, each year 0.2 to 1 extra case of leukaemia can be attributed to this exposure (within this population this is well above the annual accepted risk level of $10^{-6}$). Measures to reduce exposure to extremely low frequency electromagnetic fields (ELF) include: 1) optimising the 'clock number' by changing the position of the wires on the masts, 2) replacing three wires on each side of the masts by four (phase splitting), 3) relocate the power lines to a more favourable position, and 4) bury the power lines into the ground. Costs and effects of these measures in the Netherlands are:

| measure | remaining houses | total costs (Euro) | costs/house (Euro) |
|---|---|---|---|
| 1) clock numbers | 15,000 | 140 million | 18,000 |
| 2) phase splitting | 15,000 | 450 million | 55,000 |
| 3) relocation | 2,500 | 2,600 million | 128,000 |
| 4) underground | 1,000 | 14,000 million | 655,000 |

There are many technological problems connected to burying all power lines in the Netherlands. Furthermore approximately it will cost four times as much as simple relocating the 23,000 houses involved. Implementing the presented possibilities on a local scale may be significantly less expensive, but will never be an example of cost-effective public health polic , .

**Indoor radon**
Exposure to indoor radon increases the lung cancer risk of inhabitants. As a results of measures to reduce energy losses in the last decades residents have become more airtight, normal ventilation rates have dropped significantly. In dwellings built in 1970 radon concentrations were around 18 Bq/$m^3$, in dwellings built after 1980 the concentrations are around 30 Bq/$m^3$. Calculations based on epidemiological models point at around 800 (100-1200) cases each year that might be attributable to radon exposure (roughly 2.2 fatalities per million exposed per year per Bq/$m^3$). It is important to note that from an international point of view Dutch indoor concentrations are relatively favourable (much lower than for instance in Finland).
Measures to reduce radon concentrations in existing houses are relatively drastic and expensive: ventilation facilities in the crawl space beneath the houses and sealing of the ground floor. Annual costs of that type of measures in existing stock of residents were estimated to be in the order of 680 million Euro (for only 5% of the total stock). Introduction of standards for radiation performance (SPN) in newly built houses would be much less expensive. Adjustment of the ventilation rate and evaluation of construction materials would probably not exceed 620 Euro per new house. Additionally the heating costs would increase with a maximum of 40 Euro per year. This type of measures would cost in the order of 50,000-150,000 Euro/QALY saved. The SPN is not yet implemented in building legislation due to changes of government in the Netherlands. The introduction of the SPN might have complications for free trade within the EU.

**LPG stations in residential areas**
Due to the proximity of LPG stations, associated with a small but significant chance of explosion, at this moment more than 15,000 people are exposed to a mortality risk exceeding one in a million annually. Within urban areas it primarily concerns houses within 15 and 80 meter around the LPG-stations, as surface of approximately 0.5 hectare. The relocation of LPG-stations will cost around 0.25 million Euro which is in almost all cases much less expensive than pulling down existing houses. The cost of an avoided fatality by means of relocating a LPG-station is in the order of 3 million (±100,000 Euro/QALY).
Including opportunity costs as well a completely different picture emerges. Removing LPG-stations from the built environment means grounds within risk zones is becoming available for building dwellings or offices. Reorganising the existing LPG-stations would yield around 2000 hectare of ground to be developed. In the event building projects are developed here, this would mean a gain of around 25 billion Euro.

**Air pollution**
Approximately 3000 people die annually as a result exposure to air pollution (fine particulate matter and ozone). Road traffic is the most important source of air pollution in the Netherlands. In recent decades road traffic emissions have decreased substantially, in spite of large volume growth. In the next decade further reductions are expected of new measures. In the period 1985-1995 annual costs were around 500 million Euro yielding a emission reduction of around 4% per year and proportionally 120 to 210 less fatalities: that is 2 to 4 million Euro per life saved. For the period 1995-2010 an amount of 5-10 million Euro per life saved can be calculated. These cost per life saved are 30 to 75 times higher than the costs of traffic safety measures per life saved in the period 1980-2000. It is important to note that traffic

emission reductions have benefits outside the public health domain as well. Reduction of acid and nutrient (nitrogen) deposition has gradually improved the ecological quality of many natural systems in the Netherlands.

**Firework storage**
The storage of heavy firework within 400 meter distance of the built environment has been prohibited by law for many years. If operation and inspection of permits had been in order the probability of a disaster, such as the one that blew away a complete residential neighbourhood in Enschede, would have been nil. As a result of incomplete enforcement in practise safety risk are much higher than prescribed. This applies not only to firework storage, but to the safety of most large industrial installations. Therefore theoretically resources made available for relocation of storage facilities do not yield extra safety; in practise of course the do.

Looking at *Box 1* and, to a lesser extent, to *Box 2*, should we conclude that in several domains governmental policy is inappropriate and that it is time for a complete change? The US researchers of the 'Harvard Centre for Risk Analysis' are convinced the time is right. They claimed that more efficient investment of prevention money could save more than 200,000 life-years each year[66]. They proposed to start with the most cost-effective intervention, then the next cost-effective and repeat that procedure until the resources as spent. This new voice sounded very well in the choir of members of Congress, corporate groups, and economists who turned cost-effectiveness analysis into a weapon against the regulation idiocy that, in their view, held the United States hostage. They mounted a vigorous and successful campaign to make benefit cost analysis the sole basis for risk management decisions. As a cost-benefit test now often is more or less compulsory in new legislation, at this moment in the United States a fierce debate is going on regarding the validity of this type of calculations[xiv,80,81,82].

As already discussed health and safety policy based on this limited definition of appropriateness may conflict with other important equity aspects, that are treasured values in most Western countries:

good quality and equal accessibility of health care

solidarity with respect to high cure and care costs (people don't choose their 'expensive' disease themselves)

the availability of proper nursing and care facilities, when cure is no longer an option, and

the right to a high level of health protection[64,83].

Another, more pragmatic reason to critically observe simplistic cost-effectiveness consideration in environmental regulation is the phenomenon of 'social amplification', as discussed in the previous section. Small as the quantifiable health losses may be, the economic damages can be immense when consumers all at once start casting doubts on the integrity of industrial products, for instance in the case of BSE and the bio-industry or food stuffs that involve genetically modified organisms[50,55,69,47].

In short, dealing with risks in several domains often is a combination of different decision rules. In some cases these rules are conflicting, e.g. 'efficiency versus equity' or 'precaution versus efficiency'[73,84]. To deal with this politics and policy makers should make explicit, transparent, choices for a balance between efficiency, equity and precaution.

[xiv] This debate is partly provoked by appointment of the Harvard professor John D. Graham, head of the Risk Analysis Unit by the Bush junior administration to become head of the Office of Management and Budget of the White House.

### 3.3.3 A proposal for risk management procedures

#### *3.3.3.1 Prelude*

How are we going to use all the information we have brought together here on the nature of risk problems, the way risks are perceived by social groups, politicians and policy makers and the often implicit rules we apply to deal with them?

The complexity of our society is enormous, and as a result of rapid technological and social changes we have lost sight of what is going on. They have made life less predictable and a truckload of often-contradictory information increases our uncertainty. Individualisation has corroded social control, solidarity and cohesion. As modern citizens we refuse to accept health risk as dumb fate or Divine destiny as our ancestors use to. Instead we demand responsibility from the entrepreneur who benefits from risk generating activities, and of course the government[85,86,87]. When in 1992 a Boeing 747 crashed into an apartment building in a deprived area of Amsterdam, emphasis was still on the unspeakable grief, desperation and possible long-term health effects. Following recent disasters, such as an exploding firework storage that destroyed a complete neighbourhood and a fire in a bar ruining the lives of many young people, politics and the media were predominantly concerned with who is to blame.

On the idea that society can be constructed according to well-designed plans we have started to believe that the government can guarantee our lives to be without risk, without bad luck. As society we are prepared to make great offerings for further reduction of often-futile risks. To reduce the chances of flooding we spent billions of Euros and sacrificed large parts of our much cherished river landscape. Rather unscrupulously tens of thousands of cattle, pigs and poultry are systematically being cleared away simply to restore our faith in the safety of our food (and economic interests) without a clear picture of the real human health risks of BSE, foot-and-mouth disease, hog cholera and so on.

For a number of reasons this perceived control over man-made risks is fictitious. The risk phenomenon is essentially incompatible with total control as unfortunate concurrence of circumstances is by definition ineradicable, especially in a world of increasing complexity. The number of man-made risk generating activities and situations only increases. No stream of regulations cooked up in the Hague where our government resides (or anywhere else) will ever create a zero-risk situation for Dutch citizens. There is simply not enough money, human resource and capacity for inspection of adequate execution of rules and regulation. Another more or less paradoxical reason is the act that citizens tend not to be too worried about what the government wants from them. Although much concerned with safety and health risk issues, citizens tend to dismiss any restrictions of their freedom of action or undertaking[88].

Based on the insights that risks come in many sizes and colours, and that a number of explicit or implicit decision rules guide our dealings with risk, we will define a number of strategies based on quantitative and qualitative aspects of risks. We will start with discussing different possibilities ways for deliberation processes, and the degree to which shareholders should be involved.

#### *3.3.3.2 Types of discourse*

Deliberation is an essential element of problem definition, uncertainty management, and balancing decision rules during the process of risk management[20]. Some science-philosophical authors distinguish different levels of discourse. Dealing with relative simple, operational and uncontroversial risk problems, the discourse is often internal, within the agency, the company's risk management unit or policy department. Standard risk assessment tools and management criteria are undisputed and lead to solutions that are accepted by all parties[72,89,90]. In *a cognitive* discourse experts, preferably from involved stakeholder parties argue about an appropriate delineation, definition and explanation of the risk phenomenon, adequate and consistent

criteria for risk assessment. The more complex and uncertain the risk problem, the more multidisciplinary and deliberative the process to arrive at consensus or clarification of dissenting views. If there is uncertainty on the level of constructs or models (paradigms), scientific input is only one aspect of the evaluation procedure. A *reflective* discourse involves clarification of knowledge, but also discussion on normative aspects, such as the right balance between precaution and a harmless until proven dangerous philosophy, between efficiency and equity, or between a risk averse and a risk keen attitude towards technological innovation. Besides scientist also expert representatives of involved stakeholder groups ought to take part in these evaluative discourses, as scientific knowledge as well as societal values are at stake. A participative discourse is the most comprehensive form of deliberation. Here ambiguity and ignorance are substantial and thus the framing of the risk problem, measurement issues and formulation of possible solutions depend very much on values, attitudes and political preferences. Fundamental views on equity, environmental justice, the blessings of technological development and social change are often decisive in these deliberations. Thus this discourse involves all democratic parties as it is aimed at societal consensus on how to define risk problems, in spite of ambiguity, ignorance and often social distrust[72].

#### *3.3.3.3 Four strategies for risk management*

In four risk management strategies we will try to combine the insights in the multi-attributive nature of risk, different degrees of incertitude, the limitations of risk analysis, combinations of different decision rules and the types of discourse that are applicable. Tentatively we propose four risk types, everyone with a corresponding risk management strategy (Table 3-3).

*Operational decisions with respect to simple risk problems*

If there is no discussion on problems of uncertainty, unresolved complexity or efficiency, traditional quantitative methods of risk assessment and management will generally suffice. Calculation of health risk in terms of probability and effect (mortality) can support decisions on risk acceptance, applying standard evaluation frameworks, such as an accepted and a negligible individual mortality risk of $10^{-6}$ and $10^{-8}$ respectively according to the Dutch government's 'Premises for risk management'[17].

*Table 3-3. Risk management strategies for different types of risk problems with respect to challenge, goal, function, instrument and decision rule[72,90].*

| Problem | Instrument | Strategy (how?) | Solution (what?) | Goal | Rule |
|---|---|---|---|---|---|
| simple, minor complexity | quantitative risk analysis<br><br>risk comparison | routine, cognitive discourse, involving agency, external experts<br><br>discussion on the usual interpretation of available data and uncertainty | agreement on causality and effective measures<br><br>application of general risk criterion (e.g. $10^{-6}$) | health protection<br><br>protection of most susceptible individual | rights-based |
| appropriateness | analysis of cost-effectiveness and cost-benefit<br><br>analysis of distribution effects<br><br>historical analogies | cognitive and reflective discourse, involving agency, external experts, stakeholder experts<br><br>evaluating trade-off between maximising health gains, equity and (opportunity) costs<br><br>deliberating compensation | well-balanced measures given socio-economic and psychological context | efficient as well as fair health protection | rights and utility-based |

| Problem | Instrument | Strategy (how?) | Solution (what?) | Goal | Rule |
|---|---|---|---|---|---|
| incommen surability<br><br>controversy | multi-attributive utility analysis<br><br>sensitivity, uncertainty and scenario-analysis<br><br>negotiated rule making<br><br>historical analogies | cognitive and reflective discourse, involving agency, external experts, stakeholder experts<br><br>social support for problem definition and delineation, relevant risk attributes, risk criteria and decision rules | shared concept of problem and solutions<br><br>dispel of mistrust, misunderstanding about mutual positions<br><br>freedom of choice | trust consensus<br><br>empowerment | utility and technology |
| ambiguity, ignorance | integrated assessments/system analysis<br><br>analogy, what-if', fuzzy logic analyse<br><br>public involvement: citizen panels, scenario workshops, focus groups etc.<br><br>value-analysis | participative discourse, involving agency, external experts, stakeholder experts, democratic parties<br><br>seeking consensus in society<br><br>avoid postponement of management<br><br>technology control: diversity, containment, flexibility, substitution development, transition management<br><br>close interaction between scientific development and policy formulating (sequential, flexible) | 'democratic' resolving of conflicts of values, preferences, concern, visions | maintaining resilience, flexibility, freedom of choice<br><br>'no-regret'<br><br>broad social acceptance<br><br>sequential decision making | technology and precaution |

The discourse is internal or cognitive among experts from the agency, advising institutions and, if necessary, from involved parties (e.g. industry). Crude costs-effectiveness analysis can help decide whether the Euro for risk reduction is well spent. Main objective is *health protection of the most susceptible individual* from the perspective of everyone's right to a high level of protection. Measures should be aimed at the reduction of the additional probability of health loss to a generally accepted level in a more or less standard operational manner (the additional annual mortality risk of one in a million is a very good deal in terms of public heath). Good examples are the setting of exposure standards for toxic compounds in ambient air, at the workplace or for food additives or residues.

*Appropriate decisions in risk management*

However, 'free lunches' are scarce. A rights-based approach can be excessively expensive (total or per life-year saved) or conflicting with other interests highly valued in society (including opportunity costs), e.g. safety around large airports, Legionella in drinking water systems, pathogen-free slaughterhouses or natural toxin-free foods. Although calculated health risks (or losses) are a good indicator of the risk problem, shared by all parties, the proportionality of investments needed to save lives, life years or health adjusted life-years is disputed.

Typically in these cases a balance has to be found between every citizen's right to a high level of health protection and precaution on the one hand, and efficient use of collective resources for public health on the other. As shown in *Box 2* the cost-effectiveness of risk reduction can be significantly

improved by more specific measures aimed at high risk groups (Legionella in drinking water systems), or by focussing on new situations, instead of already existing ones (indoor radon, noise or air pollution abatement).

Finding the right balance between efficiency and equity of course is not a matter of science. Based on good scientific analysis of risk reduction, cost-effectiveness, and distribution effects, a reflective discourse involving representatives of social parties involved should lead to a broadly accepted compromise, which may include compensation for citizens who get the worst of it. An important consequence may be that not all citizens are equally protected, but at the same time collective resources are not wasted on inefficient risk reduction.

To facilitate discussion on alternative levels of acceptable risk among stakeholders, analysis of historical analogies may be helpful. Collective mortality risk acceptance that has taken shape in society over a number of years, as well as the resources spend on risk reduction may be a function of important qualitative risk attributes such as voluntariness of exposure, perceived controllability or familiarity of technology. Historical analysis may teach us something about the relation between qualitative risk attributes profiles and 'solidified' risk acceptance (and willingness to pay)[91].

In medical technology assessment implicitly and sometimes explicitly a limit of around 45,000 Euro per QALY is applied for new interventions that can reasonably be admitted as cost-effective (see also Box 1) . Of course these types of cost-effectiveness limits will differ from one domain of public health care to another. Nevertheless they can help in making considerations more explicit. Of course further empirical research is required to investigate the applicability of this idea.

*Controversial, tactic decisions in risk management*

Traditional, quantitative risk management will also fail when probability and health effects (especially mortality) are not the issue in the social commotion; when calculations of mortality or morbidity risk simply do not represent the risk as perceived by the public involved. Good examples of such risk problems are the antenna masts for cell phones (GSM), electricity power lines and possible child leukaemia risk, BSE and endocrine disrupters. The acceptability of nuclear power facilities is often discussed in terms of very small probabilities of a serious accident, while the public is primarily concerned by the magnitude of the consequences. The same goes more or less for aircraft accidents, especially after the 'Bijlmer' catastrophe in Holland: experts may claim that thanks to improvement of aviation technology the probability of another accident is decreasing. However, people are primarily worried about the next airplane hitting a crowded residential area. 'Mad cow' disease among European cattle did not cause great turmoil among the public solely as a result of a high number of fatalities. Qualitative attributes have been much more important, such as the terrible fate of young Creutzfeldt-Jakob disease patients, the stigma of BSE as an omen of great disaster brought down upon us by a rationalised bio-industry that turned herbivore cattle into 'carnivores'.

In these cases, risk management procedure should aim at achieving consensus among involved parties on problem definition and delineation, on risk attributes that should be taken in consideration and on efficacy, efficiency, and distribution effects of measures. The main purpose of the procedures is beyond simple health risk reduction, it is about appropriate deployment of resources, without loosing sight of social justice, and in some cases it is merely about gaining trust, decreasing commotion among involved citizens or about well-argued precaution.

*Strategic decisions in ambiguity or ignorance*

To the extent that ambiguity increases, just as complexity and the possible magnitude of (health)

consequences the management approach will go beyond traditional quantitative risk management procedures. Problem structuring, approaches of risk quantification, dealing with uncertainty and ignorance, application of precaution, and the design decision procedures will have to be developed in close interaction with society. Science is no longer advisor or even 'great arithmetician', but rather 'facilitator'. This implies that politicians will have to decide in explicit uncertainty. The main objective is to arrive at a broadly accepted definition of the risk problem, an approach to 'measure' and monitor the nature and magnitude of the risk, and a framework for making decisions in pace with developments in scientific knowledge. The Intergovernmental Panel for Climate Change (IPCC), comprising not only scientific analysis, but political and socio-economic evaluation as well, is a good example of such a 'post-normal' approach[93].

## 3.4 Discussion

Obviously the framework outlined in table 3-3 is rather theoretical and has to prove itself in everyday practice. Several exercises with experts from different backgrounds and with stakeholder representative indicate that the application of this type of framework may at least help to structure the available information, to identify the crucial aspects of the risk problem, to focus on the criteria that matter, and in the end to come up with definitions of the risk problem and possible solutions that are shared by different stakeholders[94,95]. But of course these exercises do not reflect the 'stubborn' practice of everyday environmental risk regulation and maintenance. Ultimately the authorised government will have to decide on which measures to take.

The State Secretary for the Environment has recently launched new proposals for 'dealing with risk in a sensible manner' in the Dutch parliament, especially with regards to a number of difficult dossiers, including indoor radon, power lines and base stations for mobile phones. The memorandum is consistent with some of the ideas discussed here. The State Secretary proposes explicit evaluation of costs and benefits, participation of citizens, explicit responsibilities for business, industry and citizens, and transparency in decision-making[96].

An important aspect of the proposed procedure may be a good a priori appraisal of the risk typology and corresponding strategy. If one starts too high on the 'risk ladder' much time, energy and resources may be wasted. If one starts too low, one might provoke unnecessary escalation, social disruption and loss of esteem for the government. Case studies will provide better knowledge of how to deal with risk typologies, and risk strategies in practise, the equivocally and acceptance by involved parties, to finally arrive at clear rules of argumentation, criteria and analogies.

Several of the approaches presented in table 3-3 require community participation, as is also advocated in the Gothenburg consensus paper[97]. Community participation may often have a positive impact of the success of project development and implementation, it may change the attitude towards causes of ill health, promote a sense of responsibility and confidence among involved groups or individuals. The involvement in the policy process may decrease the alienation among excluded groups and improve relationships with professional policy makers. However, participation is time-consuming, communities of busy people may question the value of invested time and effort. There may be problems with the legitimacy of those representing the views of often-heterogeneous communities. Some stakeholders will mobilise professional, well-informed participants much easier than others. Furthermore, the difficulty of organising participation will often conflict with the speed required for timely health impact assessment and management. So, community participation may be very appealing, but practically difficult[98,99].

Obviously, more emphasis on the societal costs of health risk reducing measures may improve policy

making. However, cost-benefits should be analysed from a comprehensive perspective (e.g. large enough time-horizon, broad spectrum of possible costs and benefits), encompassing not only the present costs of implementation, but also possible future, ancillary benefits of technological innovation, stimulated by measures to protect the environment. Ex post analyses indicate that ex ante cost assessments tend to overestimate the actual costs, often as a result of unanticipated gains of innovation (e.g. emission reduction of CFC and $SO_2$, asbestos ban, and occupational lead exposure reductions in the United States)[100,101].

Often prevention at new situations will prove much less expensive than solving problems at existing situations. This applies to building underneath power lines, radiation standards for construction materials, as well as to building within safety risk zones or explicitly evaluate health aspects in urban planning. Better enforcement of existing guidelines may in many instances be a very cost-effective solution to avoid expensive retrofit measures in existing situations.

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