Perspectives on uncertainty and risk : the PRIMA approach to decision support

Perspectives on Uncertainty and Risk

The PRIMA Approach to Decision Support

by

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Errata

p.6 and p. 21: a wrong reference is mistakenly copied from our Endnote library. Radford et al. (1976) (footnote 15 and p. 21) is not used in this thesis.

p. 196: Table 7 should have been referred as Figure 7. The figure presented here as Figure 7 is actually Figure 8 (see p. 198).

p. 311: The remark (*check*) should be read as "the decrease of NO_x-emissions in the cities and the decrease of hydrocarbon and the NO_x-level on regional and European scale".

Furthermore, some typing errors throughout the thesis have survived checks and double checks.

This book is dedicated to all active dreamers

Contents

Acknowledgements

Writing an *interdisciplinary* book *alone* is a contradiction in terms. Probably for that reason interdisciplinary PhD theses are still rare. I am not even able to pretend that this piece of work was a solo-activity. The scientific mores, however, requires that I am the one and only author of this thesis. The compromise is that my name stays solitarily at the cover. However, I will use the plural 'we' throughout this thesis to indicate that most of the inspiration and creativity arose out of teamwork and that all thoughts and ideas presented in this thesis have been thoroughly improved through discussion with colleagues.

First and for all, it is hard to express how grateful I am to Jan Rotmans. Without his expertise, vision and endless encouragement and enthusiasm, I would have certainly lost the faith that I could write a thesis that would be worth the effort. In the course of time, we grew into a team in which each of us has a clear role to play. It is no exaggeration to state that alone I would have done less than half of what we did together. My two PhD supervisors, Jan Rotmans and Rob Hoppe, shared an exceptionally critical attitude, but in a complementary way. With the result that no single sentence was left uncriticised. I would like to thank Rob Hoppe for his contribution to this thesis and my scientific development. Thanks for helping me to make this thesis at least interesting to social scientists, and for preventing me to fall into the trap of naïveté on political and policy matters.

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It would have been much more difficult to write this thesis without the team-work I encountered throughout my career. I would like to thank my former colleagues in the so-called 'globo-team' around Jan Rotmans at RIVM, where I took some first steps on the road that would ultimately resulted in this thesis. I learned a lot from their expertise on sustainable development issues. I owe a special word of thanks to Arthur Beusen and Henk Hilderink, who were always willing to help with the necessary modelling work and experiments needed to advance the concept of perspective-based model routes. Furthermore, I would like to thank Esther Mosselman, who apart from making very functional art that helped to communicate my ideas, turned out to be a room-mate in the best sense of the word.

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The actual PhD research was carried out at the International Centre for Integrative Studies (ICIS), Maastricht University, Ther Netherlands, established by Jan Rotmans and myself about 2½ years ago. The major advantage was that this context provided me with the opportunity to organise support. I would like to thank Chantal Timmermans-Storms, Bastien Clement and Maud Huynen for their supportive literature surveys on risk, pluralism and specific literature requests, respectively. I am more than grateful to Rian Langendonck and Frank van Asten. Together we carried out the case-study work on RIVM's Environmental Outlooks. Through hard work and almost endless commitment, they have both produced a very good master thesis that served as very valuable input to Chapters 6, 7 and 8. The whole ICIS-team has been very supportive, both through their interest and by providing a helping hand when necessary. I would explicitly like to thank those colleagues who took the time and effort to comment on previous drafts, i.e. Pim Martens, Dale Rothman, Nicole Rijkens-Klomp, Bas Amelung, Philip van Notten, Janneke Hoekstra and Debby Jochems. Furthermore, I would like to thank the secretariat - Simone Pittie, Marie-Lou Mestrini and Debbie ten Berge - for taking care of the procedural aspects of the PhD trajectory and the communication with the faculty and the university, the review committee, the graphical designer and the publisher.

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Apart from the professional acknowledgements, I would like to thank those in my personal life that gave me the support and energy needed for such an intensive activity as producing a PhD.

Saskia, thanks for the way you were my sister and friend during my PhD period. Arjet, Birgit, Diederik, Eric, Esther, Fieke, Ilse, José, Marlo, Monique, Peter, Simone, Tess, and their partners: it is good to know that for being friends, it would not have made any difference whether I succeeded in finishing my PhD or not. At the same time you supported me in one way or the other more than you probably realised. I know that the period in which I was writing my PhD weighted on the time-slots available for sharing our friendship. Thanks for your support and understanding. In this context, I owe a very special word of thanks to Daniel Gerdes, who read the whole thesis to check the English. I would also like to thank my girl-scouts and colleague staff members for guaranteeing the necessary distance to my research in the weekends.

Finally, I would like to thank the families that adopted me in various periods in my life. I would like to thank my uncle Ton and aunt Gerda, and their children Chris and Astrid for the family warmth they gave and give to me. Frances, Derek and Gael served as my Enschede family. At the time I was wondering whether I would ever graduate, Frances already predicted that I would do a PhD. Heidi, Franz and their kids Nina, Eva and Tim were my Swiss home. Especially abroad, such a warm and comfortable friendship and being treated as member of the family are a gift for which I can never be grateful enough. Last but not least, Cor and Leida, you are outstanding in the role of parents of a mature, quasi-independent and busy woman. Thanks.

The world isn't always that beautiful, but life is a wonder. In sum, I want to thank everyone who inspired me and coloured my world. I hope this thesis gives you something back.

Marjolein B.A. van Asselt

Maastricht, November 1997 - July 2000

CHAPTER I

Introduction and research methodology

In a nutshell[*]

The decisions of modern life are complex, giving rise to often intractable uncertainty in decision making. This uncertainty can take several forms. Different perspectives lead people to perceive and seek to manage the world in different ways. The approach proposed in this thesis enhances awareness of this pluralism and helps Integrated Assessment practitioners to consider the possibilities and consequences of various equally legitimate possible development pathways and, hence, avoid being over deterministic and positivistic in their practice.

[*] I owe this condensed summary of the ambitions to Steve Rayner.

In face of complexity, decision-makers usually just muddle along. Why?

First of all, what is a complex problem? A decision-making issue is complex, if it satisfies the following characteristics[1] (see also Figure 1):

- there is not one problem, but a tangled web of related problems (multi-problem).
- the issue lies across or at the intersection of many disciplines[2], i.e. it has an economic, environmental, socio-cultural and institutional/political dimension (multi-dimensional).
- the underlying processes interact on various scale levels (local, regional, national, continental and global) and on different temporal scales[3] (multi-scale).

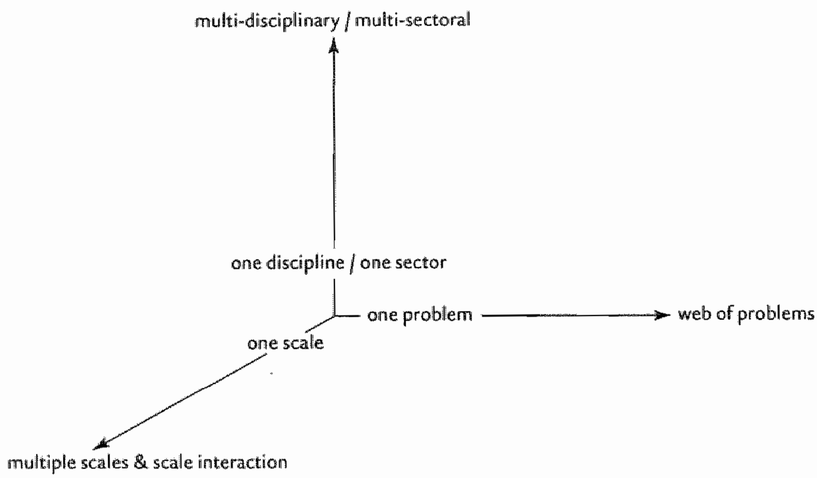

FIGURE 1 The three dimensions of complexity

We do not argue that previous societies were not complex or that life used to be easy. The Inca-culture is an obvious example of a very complex society in ancient times. However, this culture was bound to a specific geographical area, and can thereby be considered as a kind of independent subsystem. We argue that the essence of today's complexity lies in the vanishing of geographical borders and subsystem boundaries. Nowadays, changes at one place on Earth can impact on the

1 Compare (Rotmans 1998a)
2 Compare (Schneider 1997)
3 Compare (Rotmans 1998a)

lives of people and the state of the environment around the globe due to mutual interactions and interrelations between social, economic, institutional, technological and ecological processes.

The number of complex issues swells, due to scale-enlargement, globalisation, technological innovation and an increased interconnectedness. However, our society is not prepared to manage complexity: governments are subdivided in ministries, science is organised along disciplines, business is structured into sectors, and NGOs defend a specific stake. Although the words intergovernmental, interdepartmental and interdisciplinary belong to our vocabulary, they have not really developed into common practise.

Decision-makers are and will be increasingly confronted with complex issues. Muddling along doesn't seem to be the best strategy. It is not fair to blame decision-makers. They are not adequately equipped for this task. They lack tools, methods and strategies that enable them to do the job. They lack adequate decision-support. Why?

1. Complexity, uncertainty and risk

Complex issues are complicated. There are two major reasons. Due to the scope of complexity, more and more actors are involved, either directly or indirectly. Decision-making on complex issues thus implies consideration of an increasing variety of, often conflicting and contradictory, perspectives, interests and needs. Notwithstanding the apparent success of the "poldermodel"[4], decision-making bodies, whether governmental or business, struggle with this consequence of complexity. Second, as will be argued in this thesis, complexity goes hand in glove with fundamental uncertainty. Important complex phenomena like climate change, technological innovation, and war, and underlying processes (like biogeochemical processes, market mechanisms, and human behaviour) are not fully understood. As will be argued in this thesis, in such cases uncertainty cannot be banned[5]. Decision-making on complex issues is thus decision-making in uncertainty. Uncertainty is a feature our society feels uncomfortable with[6]. As will be argued in this thesis, no methods and tools are currently available to manage uncertainty in decision-making in an adequate manner.

4 Dutch model of consultation and negotiation-economy
5 See also (RMNO 1998)
6 Compare (Hofstede 1991)

Complex issues are important. The risks associated with complexity can be quite substantial. Due to the character of complexity, the risks cannot be limited in space, nor in time. Furthermore, there are different perspectives on risk — e.g. risk-seeking, risk-accepting and risk-aversive[7] —, which makes it difficult to define risks unequivocally: multiple risk definitions are equally legitimate. As will be argued in this thesis, the current tools and methods for risk analysis are not adequate to evaluate risks associated with complex issues. Complexity demands a new 'risk logic' and a new form of risk analysis.

2. Decision-support

Due to uncertainty and multiple risk definitions, science cannot come up with definite recommendations for complex issues. On the one hand, this may be seen as good, because it frees society from 'technocratic patronising'[8]. On the other hand, it may lead to irresponsible management if uncertainty is used to postpone decision-making.

In the face of complexity, the way knowledge and science are currently used in decision-support is problematic[9]. On the one hand, because in general uncertainty is hidden, ignored or even denied. On the other hand, because risks are usually estimated from one perspective. The way in which science handles uncertainty and risk affects the manner it communicates uncertainty and risk to decision-makers[10]. The traditional methods and tools are inadequate to address and communicate inherent uncertainty and plural perspectives in scientific knowledge. And even worse, applying these classical methods is likely to reinforce the denial of uncertainty and 'mono-thinking' about risk.

Although the fears for a technocratic society ruled by scientific experts are still alive, in our point of view it is much more likely that decision-makers will turn their back on scientific experts, either explicitly or implicitly. The latter by using/abusing scientific advice selectively as 'underpinning' of taken views[11]. Due to uncertainty and pluralism, the ideal of prediction and truth is corroded. However, in the current web of engagements between decision-makers and scientists, the latter still claim, or are forced to claim, levels of certainty that the human stock of knowledge does not support. Both seem to be kept in the paradigm of 'science-speaking-truth-to-power'.

7 See Chapter 3B
8 (Beck 1992)
9 See also (Hoppe 1999)
10 (O'Riordan and Langford 1999)
11 (RMNO 1998)

Scientists may have the feeling that they cannot make uncertainties explicit in their recommendations, because it deprives them of credibility (and power). But in the current setting every disclosed 'wrong prediction' undermines the trust in science. And, due to complexity, the number of 'wrong predictions' will only increase. Such a negative spiral may in the end put science at the margins of societal debates.

Due to uncertainty and risk, the ideal of finding the 'optimal, most effective and most efficient solution' vanishes into thin air. In the face of uncertainty and risk, the challenge is to find strategies that are robust, i.e. strategies that appear to trigger a favourable future, that seem to avoid highly undesirable ones, and that are flexible enough to be changed or reversed if new insights emerge. Scientific knowledge, an informed awareness of the limits to knowing, and the systematic way of thinking associated with science can be useful in the common search for robust strategies that address societal problems and make the most of opportunities. Scientific decision-support in principle thus has a role to play.

Taking the above into account, decision-support is thus not simply the provision of knowledge per se. The quality of decision-making does not necessarily increases if more knowledge is available. Decision-support should therefore not limit itself to communicating the relevant scientific insights, but it should also enable decision-makers to form their opinion on the associated uncertainty and risk[12].

Complex issues, such as transport, infrastructure and mobility, cannot be studied by a single scientist behind a desk in an ivory tower. Due to the scope of complex issues, actor's perceptions, expectations, attitudes, perspectives, norms and values do matter. This implies that scientists can (and should) learn from the experience, expertise and views of non-academics as politicians, civil servants, business people, representatives from NGOs, artists and ordinary citizens. The implication is that decision-support on complex issues should be participatory[13].

The challenge for decision-support is thus to find ways to use knowledge and to understand uncertainty in such a way that it enables to inform societal debates about risks. Taking the above considerations into account, the aim of scientific decision-support in face of complexity can be formulated as:

> ***Decision-support is a structured and participatory search process that aims to provide robust insights that facilitate decision-makers to act consciously in a complex, and thus uncertain and risky, world.***

12 (Gezondheidsraad 1995; 1996; Fischhoff 1995)

13 In this thesis the notion 'stakeholders' is used in the broad sense, comprising everyone who directly or indirectly is involved in or affected by the complex issue under concern.

To that end, new assessment methods which enable to address and communicate uncertainty and risk are necessary. The current thesis aims to make a valuable and constructive contribution to this methodological challenge.

3. Integrated Assessment

This thesis builds upon the tradition of Integrated Assessment (IA). In this context, IA is considered as a particular form of decision-support. IA can probably best be described as a structured process of dealing with complex issues, using knowledge from various scientific disciplines and/or stakeholders, such that integrated insights are made available to help responsible decision-makers to think about problems and/or to evaluate possible actions[14]. The principle of Integrated Assessment is that bits and pieces from different knowledge domains are combined into one puzzle in order to gain relevant insights for decision-making that go beyond the reach of separate disciplines. Integrated Assessment distinguishes itself from intuitively-based processes through the usage of formal frameworks, systematic procedures and scientific knowledge. It is distinct from interdisciplinary research by its a-priori decision-support ambition.

Approaches currently available in Integrated Assessment suffer from either one or two of the following disadvantages:

- the methods do not allow to address the most salient uncertainties and risks
- the associated uncertainty and risk measures are not understandable to non-scientists in general and decision-makers in particular.

Both disadvantages are undermining the key ambitions of Integrated Assessment: to analyse and interpret complex issues, and to communicate integrated insights to society and decision-makers in particular. How to deal with inherent uncertainty currently plays a key role in actual methodological debates in the IA community[15]. Against this background, the current thesis aims to provide a substantial contribution to IA methodology. The intention is that the thesis is also of interest to neighbouring fields of decision support, such as risk analysis, technology assessment, impact assessment[16], life-cycle analysis, policy analysis and operations research.

14 See also (Rotmans and van Asselt 1996) (Rotmans 1998b) and (Rotmans and van Asselt 2000)
15 See, for example, (Jäger 1998; Radford et al. 1976; Rotmans 1998a; 1998b; Tol and Vellinga 1998)
16 E.g. environmental impact assessment and social impact assessment

4. Research perspective

It will be argued further on in this thesis that science is a creative process in which social and individual values interfere with observation, analysis and interpretation. In this view a scientist is a societal actor. So before outlining the research approach, we consider it necessary to clarify our research perspective and attitude.

The research attitude can be characterised as moderately social-constructivist[17], in the sense that we accept that science is a social process, however the existence of facts and reality is not fully denied. We argue that in case of complex societal issues objective scientific assessment is impossible, without arguing that science is just another way of argumentation.

The issue of decision-support can be addressed from either the supply-side (i.e. the scientists and analysts) or the demand-side (i.e. the decision-makers and the stakeholders)[18]. The perspective guiding the current thesis can be characterised as 'supply-driven'. There are several reasons for this choice, both principal and practical.

We are more and more convinced that profound knowledge of the policy sciences' literature and/or substantial experience with the decision-making practise is needed to be able to gain a sufficiently rich and realistic understanding of the demand-side. It is at the moment beyond our competence to reason adequately from a demand-driven perspective in this particular thesis. If the thesis would have taken such a perspective, it is more than likely that it would have resulted in a naïve and caricatural exercise of no use for decision-support. Having worked at RIVM, the Dutch Environmental Planning Agency, having participated in two large projects for the European Commission[19] and being involved in various IA consultancy projects[20] at the International Centre for Integrative Studies (ICIS), the primary researcher is rather knowledgeable of and experienced with the supply-side of decision-support.

The principal, and thus the decisive, reason for choosing a supply-driven perspective, is that we are convinced that there are 'clues' on the supply-side. The majority of the decision-makers still expects certainty from science and will therefore not have an a-priori interest in decision-support that takes uncertainty as starting point. The first step towards a new mode of decision-support is that the decision-support suppliers acknowledge inherent uncertainty and pluralism. This already

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17 See also Chapter 3A, 3B and 4.

18 See Chapter 2.

19 i.e. the ULYSSES project e.g. (Dürrenberger et al. 1997; Jaeger et al. 1995; Kasemir et al. 1997; Toth et al. 1998; Kasemir et al. 1999; Dahinden et al. 1999) and the VISIONS project (Rotmans 1997; Rotmans and van Asselt 1997; Rotmans et al. 1999)

20 E.g. for the Province of Limburg (the so-called POL-project) (ICIS 1998; 1999b) and the city of Maastricht (ICIS 1999a).

requires a kind of paradigm-shift on the supply-side. The next step is to sketch alternative strategies to deal with uncertainty and risk in the practise of decision-support. Such a practical translation is necessary to consolidate support with the practitioners. In sum, we argue that a promising avenue towards improved decision-support is to attempt to gain support on the supply-side for the need for change, and secondly to develop an alternative approach that seems feasible to the practitioners in decision-support.

As a theoretically sound and practically feasible alternative approach to decision-support is available as a prototype, the next step would be to discuss such an example study with the demand-side, with the aim to raise consciousness on the impossibility to escape uncertainty and risk. As argued in technology assessment[21], preferences and expectations are shaped by the interaction with a prototype. This implies that concrete alternatives are needed in order to facilitate a sensible discussion between the supply and the demand-side. Otherwise it is difficult to imagine what would be the consequences of a new interplay between science and policy for the practise of decision-making.

The current thesis can be considered as an attempt to build a prototype that may enhance a consciousness-raising process and thus an alteration of current preferences and expectations. First on the supply side and, in a later stage, on the demand side. The current thesis aims both to be a contribution to scientific methodology and to serve as a catalyst in the decision-support community. The long-term objective is to encourage and promote a fundamental transformation of the interplay between decision-making and science. The research attitude underlying this thesis can thus be characterised as that of an active intervenor as opposed to a passive observer. We consciously choose to act as a change agent, instead of being an outsider to the process.

The research perspective can also be considered as 'science-driven', because it holds, as follows from the introduction so far, that scientists and scientific knowledge have something to offer to decision-makers. In our point of view, a society that doesn't use the available stock of knowledge and the specific competence of experts ignores a valuable resource. And in doing so, it may head towards an undesirable future that could have been avoided. Without this conviction, the present thesis would have never been written.

21 See, for example, (Rip 1995)

5. Aim of the thesis

Central to this thesis is the acceptance of uncertainty and plural risk definitions as being inherent to complex issues. The above detour around complexity, uncertainty, risk, decision-support and Integrated Assessment serves as basis for our problem definition, which on its turn sets the scope for the research hypotheses and questions.

Complexity provides room for different interpretations of uncertainty and different definitions of risk. As a consequence, science cannot come up with definite recommendations for decision-making. This has severe consequences for decision-support. In view of inherent uncertainty and risk, the task of decision support is then to assist decision-makers to act consciously in an uncertain and risky world by structuring and facilitating the search process for robust strategies. However, there is a yawning gap between this theoretical ideal and the current practise of decision-support, including Integrated Assessment. The goal of this thesis is to provide a contribution to bridging this gap through development of Integrated Assessment methodology.

5.1. PROBLEM DEFINITION

The overall ideal of our research programme is to improve the interplay between science and decision-making in order to allow the human stock of knowledge to be used in an effective and adequate manner. Effective means that scientific decision-support really facilitates decision-making in taking robust decisions. Adequate in this context signifies that decision-support recognises both the potency and the limits of scientific advice, and that it doesn't claim levels of certainty or plausibility that the evidence doesn't support.

The umbrella purpose of this thesis is to address the following overarching question:

> *What are theoretically sound and practically feasible approaches to Integrated Assessment that enable to handle and deal with uncertainty and risk in an adequate and effective manner?*

or to phrase it in a more accessible manner:

> *How to bridge the observed gap between the theoretical ideal and the practise of Integrated Assessment?*

5.2. RESEARCH HYPOTHESES

Because the way in which science handles uncertainty and risk frames the manner scientists communicate with decision-makers, a methodological approach to the above research purpose is both legitimate and promising. Furthermore, it seems that the traditional assessment methods and tools are inadequate to deal with uncertainty and risk in decision-support endeavours. Our research hypothesis therefore holds:

Hypothesis

> **There is a need for new assessment methods for managing and analysing uncertainty and risk.**

This hypothesis is falsified in case an assessment method exists that enables to address both all types and sources of uncertainty as well as all relevant risk definitions and perceptions in such a way that decision-makers understand the quality and the impact of the derived recommendations. Furthermore, testing the above hypothesis implies analysing whether the available methods are problematic in view of uncertainty and risk.

Multiple interpretations of uncertainty and plural definitions of risk imply pluralism. Pluralism refers to the existence of different viable and legitimate perspectives. This implies that the approaches for managing and analysing uncertainty and risk have to consider multiple perspectives. The basic requirement guiding this thesis involves that perspective-based/pluralistic methods are in principle able to deal with inherent uncertainty and risk.

Requirement

> **Assessment methods addressing uncertainty and risk have to effectively and adequately deal with pluralism.**

The above requirement is normative. It would be falsified if it can be convincingly argued that there is at least one 'mono-istic' (positivist) method that adequately addresses multiple interpretations of uncertainty and plural risk perceptions. Testing the hypothesis and the above requirement will enable to convincingly demonstrate in a scientific way both the need for, and the main features of, new approaches to deal with uncertainty and risk analysis in Integrated Assessment.

5.3. RESEARCH QUESTIONS

The above hypotheses form one cornerstone for the current thesis. Testing the above hypotheses will create a basis for an alternative to decision-support, by identifying the criteria new assessment methods have the satisfy. But it would not result in a bridge, not even a prototype of a bridge, between the theoretical ideal and actual practise. To that end, the following research questions will also be addressed in the current thesis:

- What concepts, tools and methods would a pluralistic framework for integrated uncertainty management and risk analysis deploy and what steps would it involve?
- How can this theoretically sound pluralistic framework be used in actual decision-support?
- In what way and to what extent is this pluralistic framework a feasible and adequate alternative for decision-support?

Addressing these questions will enable to explore the practical feasibility of pluralistic assessment.

5.4. TARGETED OBJECTIVE

The aim of the thesis is to advance improvement of the practise of Integrated Assessment by enriching the current methodology ("tool kit"). Our effort is specifically directed to approaches that enable to address and communicate inherent uncertainty and risk. The ambition is thus to develop an alternative assessment methodology, that satisfies the criteria associated with uncertainty management, The targeted concrete objective guiding this thesis is thus:

> *to develop a pluralistic framework for integrated uncertainty management and risk analysis that is theoretically sound and to explore whether it is practically feasible.*

6. Research approach

In this section we will delineate our research approach. The research approach signifies how the above research hypotheses will be tested and how the research questions are addressed in order to realise the research objective. It furthermore describes which methods will be used, and how. It will be argued that the chosen approach is valid, legitimate and sound in view of the research purpose and the ultimate objective.

6.1. RESEARCH PHILOSOPHY

We will argue on theoretical and empirical grounds that uncertainty and risk are problematic issues in decision-support. A framework for pluralistic uncertainty management and risk analysis will be proposed. The aim is to apply this framework in practice in order to explore its practical feasibility. These experiences will then be used to draw lessons for Integrated Assessment (see Figure 2).

6.2. RESEARCH METHODOLOGY

The following steps will be taken in order to test the hypotheses and to answer the research questions:

- problem analysis
- design of a pluralistic framework
- case-study on uncertainty management and risk analysis in the practise of decision-support
- experimenting with the pluralistic framework in the practise of decision-support
- evaluation

The different steps will be discussed in more detail in the following subsections in order to make explicit which research methods are chosen and why.

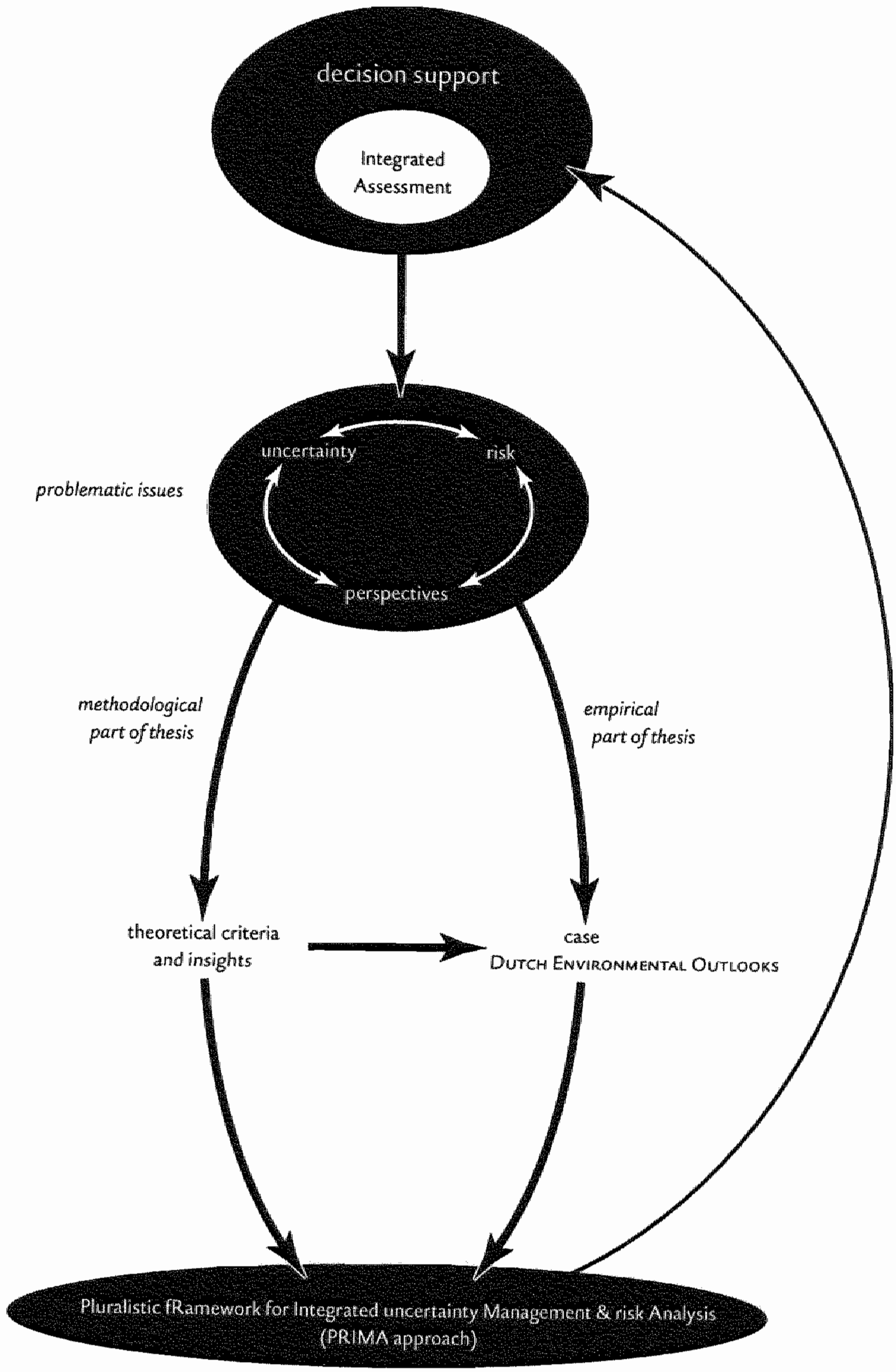

FIGURE 2 Research philisophy

6.3. PROBLEM ANALYSIS

This first step involves a theoretical investigation of the concepts 'uncertainty' and 'risk' in relation to decision-support. The theoretical part of this thesis involves an interdisciplinary literature review and analysis involving the following scientific disciplines or fields of research:

- uncertainty analysis (mathematics)
- risk analysis (assessment, management and communication)
- history of science
- philosophy
- social studies of science
- sociology
- psychology
- economics
- anthropology
- policy sciences
- technology assessment

The literature assessment will allow conceptualisations of the concepts uncertainty and risk. The theoretical analysis will furthermore yield criteria which have to be satisfied in view of inherent uncertainty and risk. Against this background, ideas on pluralism, perspectives, participation and robustness as expressed in the scholarly literature will be evaluated. This evaluation will yield theoretical building blocks that can be used to sketch an assessment approach in which uncertainty and risk are the guiding principles. This step involves on the one hand targeted literature analysis, and on the other hand systematic creative and interdisciplinary thinking.

6.4. DESIGN OF PLURALISTIC FRAMEWORK

Theorising about uncertainty, risk and perspectives will be used to develop a theoretically sound framework for decision-support. To give a foretaste of the contents of this thesis, the major principles that result from the theoretical endeavour are outlined here.

Central in the proposed framework is to disentangle controversies on complex issues in terms of salient uncertainties and relevant risk dimensions. The salient uncertainties are then 'coloured' according to various perspectives. Starting from these perspective-based interpretations, we arrive at various legitimate and consistent narratives. This set of narratives then indicates a variety of possible futures. Integrated analysis of this set of futures allows to evaluate autonomous and policy-driven developments in terms of plausibility and risk. In this way, the level of uncertainty of the underlying knowledge can be made explicit in terms of risk. Based on such an integrated assessment, the perspective-based approach is supposed to reveal robust insights relevant for decision-making. The proposed framework for decision-support will be referred to as the PRIMA-approach, an acronym for Pluralistic fRamework for Integrated uncertainty Management and risk Analysis.

In order to be of practical use, one of the challenges the present thesis faces is to translate this framework into concrete stages and steps, and in concepts and tools that can be be used to implement a particular step and in terms of deliverables. Although the framework will be generic, which implies a certain level of generality, the aim is that it has to lend itself quite easily into use for particular assessment pruposes. This ambition will be explored through experiments with the PRIMA approach in practice, which empirical research constitutes the second part of the study.

This research step belongs to the heart of methodology development. In a certain way, it can be considered as a design activity and thus shares some key features with engineering. The end product of this endeavour will be a framework that describes different steps and stages.

6.5. CASE-STUDY

The empirical perspective involves exploring how uncertainty and risk are currently treated and managed in actual decision-support and why in this way. A case-study is the preferred strategy when "how" and "why" questions are being posed about a contemporary phenomenon over which the investigators have no control[22]. It is clear that we are not interested in the "dead past", (i.e. that is when no relevant persons are alive to report, even retrospectively, what occurred), but in contemporary decision-support processes. In studying assessment practices, it is obvious that it is beyond our reach to set up "controlled experiments" or to manipulate behaviour.

Before choosing the case-study approach as the strategy for empirical inquiry, it is important to reflect on the kind of scientific conclusions that can be derived from case-study research. Case-studies in principle yield conclusions that are analytical

22 (Yin 1994)

generalisable, i.e. to theoretical propositions, and not to populations or universes (statistical generalisation). For our purpose, we are interested in insights that enable us to draw conclusions about the nature of the assessment practice in the light of our theoretical understanding of uncertainty and risk. This implies that our interest is in analytical generalisation. Evaluating our ambitions, the case-study approach seems to be the appropriate research strategy.

We decided to do one in-depth case-study instead of a series of case-studies. We realise that this implies that the conclusions may be biased by the specifics of the particular case. However, because of the fundamental character of uncertainty and risk, it is to be expected that a qualified case-study is demanding and time-consuming. In view of our purpose, it is highly important to ensure that we are able to gain a multi-dimensional understanding of actual decision support practise. This implies that in this context it is prudent to opt for one in-depth case study. The idea is that the in-depth case-study will shed some light on how uncertainty and risk are managed and analysed in practice. In view of the theoretical analysis of uncertainty and risk, it will be evaluated whether the adopted approach(es) are adequate.

We have selected the Dutch Environmental Outlooks (in Dutch: Milieuverkenningen) for our case. The Environmental Outlooks[23] are produced by RIVM, the National Institute for Public Health and the Environment, being the official decision-support institute on environmental policy. RIVM has the status of environmental planning agency (in Dutch: Milieuplanbureau). Since the publication of the first environmental outlook, well-known as "Concern for Tomorrow"[24], these environmental forecasts play a key role in Dutch environmental policy-making. The Environmental Outlook endeavour can be adequately characterised as institutionalised decision-support. The Environmental Outlooks aim to provide an analysis of the environmental and health impacts associated with a particular evolving of societal pressures (e.g. in terms of economic growth, demographic developments, and consumption and production patterns). Due to the complexity of these dynamics, the analysis is beset with uncertainty. On the other hand, by aiming to provide recommendations for environmental policy, the Environmental Outlooks touch upon the issue of societal risks. The Environmental Outlook process is generally considered to be a decision-support activity that can be characterised as Integrated Assessment. These features imply that the Dutch Environmental

23 (RIVM 1988; 1991; 1993; 1997)
24 (RIVM 1988)

Outlooks constitute a relevant case in the context of this thesis. Furthermore, RIVM's Environmental Outlooks inspired decision-support activities in other countries, at the European level[25] and even at the global level[26]. Because of this, the case of the Dutch Environmental Outlooks is also an attractive one: because it played an exemplary role in the past, this case-study is an interesting one in view of its potential for analytical generalisation.

So far, RIVM has produced four Environmental Outlooks. We propose a multiple-case approach, i.e. the four Environmental Outlooks are considered to be separate cases that are independently studied (vertical analysis). This enables to address in a second instance to question whether, and if so how, the way uncertainty and risk are dealt with changed over time (horizontal analysis). The case-study will comprise[27]: i) document analysis, ii) interviews with the analysts involved in the Environmental outlook process, iii) a focus group with the interviewees and some additional RIVM executives to check the conclusions in an interactive manner, and iv) questionnaires among a broader group of RIVM analysts participating in the environmental assessments.

The retrospective case-study has primarily a deconstructive character. The assessment practice is deconstructed in order to assess the fundamental character of inherent uncertainty and plural risks in relation to decision-support in an empirical manner. The aim of this empirical investigation is to evaluate whether the current practise of decision-support in case of complex issues is problematic and to signify whether there is a practical need for new approaches.

6.6. EXPERIMENTING

As indicated above, the practical usefulness of the generic framework can only be explored through use. In order to explore whether the proposed framework is practically feasible, experience has to be gained with the application of this framework in an actual assessment context. Feasibility in this context implies that practitioners themselves indicate that this approach has a surplus value compared to current practise and that it can in principle be applied within the limits of their practical constraints.

25 (EEA 1995)
26 (UNEP 1997)
27 The various methods and the motivation will be discussed in more detail in Chapter 6.

In this step, the proposed method for integrated uncertainty management and risk analysis is applied to the 5th Environmental Outlooks. This prospective approach has the advantages that problematic characteristics of current practise observed in the retrospective case-study can be dealt with in a constructive manner. In this way, the thesis goes beyond superficial (easy) criticism on RIVM's practise. The case-study material enables to understand the current practise, its strengths and weaknesses, and allows to build up credibility, mutual respect and trust. Active participation of the professionals involved in the Environmental Outlook processes in the course of this research phase is a pre-requisite. Only with help of the analysts it will be able to evaluate whether, and if so in what way, the pluralistic approach lends itself to implementation in practise.

This research phase is partly methodological (i.e. drafting a case-specific version of the PRIMA framework) and partly empirical. Empirical methods used in this part of the study are a secondary analysis of the case-study interviews, a focus group with the interviewees supplemented by some senior professionals, and a participatory workshop with analysts involved in the preparation of the 5th Environmental Outlook. It is intended to use additional questionnaires at the workshop to complement the social process with individual observations, experiences and preferences.

The intended participatory process is meant to be a mutual learning exercise. The aim is that we encounter the practical criteria and boundary conditions to pluralistic decision-support, while RIVM get acquainted with an alternative approach to decision-support that enables them to manage and analyse uncertainty and risk in a way that is more in accordance with theoretical and epistemological insights. This intention has become quite opportune in the course of the research described in this thesis, due to a public debate on the way RIVM is dealing with uncertainty in their decision-support endeavours[28].

We have to be careful with the conclusions that can be drawn about feasibility, because the outlined research approach implies a limited group of practitioners will be involved all employed by the same the decision-support institute.

28 See Chapter 6 and (van Asten 2000).

6.7. EVALUATION

The experiences gained will enable us to improve the proposed framework. The experiences in the empirical phase of the research thus feed back into the proposed framework, either in terms of improvement and refinement, or in terms of specifying critical aspects of the assessment context that guides some specific implementation choices, or by concluding that the proposed framework is a theoretical ideal that has nothing to offer to the practise of decision-support.

This last research phase will involve a critical evaluation in which the strengths and weaknesses of the proposed approach for Integrated Assessment are addressed. With regard to the latter, it is worthwhile to explore whether and in what way the proposed approach can be used in a complementary way with existing assessment methods, and it is essential to evaluate if this proposed approach in principle elevates the quality of Integrated Assessment.

7. Structure of the book

It is difficult to reflect the cyclical and iterative nature of our research into the most linear form of communication, i.e. a book that is supposed to be read from the beginning till the end. Nevertheless.... Where this first Chapter discusses the research philosophy and the research approach, Chapter 2 sets the scope of the thesis by providing a state-of-the-art overview of Integrated Assessment in terms of current practises and challenges for the future.

As argued above, uncertainty and risk can be considered as two sides of the same coin. It depends on the perspective of the reader which angle s/he prefers. It turned out to be a mission impossible (and probably a wild-goose chase) to integrate the two modes of thinking into one theoretical overview. For that reason, we have chosen to produce two variants of Chapter 3, i.e. one reasoning from the concept of uncertainty (Chapter 3A) and the other from the notion of risk (Chapter 3B). The first is supposed to be primarily of interest for IA modellers and interested natural scientists, where the second one is expected to comply initially with the social scientists in Integrated Assessment and decision-makers' conceptualisations. Both chapters result in theoretical criteria for addressing and communicating uncertainty and risk in Integrated Assessment. Notwithstanding the fact that the variants share the same conclusions, they differ, so it may be interesting to read both after all.

In Chapter 4 the relationship between uncertainty and risk is explored in order to assess how the two notions can supplement each other. The theoretical criteria that result from the previous Chapters, i.e. pluralism, participation and robustness, are studied in more depth and the interlinkages between these criteria are explored in order to provide a basis for crystallising the ideas. The theoretical endeavour in this and the previous chapters then culminates into defining integrated uncertainty management and risk analysis in a way that is theoretically sound.

In line with the theoretical criteria and conditions discussed in the previous part of the thesis, in Chapter 5 a pluralistic framework for integrated uncertainty management and risk analysis is proposed, referred to as the Pluralistic fRamework for Integrated uncertainty Management and risk Analysis (PRIMA). The proposed stages and steps are discussed as concrete as possible. The aim is that this general framework can be used as a kind of 'ideal plan' that inspires and challenges practitioners to set up pluralistic assessment processes tailored to their specific case and circumstances.

The second part of the thesis has an empirical flavour and concentrates on the case of the Dutch Environmental Outlooks. Chapter 6 describes the background and introduces the approach followed in the empirical research. Chapter 7 reports the results of the retrospective case-study. It will assess how uncertainty and risk are dealt with in the previous Environmental Outlooks, and whether this approach is problematic. Chapter 8 summarises the experiences with the first phases of the PRIMA in the context of the 5th Environmental Outlook process. It will evaluate the practical constraints and challenges associated with putting uncertainty and pluralism at the heart of the assesment job.

Chapter 9 closes the thesis with concluding remarks and a discussion on decision-making on complex issues in the light of the insights gained. In doing so, the thesis hopes to communicate that there may be alternatives to muddling along.

It is our intention that this thesis may serve as a kind of manual for pluralistic integrated assessment.

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Integrated Assessment[1]

Integrated Assessment (IA) has been a rapidly evolving field during the last decade. This does not imply that Integrated Assessment is something new. In an earlier publication[2], we argued that the Egyptian farmers in pre-Christian times were already performing integrated assessments. For decades, scientists have been working with decision-makers to address local and regional problems, especially in the field of environmental policy, though it was not necessarily called "Integrated Assessment". It is only recently that Integrated Assessment has been recognised as a profession in its own right and as a specific branch of scientific research. The current state can be considered as the culmination of a multi-decade process that involved both the changing nature of the issues on the societal agenda as well as the evolution of the ways these issues have been analysed by scientists and managed by decision-makers[3].

1. Key features of Integrated Assessment

Integrated Assessment is still in the phase of development in which many definitions and interpretations circulate[4]. Notwithstanding this diversity, these definitions have two elements in common, i.e. its interdisciplinary character and its decision-support aim[5]. "Integrated" conveys the message of interdisciplinarity, and "assessment" that of policy relevance[6]. "Integrated" means that the information is assembled from a broader set of domains than a single discipline. "Assessment" does not mean doing new research -although this is not excluded-, but it does mean making knowledge relevant and helpful to decision-makers[7]. IA has thus the explicit purpose to inform

1 This Chapter builds upon reviewed and published papers in which the author was involved, esp. (Rotmans and van Asselt 1996; 1999; 2000 (inpress); Rotmans et al. 1997; Rotmans and Dowlatabadi 1998; Rotmans 1998a, 1998b; Pahl-Wostl et al. 1998)
2 (Rotmans and van Asselt 1996)
3 (Toth and Hizsnyik 1998)
4 (Jaeger et al. 1997; Parson 1996b; Ravetz 1997; Rotmans and van Asselt 1996; Weyant et al. 1996)
5 (Rotmans 1998b; Tol and Vellinga 1998; Toth and Hizsnyik 1998)
6 (Tol and Vellinga 1998)
7 (Jäger 1998; Parson 1995; 1997; Toth and Hizsnyik 1998)

policy and to support decision-making. Integrated Assessment is accordingly viewed as a process, including but not restricted to its formal products, in which the scientific quality is central. Taking this into account, IA can probably best be described as:

> *a structured process of dealing with complex issues, using knowledge from various scientific disciplines and/or stakeholders, in such a manner that integrated insights are made available to responsible decision-makers.*

IA thus involves an interdisciplinary process of gathering, combining, interpreting and communicating knowledge from diverse scientific disciplines and knowledge domains to allow a better understanding of complex phenomena. The aim is to analyse and explore past, current and future developments in terms of plausibility, desirability and feasibility. Integrated assessments should have added value compared to insights derived from disciplinary research. An integrated approach ensures that key interactions, feedbacks and effects are not inadvertently omitted from the analysis. The implicit conviction is that some kind of synergy will emerge from the integrative process. In a way, Integrated Assessment can be considered as a form of policy analysis[8] applied to particularly complex societal problems.

Integrated Assessment attempts to shed light on complex issues by illuminating different aspects of the societal issue of concern: from causes to impacts, from options to strategies. Integrated assessments thus involve a scale of aspects and a set of intricate interlinkages[9]. IA aims to create a more holistic picture by integrating the separate components into one framework[10]. A holistic perspective presupposes that there are manifold causal relationships between different hierarchical levels, as opposed to a reductionist model in which cause-effect chains are uni-directional (see Figure 1)[11]. Furthermore, a holistic approach addresses multiple dimensions, while a reductionistic one is usually restricted to a single dimension.

Although participation of stakeholders is not a necessary prerequisite, the conviction in the IA community has grown that participation of stakeholders is a vital element in IA[12]. The engagement of non-scientific knowledge, values and preferences into the IA process through social discourse will improve the quality of IA by giving access to practical knowledge and experience, and to a wider range of perspectives and options. Communication should be at the very heart of IA. Integrated Assessment aims to be an iterative, continuing process, where integrated

8 See, for example, (Majone and Quade 1980; Weimer and Vining 1989; Parsons 1995; Quade and Carter 1989)
9 (Kates et al. 1985)
10 (Rotmans 1990; 1998a)
11 (Rotmans 1998a)
12 See, for example, (Cohen 1997; Rotmans and van Asselt 1996; Funtowicz and Ravetz 1994; Jäger 1998; Kasemir et al. 1999b; Parson 1997; Tol and Vellinga 1998; Toth and Hizsnyik 1998)

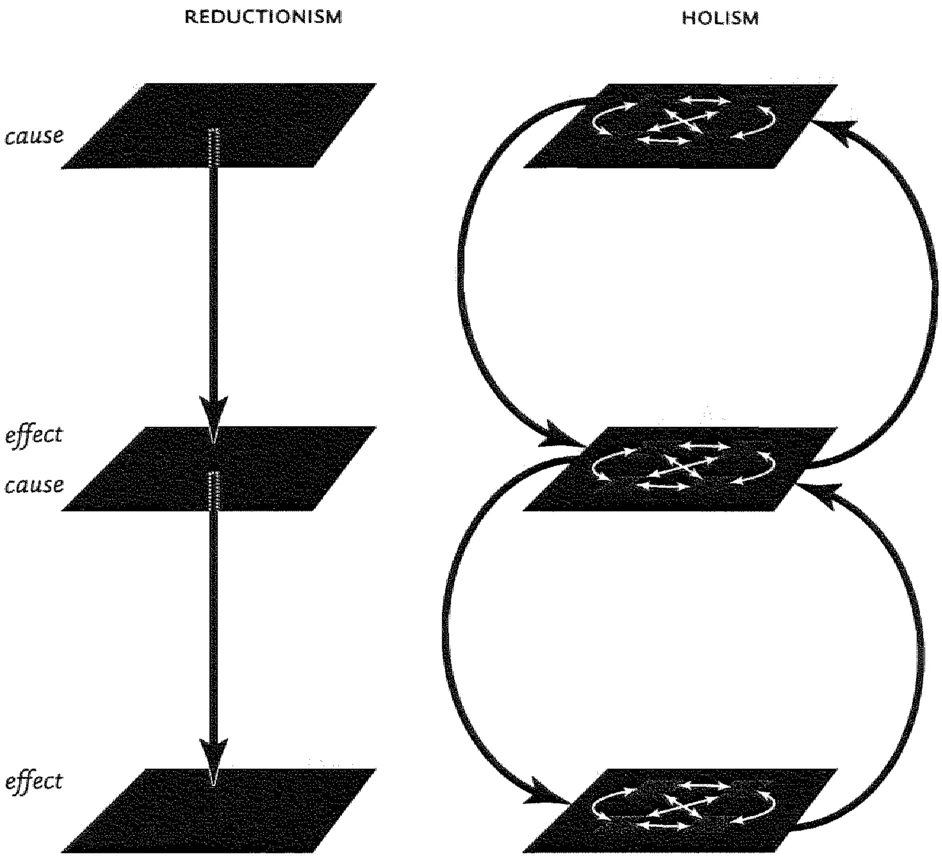


FIGURE 1 Holism versus reductionism

insights from the scientific and stakeholder communities are communicated to the decision-making community, and experiences and learning effects from decision-makers form an input for scientific and social assessment. IA aims to be a forum in which interdisciplinary science outlines the state-of-the-art knowledge pertaining to the issue of concern, including the inherent uncertainties, value judgements and preferences. The stakeholders indicate what is desirable and acceptable, and what is not. They can also provide knowledge other than that of the 'experts'. Ideally, together they come out with visions and recommendations that satisfy societal constraints. This does not necessarily mean consensus: the integrated assessments can also highlight conflicts and differences of opinion. The visions and insights resulting from this participatory process may then facilitate the decision-making processes.

The ideal picture of Integrated Assessment is a cyclic and participatory process comprising various parallel actions and a wide diversity of actors as summarised

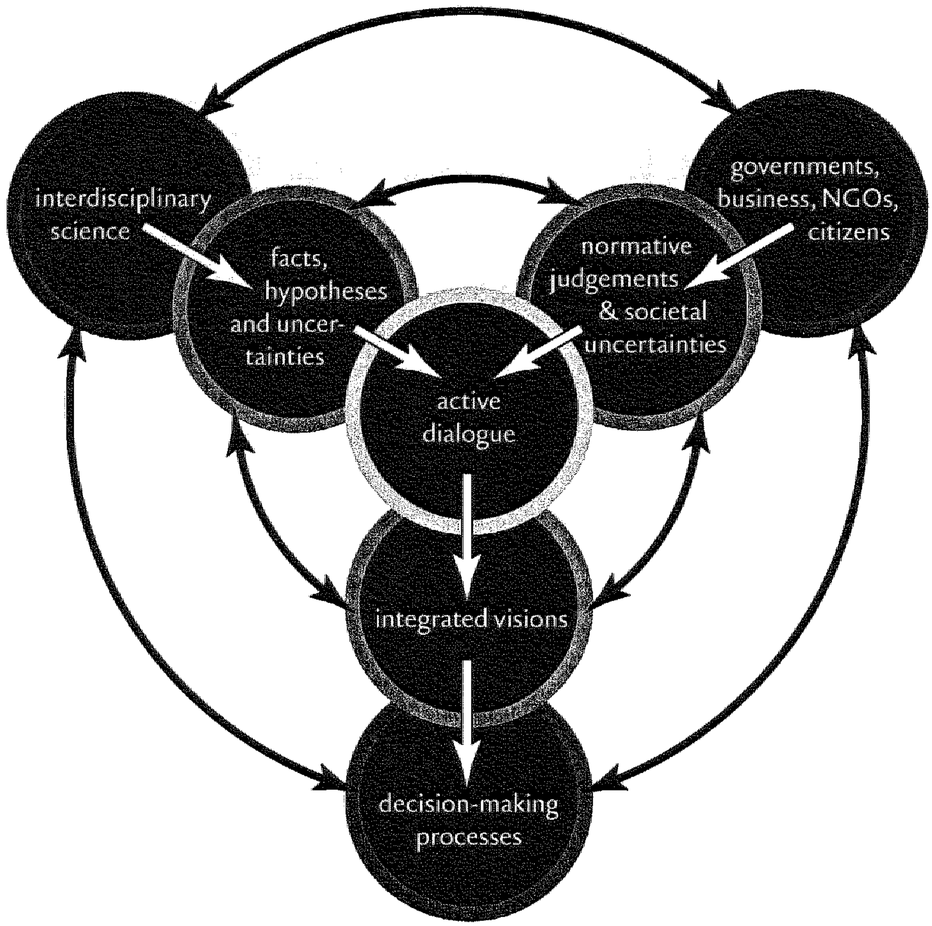


FIGURE 2 IA process

in Figure 2. The two pillars are i) the participation of scientists in the form of interdisciplinary research, and ii) the participation of societal actors, such as the policy community, the business community, non-governmental organisations (NGOs) and the general public.

IA has a number of advantages. In general terms, it may help to:

- put a complex problem in the broader context of other problems, by exploring the interrelations of the specific problem with other issues
- identify major uncertainties in the underlying cause-effect chains
- set priorities for research topics by identifying and prioritising decision-relevant gaps in knowledge
- shape the decision-making agenda
- assess robust response strategies to complex problems

There is a growing interest in Integrated Assessment, both from the scientific and from the policy side. The scientific interest is, for example, revealed by the initiation in 1996 of a new journal called 'Environmental Modelling and Assessment', with Integrated Assessment as a flourishing section, the establishment of the European Forum for Integrated Environmental Assessment (EFIEA)[13] in 1998 in which over 30 European research institutes participate, the first informal initiatives to set up a global society for Integrated Assessment, and the increasing number of research programs, workshops, seminars and conferences devoted to Integrated Assessment[14].

There is a growing recognition for Integrated Assessment in the policy realm. In the United States, the notion of IA is used to scope the governmental nationwide programme on climate change impacts[15]. In Europe, the policy interest in Integrated Assessment is primarily clear at the European level. The European Environment Agency (EEA) characterises its activities as Integrated Assessment[16], and the European Commission[17] sponsors and stimulates a number of IA endeavours, ranging from advanced study courses[18], R&D programs, conferences, to the above mentioned EFIEA. In the context of policy interest in IA, it is important to note that decision-makers participate in EFIEA alongside scientists.

Integrated Assessment is not a panacea for all societal problems. As argued above, it is in principle pre-eminently suitable for complex problems. Furthermore, it is important to realise that notwithstanding this growing interest, Integrated Assessment is at the moment more a research principle than an established approach. Many of the methods employed are relatively immature and the application of established methods in IA is not straightforward. There are some good examples of studies which can guide new endeavours, however, a kind of textbook that enables us to learn (and to teach) Integrated Assessment is lacking. At the moment, the art of Integrated Assessment is mainly tacit knowledge[19]. There is a clear need for codes of practise to set up and assess IA processes, and for quality rules to design and

13 (Tol and Vellinga 1998) ; website: http.www.vu.nl/english/0_0/instituten/IVM/projects/research/efiea/

14 For example, the sessions and plenary lectures on Integrated Assessment in the context of: the Open meetings of the International Human Dimensions of Global Change Reserach community (Duke, 1995; Vienna, 1997; Tokyo, 1999), the annual EMF15-summer-workshops at Snowmass since 1994, the Scope-workshop on ecological economics and integrated assessment (Boston, 1996), the European conference on Integrated Assessment in Toulouse (1996), the large IPCC conference on Integrated Assessment modelling, (Tokyo,1997), the symposium of the American Association of Geographers sponsored by, among others, the National Science Foundation (Washington, 1998), the meeting of the International Society for Ecological Economics (Santiago di Chili, 1998) a workshop organised by the Dutch Council for Environmental and Nature Research (RMNO) (the Netherlands, 1999) on Integrated Assessment.

15 US Global Change Research Programme (see http://www.usgcrp.gov/)

16 Building upon the presentation of Mr. Stanners of EEA at the first VISIONS Euroworkshop (Anastasi et al. 1999b)

17 Esp. within the Fifth Framework Programme on Environment and Climate, DG XII.

18 For example, the 1999 advanced study courses 'Tools and methods for Integrated Assessment' (Maastricht, the Netherlands) and the course 'Decision tools and processes for Integrated Environmental Assessment' (Barcelone, Spain).

19 (Brand 1994)

evaluate the products delivered by IA endeavours. Transparency is needed, so that the process and the products can be judged by an extended peer community[20], involving other IA practitioners, disciplinary experts, users and affected publics. Without such maturation, IA is doomed to degenerate to a (popular) buzzword.

The aim of this Chapter is twofold. On the one hand, it gives an overview of the state-of-the-art in Integrated Assessment. On the other hand, it scopes the thesis by identifying the crucial methodological challenges that IA currently faces. To that end, this Chapter first discusses the policy dimension of IA. Then a taxonomy to characterise IA-studies is proposed. In the following section, IA methodology is discussed in more depth, and ideas are explored how the various methods could be used in a fruitful, complementary manner. The issue of quality is crucial, both in terms of the state of the art as well as methodological challenges. This Chapter concludes with identifying key challenges that clarify the ambitions this thesis aims to fulfil.

2. The policy dimension of IA

It is the explicit aim of IA to assist decision-makers and to facilitate decision-making. That does not necessarily imply that it has done so in the past. Good intentions do not guarantee success. IA has contributed to the climate change debate in exploring impacts of climate change, mitigation and abatement strategies, issues in co-operative implementation, the likely equity effects of candidate policies, and complicating factors such as aerosols[21]. It has continuously underpinned the policy discussion on the questions: when do we have to act, what kind of action and in what pace? IA has also proven to be useful in the field of acid rain, where the IA model RAINS played a guiding and supportive role in the negotiating process of emission reductions of SO_2[22]. But little understanding exists regarding what sorts of assessment processes have been most effective, or why others have failed[23].

The Global Environmental Assessment project[24] is the first systematic endeavour to evaluate the impact of integrated assessments and to learn from accumulated experience about the policy dimension of IA. The questions studied in the GEA project are:

20 A concept introduced and put forward by Funtowicz and Ravetz, see for example (Funtowicz and Ravetz 1992a; 1992b; 1993a; 1993b; 1994).
21 (Rotmans 1998a)
22 (Hordijk, 1991a, 1991b)
23 (GEA 1998)
24 (GEA 1997, 1998) (Clark et al. 1997) (Clark and Dickson 1998)
See also http://environment.harvard.edu/HERO/wrapper/pageid%3Dgea%

- Why are some kinds of assessments performed, while others are not?
- How have assessments actually affected society's understanding of global environmental issues and scientific research?
- Under what conditions and in what ways have assessments been able to influence preferences, behaviours and policies of significant actors?
- What makes a specific assessment credible?
- How can assessments be designed and implemented to better serve specific needs?

This project that runs until 2001 will hopefully in the end, shed clearer light on the policy dimension of IA.

On the one hand, the demand for policy relevant science to illuminate policy issues seems to be greater than ever[25], on the other hand there seems to be quite a lot of scepticism regarding the relevance of Integrated Assessment for decision-making[26]. Integrated Assessment suffers from a technocratic image. Outsiders have the feeling that the underlying thought is that if complex problems were left to rational scientists and all the irrationality associated with policy-making was eliminated, then better decisions would have been taken[27]. This image is strengthened by the harsh attacks of some social scientists[28] on the IA community in general and on IA-modellers in particular. We cannot vouch for all IA practitioners, but in our informed view the majority of the IA-practitioners does not consider, and does not even want, Integrated Assessment to be a substitute for political and decision-making processes. Integrated Assessment is generally viewed as a multi-step process that may provide a bridge between science and decision-making[29].

There is a broad literature that discusses the linkages between science and policy. Policy sciences, for example, explicitly study how political judgement can be informed by scientific expertise in view of the inherent limits to human understanding[30]. Policy science is thus concerned with the production and application of knowledge in policy. Much of this literature is relevant for IA in order to gain 'political awareness'[31] and sufficient understanding of decision-making processes. It is beyond the scope of this thesis to give a comprehensive synthesis of this scholarly literature.

25 (Clark and Dickson 1998)
26 See, for example, (Haigh 1998)
27 (Haigh 1998)
28 for example, (Darier 1999; Jasanoff and Wynne 1998)
29 ((Jäger 1998)
30 (Dror 1971; Lasswell 1971; Lindblom 1968) and compare (Hoppe 1999)
31 (Haigh 1998)

We restrict ourselves to summarising some major lessons that can be learned from that literature[32].

First, it is misleading to think that science and policy take place in two largely distinct realms. Mutual interactions between science and policy are prevalent, esp. in the field of Integrated Assessment. For example, due to personal contacts, financial ties, institutional commitments, political pressure, and scientific activists the two realms evolve into a rather seamless web[33]. Scientists are also citizens with a political opinion. These linkages create a field of tension between policy relevance and scientific mores. Integrated Assessment faces the danger of falling between two stools in lacking credibility on both sides. That this is a possibility that IA practitioners should not ignore is evident from the RIVM-case[34]. On the one hand, the policy-makers doubted whether RIVM's assessments were scientific enough, while on the other hand, scientists blamed the institute of being too involved with policy-making.

Furthermore, it is also clear that the interactions between science and policy cannot be viewed as entirely linear. The constructive, active character of scientific knowledge in decision-support, as opposed to the linear view of knowledge simply being transferred from science to policy, should be emphasised[35]. The mutual construction of science and policy can be characterised by the 'politisation of science'[36] and 'scientification of policy'. These imply that scientific research is subject to political pressures, while at the same time, science has 'cognitive authority'[37] in, and privileged access to, policy domains.

Another important lesson from this body of literature is that the relevance of Integrated Assessment differs over the course of the policy process. Although in practise the policy process is not a smooth sequence in stages, steps or phases[38], it is useful to think in terms of a "policy life cycle"[39] in order to illuminate the contribution IA in principle can have in the decision-making process (see Figure 3). Roughly speaking, four phases can be distinguished: i) ignition, ii) strategic policy formulation, iii) political decision-making and iv) implementation. Haigh[40] argues that in the first phase the public opinion plays a crucial role in raising the temperature

32 See also (Jäger 1998)
33 Compare (van Asselt 1994)
34 See Chapter 6 and Appendix 1.
35 E.g. (Sabatier 1987; Van Eijndhoven and Groenewegen 1991)
36 (Weingart 1983)
37 (Hoppe 1999)
38 See, for example, (Jäger 1998; Kingdon 1984)
39 (Winsemius 1986)
40 (Haigh 1998)

sufficiently for politicians to feel able to act. Rotmans[41] argues that Integrated Assessment can facilitate this consciousness-raising process, either by helping to identify the problem or by helping to excite public conscience. It is generally accepted that Integrated Assessment can play a vital role in the policy formulation phase. Tol and Vellinga[42] argue that one of the important contributions IA can make to the decision-making process lies in defining the problem and spelling out the various views on the problem at stake. The policy formulation phase necessitates an assessment of the issue at stake in order to figure out the characteristics of the problem and what strategies would address the problem and optimally use opportunities. In the last phases, i.e. the political decision-making and the implementation phases, there is a greater need for detailed sector- or theme-specific studies, that provide an in-depth study of specific decision options, than for broad integrated studies. In Rotmans et al.[43], we argued that the integrated character of the ultimate decision options is in principle guaranteed by the integrated feature of the preparing phases.

There is a risk that, notwithstanding the actual need for science-based expertise in decision-making, the policy dimension of IA primarily serves to legitimise the work of the IA community to outsiders. The key challenge for Integrated Assessment is effectively facilitating and supporting policy-oriented learning[44]. In order to understand what are the necessary features of IA, both evaluations of previous

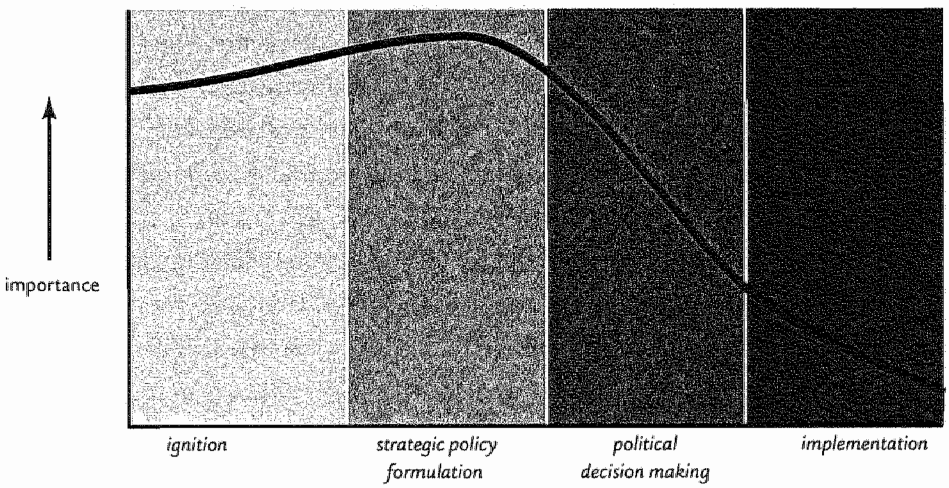


FIGURE 3 Integrated Assessment related to stages in policy making

41 (Rotmans 1998a)
42 (Tol and Vellinga 1998)
43 (Tol and Vellinga 1998)
44 e.g. (Weyant et al. 1996), (Rotmans and Dowlatabadi 1998), (Parson and Fisher-Vanden 1997) For literature on policy-oriented learning see (Sabatier and Jenkins-Smith 1993)

assessments, and the involvement of policy scientists and decision-makers in the constituent debates in the IA community are pre-requisites. In that context, the IA community is currently following a promising avenue: the European Forum for Integrated Environmental Assessment (EFIEA) has the explicit aim to address such issues and to bring together IA practitioners, policy scientists and decision-makers.

3. Taxonomy of IA studies

The variety of assessments that are or can be characterised as 'Integrated Assessment' is rather heterogeneous. Most efforts to characterise this variety are outdated[45], because they were restricted to IA modelling studies. In order to characterise the whole spectrum, it is useful to identify major differences along the following dimensions:

- research perspective
- focus
- adopted method

With regard to the dimension ***research perspective***, the distinction between supply-driven and demand-driven is crucial (see Figure 4)[46]:

- In *supply-driven* IA studies, a group of scientists anticipates the societal relevance of a complex theme. The scientific problem definition frames the assessment.
- *Demand-driven* IA is a participatory endeavour in which decision-makers and stakeholders (and scientists) explore which complex issues are highly relevant to a future society. The resulting common agenda and exploratory assessment then frames the integrated assessment.

The major difference between the two thus involves "who is defining the problem?" The majority of IA studies so far have been supply-driven. The most prominent example is Integrated Assessment of climate change, which was dictated at the start by the (multi-) disciplinary research agenda, rather than the policy agenda.

The focus of IA studies can also be used as distinctive feature. We propose to distinguish between global IA studies, regional IA studies and theme-specific IA studies. Global integrated assessments address the world as a whole, regional IA studies[47] concentrate on a particular geographical area, such as a world region, a

45 e.g. (Weyant et al. 1996; Rotmans and Dowlatabadi 1998; Parson and Fisher-Vanden 1997)
46 (Rotmans 1998b)

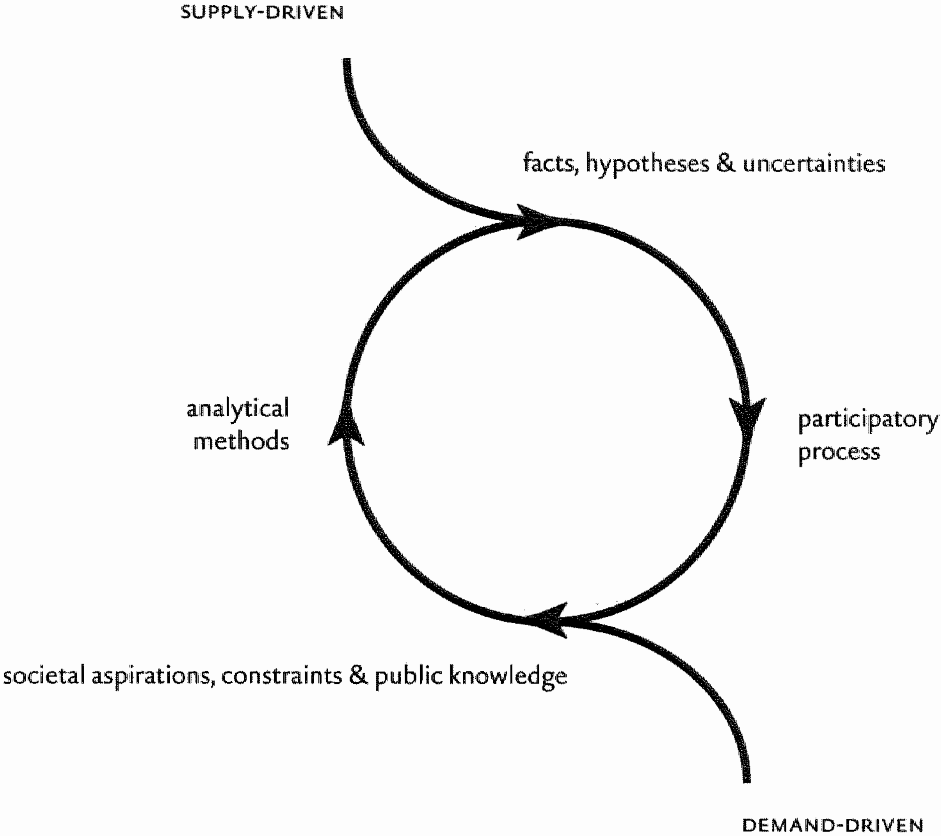


FIGURE 4 Demand-driven versus supply-driven IA

country, a city or a river basin, and theme-specific integrated assessments focus on a particular issue or sector like acidification or energy.

Thus far, most IAs operate on the global level. There have been only a few examples of integrated regional studies, most of which are climate impact studies, such as the MacKenzie Basin impact study[48], the MINK impact study[49], the regional US impact study[50] and the CLEAR-study[51]. A notable exception is the integrated study on the future of Canada[52]. Where global assessments are useful to create a rough, but holistic picture, working at the regional scale level has two advantages: i) IAs can focus on concrete issues at stake; and ii) IAs can be made geographically-

47 Also referred to as focused (compare Anastasi 1997).
48 (Cohen 1993)
49 (Rosenberg 1993)
50 (Mendelsohn et al. 1996)
51 (Cebon et al. 1998)
52 (Robinson 1996)

explicit, which allows for analysing trade-offs between problems, sectors, resources and scale levels.

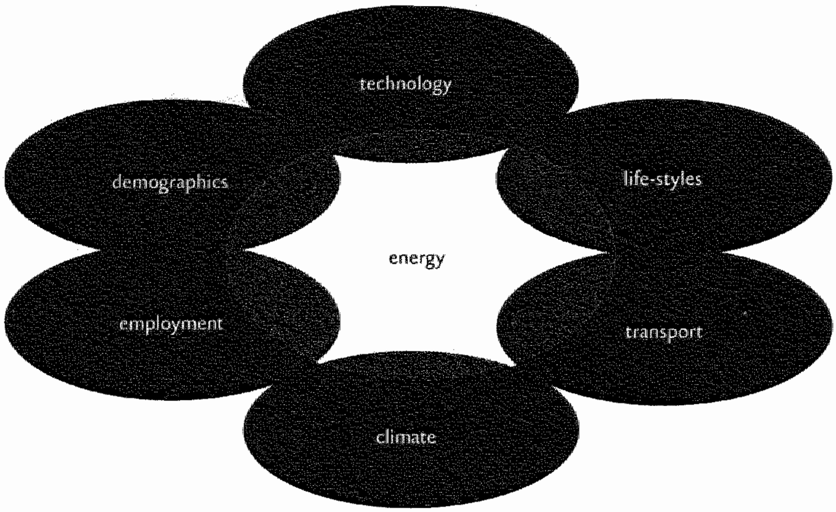


FIGURE 5A Visualisation of theme-specific IA

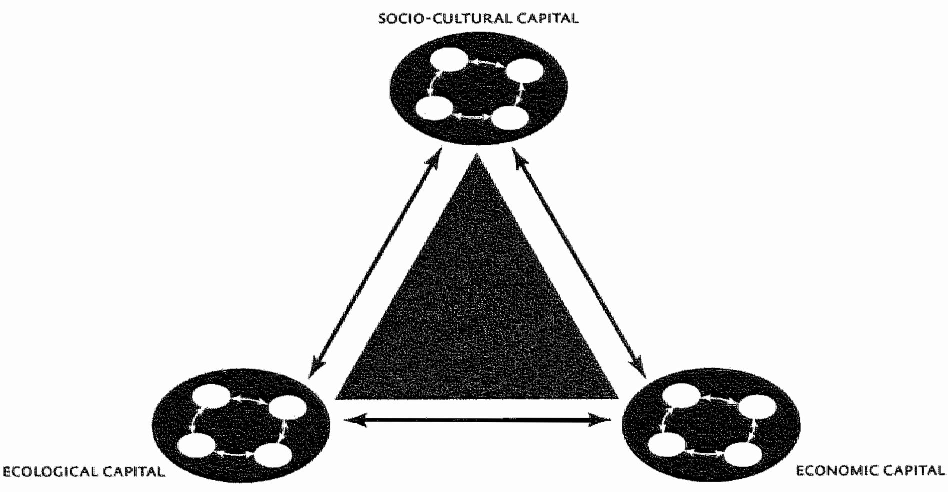


FIGURE 5B Visualisation of general IA

The majority of current IA-studies are theme-specific; most being devoted to climate, and some to acidification. The difference between theme-specific and general integrated assessments is visualised in Figure 5[53]. Examples of general integrated assessments are studies addressing global change and/or sustainable development[54].

The advantage of a theme-specific approach is that it has a clear focus and it is easier (although not necessarily simple) to define the targeted problem. Integrated assessment in this context means evaluating the whole cause-effect chain of the problem from a synoptic perspective. For example, in the case of acidification this implies that an integrated assessment should cover the pathway from economic and industrial factors affecting emissions, to the ecological impacts resulting from emissions[55]. In the case of climate change, an integrated assessment should comprise the full cycle of cause-effect relationships ranging from socio-economic development, the associated greenhouse-gas emissions, atmospheric concentrations of these substances, to the resulting climate change, the induced biophysical impacts, economic damages and societal and ecological risks[56]. Other examples[57] of complex themes addressed by IA-studies are biodiversity[58], human health[59] and water[60], and IA-projects are currently under way addressing tourism[61], transport[62], and desertification[63].

The distinction between regional and theme-specific studies is not mutually exclusive; there are regional, theme-specific studies. However, in practise there is a clear difference between regional theme-specific studies and theme-specific regional studies. The first will be classified as regional studies and the latter as theme-specific. The ESCAPE-model6[4] is a climate model, but with the specific purpose of investigating effects and possible response strategies for Europe. The RAINS model has Europe as its scale level, however, it is first and foremost an integrated study on acidification.

Another common way to characterise IA studies is by means of the adopted ***method***. Various techniques have been and are used in Integrated Assessment[65], e.g.

53 See for a description of the triangular model ICIS (1999).
54 see, for example, (Robinson 1996; Rotmans and de Vries 1997 and Rotmans and van Asselt 2000 (in press)) Compare the research agenda of Industrial Transformation (IHDP 1999) which can also be considered as a proposal to carry out a general integrated assessment (although it is not explicitly named so).
55 (Alcamo et al. 1990)
56 (Rotmans 1990; Dowlatabadi and Morgan 1993a; Toth 1997)
57 Compare (Rotmans 1998a)
58 (Rotmans et al. 1994)
59 (Martens 1997; McMichael 1997)
60 (Hoekstra 1998), see also (Rotmans 1998a) and (Middelkoop et al. 1998)
61 (Rotmans and Dowlatabadi 1998).
62 (EFIEA and IEEP 1998)
63 (Mairota et al. 1998)
64 (Rotmans et al. 1994)
65 See (Parson 1996a; Rotmans 1998a; Weyant et al. 1996)

i) multidisciplinary expert panels, ii) collaborative interdisciplinary research teams who exchange and share knowledge across their fields, iii) modelling, iv) individual essays by authors with multidisciplinary competence, v) scenario-studies and vi) participatory methods. In general, two types of Integrated Assessment methods are distinguished[66]: analytical methods[67] and participatory methods[68].

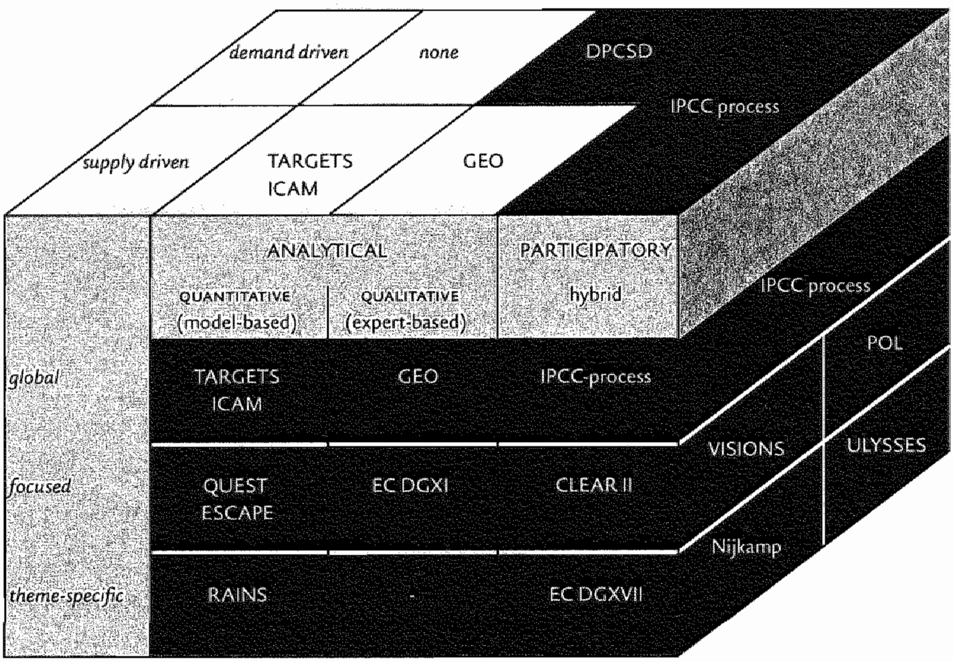


FIGURE 6 3-dimensional taxonomy of IA-studies with some examples[69]

66 (Rotmans 1998b; Tol and Vellinga 1998; Toth and Hizsnyik 1998)

67 Also referred to as expert-based methods or modelling methods.

68 Also labelled as interactive or communicative methods.

69 Legend: TARGETS: (Rotmans and de Vries 1997); ICAM: (Dowlatabadi and Morgan 1993b); QUEST: (Biggs et al. 1998 (in press); Rothman et al. 1998 (in press)); ESCAPE: (Rotmans et al. 1994); RAINS: (Alcamo et al. 1990); DPCSD: (UN-DPCSD 1997); GEO: (UNEP 1997); EC-DGXI: (EC-DGXI 1997); IPCC-process: (IPCC 1990; IPCC 1992; IPCC 1994; IPCC 1996a; IPCC 1996b; IPCC 1998); CLEAR: http://CLEAR.eawag.ch/; EC-DGXVII: (EC-DGXVII 1996); VIS.: See Box 2; Nijkamp: (Nijkamp et al. 1997); POL: (ICIS 1999) (Rijkens 1999); ULYSS.: See Box 1

Analytical methods are generally rooted in the natural sciences. What they share is their provision of analytic frameworks for representing and structuring scientific knowledge in an integrated manner. They have the common aim of collecting expert judgements of scientists whose knowledge and expertise span the domains relevant to the issue(s) of concern and to gather these insights into an integrated picture. Knowledge elements from various disciplines are combined in an analytical framework, to assess the socio-economic and environmental consequences of human activities. The group of analytical methods is reasonably well defined and basically includes model-based analysis and scenario studies. Analytical methods can result in either quantitative or qualitative assessments. The first type of assessments is model-based. To make a distinction between qualitative assessment resulting from participatory processes and those resulting from analytical work, the latter can be characterised as expert-based assessments.

Participatory methods stem from the social sciences, in particular sociology, anthropology and geography. Participatory methods explicitly involve non-scientists in the assessment effort. The group of participatory methods involves a plethora of techniques, varying from expert panels, in-depth interviews, to gaming, policy exercises and focus groups. In its extreme form, the whole IA is considered to be a participatory process. What these participatory methods have in common is the aim to set up stakeholder involvement. Participatory techniques are particularly relevant for problem structuring, communication and in analysing qualitative aspects.

Figure 6 provides some examples of different types of IA-studies along the lines of the above distinctions.

4. IA methodology[70]

Because neither a unifying theory nor clear recipe for integration is available, the choice of a method or a combination of methods is crucial in any integrated assessment. For that reason we will discuss the two classes of methods - analytical and participatory methods - in some more depth. We will furthermore discuss how these methods could be used in a complementary manner.

70 This section builds upon (Rotmans 1998b; Rotmans and van Asselt 2000 (in press)).

4.1. ANALYTICAL METHOD: IA MODELLING

Integrated Assessment models are formal, quantitative frameworks that describe as much as possible of both the cause-effect relationships of a specific issue (vertical integration) and the interlinkages and interactions among different issues (horizontal integration). Current projects in IA modelling build on a tradition started in the early seventies by the Club of Rome[71]. In this context the first global computer simulation model, the World3 model, was developed. This model describes links between the major social and physical components of the world system. This model inspired the development of numerous global models, focusing on resource depletion, population and pollution[72].

The next generation of IA models explicitly addressed environmental issues. The first among these models emerged in the late 1970s and the early 80s from earlier energy modelling[73]. Meanwhile, the RAINS model of acidification in Europe was developed[74]. The phenomenon of global climate change has prompted the development of a new series of IA models[75]. The first model that comprised a fully integrated representation of climate change from sources to impacts was the IMAGE 1.0 model[76]. Since then approximately 40 IA models of climate change have been developed[77].

There is general agreement that two types of IA models can be distinguished. Weyant et al.[78] classify them as:

- policy optimisation models, which try to optimise key policy variables given certain policy goals;
- policy evaluation models which try to evaluate the environmental, social and economic consequences of specific policy strategies.

However, a number of IA-models that are characterised as policy evaluation models can also be used for optimisation experiments (e.g. RAINS). The two schools of modelling can also be classified according to their origins[79]:

- ***Macro-economic oriented school***, that represents simple, fully parameterised decision-analytic formulations of a policy-relevant complex problem;

71 (Meadows et al. 1972a; Meadows et al. 1972b)
72 A review of the first decade of IA modelling avant-la-lettre can be found in (Meadows et al. 1982)
73 (Edmonds and Reilly 1985; Nordhaus 1979).
74 (Alcamo et al. 1990)
75 The first steps to an integrated model of climate change were taken by (Lashof and Tirpak 1989; Mintzer 1987; Rotmans 1986)
76 (Rotmans 1990)
77 (van der Sluijs 1997); Recent overviews of IA modelling activities in the field of climate change can be found in (Rotmans and Dowlatabadi 1998), (Schneider 1997) and (Parson and Fisher-Vanden 1997). Comparison and review of IA models of climate change are performed in the context of Energy Modelling Forum (EMF) ((Beaver 1993) and (Gaskins and Weyant 1993)).
78 (Weyant et al. 1996)
79 (Rotmans 1998a; Rotmans and Dowlatabadi 1998)

- ***Biosphere oriented school***, that represents a more comprehensive, process-oriented description of a policy-relevant complex problem.

Most macroeconomic-oriented models are neo-classical models based on an equilibrium framework, using traditional economic concepts regarding optimisation and capital accumulation, largely ignoring environmental dynamics. The most well-known example of the macro-economic oriented school is the DICE model[80]. Two variants have been developed later on, namely a regionalised version RICE[81], and another with uncertainty ranges in key parameter values, i.e. PRICE[82]. Other well-known examples of this school are the CETA model[83] and the MERGE model[84].

Biosphere-oriented models, however, focus on a systems-based description of the geophysical and biogeochemical processes and feed backs, but do not adequately represent the socio-economic system. Representatives for the biosphere-oriented school of IA modelling are the IMAGE models (IMAGE 1.0[85], IMAGE 2.0[86]). Another model in this school is AIM[87].

Meanwhile, some attempts are being made to combine the best of both worlds, yielding a hybrid of the two categories above. These hybrid models may contain a detailed general equilibrium model for the economy that interacts with a dynamic environment, such as GCAM[88] and the MIT model[89]. They may also use complexity and uncertainty as guiding modelling principles for both the human and natural system, of which ICAM[90] and TARGETS[91] are examples. Therefore, the macro-economic IA models and the biospheric IA-models can be considered as polar ends of a continuum populated by many IA modelling efforts, with in the middle IA models in which the various aspects are treated on an "equal footing"[92].

Any attempt to fully represent a complex issue and its numerous interlinkages with other issues in a quantitative model is doomed to fail. Nevertheless, even a simplified but integrated model can provide a useful guide to complex issues and complement disciplinary models. Among the major strengths of IA models are:

80 (Nordhaus 1992; 1994)
81 (Nordhaus and Yang 1995)
82 (Nordhaus and Popp 1997)
83 (Peck and Teisberg 1992)
84 (Manne et al. 1994)
85 (Rotmans 1990)
86 (Alcamo 1994) (Leemans et al. 1998)
87 (Morita et al. 1994; 1995)
88 (Edmonds et al. 1994b)
89 (Prinn et al. 1996)
90 (Dowlatabadi and Morgan 1993a)
91 (Rotmans and de Vries 1997)
92 (Tol and Vellinga 1998)

- ***tracing assumptions to conclusions***: whereas humans are relatively weak in making large numbers of calculations, this is exactly the area where computers excel.
- ***exploration of interactions and feedbacks***: explicit inclusion of interactions and feedback mechanisms between subsystems can yield insights that disciplinary studies cannot offer;
- ***flexible and rapid simulation tools***: the simplified nature and flexible structure of IA models permit rapid prototyping of new concepts and scientific insights;
- ***consistent frameworks to structure scientific knowledge***: critical uncertainties, gaps in scientific knowledge and weaknesses in discipline-oriented expert models can be identified;
- ***tools for communication***: IA models can[93] be useful tools for communicating and discussing complex scientific issues among decision-makers, disciplinary scientists, stakeholders, and the general public.

Obviously, IA models also have limitations and weaknesses, some of which are insolvable, because they are inevitable mirror-drawbacks of some of the advantages. Other disadvantages are in principle surmountable. Among the most important current deficiencies are:

- ***high level of integration***: many processes occur at a micro level, far below the spatial and temporal aggregation of current IA models;
- ***limited calibration and validation***: the high level of aggregation implies an inherent lack of empirical variables and parameters, and current data sets are often too small and/or unreliable to be able to apply;
- ***inadequate treatment of uncertainties***: IA models are prone to an accumulation of uncertainties and to a variety of types and sources of uncertainty;
- ***absence of stochastic behaviour***: most IA models describe processes in a continuous, deterministic manner, excluding extreme conditions that may significantly influence the long-term systems behaviour.

The latter two can in principle be overcome by innovations in the modelling practise. These weaknesses will be addressed in detail in the following Chapter.

93 It should be noted that most of the current model interfaces are too complex or the models too slow to be useful in an interactive way, and also that most current IA-models are not explicitly designed with non-scientific users in mind. In practise this implies that a new generation of IA models seem to be necessary to realise the potency of IA models as broad communication tools (see ULYSSES experience, Box 1).

4.2. ANALYTICAL METHOD: SCENARIOS

Thinking about the future is often done by means of scenarios. Theoretically speaking, scenarios are hypothetical sequences of events, constructed for the purpose of focusing attention on causal processes and decision points[94]. In practice, scenarios are coherent descriptions of alternative images of the future, created from mental maps or models that reflect different perspectives on past, present and future developments. Ideally, they should be internally consistent, plausible and recognisable stories exploring a path into the future[95]. Although many scenario definitions exist, most of them share the following characteristics:

- scenarios are ***hypothetical***, describing possible future pathways;
- scenarios describe ***processes***, representing sequences of events over a period of time;
- scenarios consist of ***states, events, actions and consequences*** which are causally related;
- scenarios start from an ***initial state*** (usually the present), depicting a final state at a fixed time horizon.

Scenarios are perhaps most effective when seen as a powerful tool to broaden perspectives, raise questions, and challenge conventional thinking. However, that is not the way they have been used. Many scenarios developed in the past had a rather dogmatic and predictive character. Looking back at developments over the past 25 years, however, one clear lesson can be learned from scenario-based assessments made in the 1970s: dogmatic predictions regarding the earth's future are unreliable and can be politically counterproductive[96].

Nowadays, it is generally accepted that scenarios do not predict, but rather paint pictures of possible futures and explore the different outcomes that might result if basic assumptions are changed, for example, regarding policy interventions. So the only relevant questions that scenarios can address are not whether an event will happen in the future, but how might it happen, what we could do if it does and what we might be able to do to prevent it from happening.

During the last decade, this increased understanding has resulted in a number of well-thought out scenario exercises, which have proven their value in a particular

94 (Kahn and Wiener 1967)
95 see also (Anastasi 1997)
96 (UN-DPCSD 1997)

context[97]. For example, the IPCC[98] has developed two sets of scenarios, which illustrate the impacts of specific developments in population growth, energy use and technology in terms of resulting emissions and atmospheric concentrations of greenhouse gases and its associated patterns of climate change. Currently a new scenario-process is well under way[99]. Shell[100] has produced a number of world scenarios, where three alternative societal visions have been formulated and weighted against their economic robustness. The World Energy Council[101] developed global scenarios focusing on energy that underlined the importance of diversity of supply, assuming shifts in the energy system due to autonomous technological developments and market forces and not through government interference. The Global Scenario Group has recently produced three classes of global scenarios, based on alternative social visions[102]: Conventional Worlds, Barbarisation, and Great Transitions, described in terms of economic scale, equity, environmental quality, technological change, and degree of social and geopolitical conflict. One of the more comprehensive scenario studies has been undertaken by Robinson et al.[103], sketching a desirable, sustainable future for Canada in 2030, and the changes that would need to occur to let this future vision evolve. At the European scale a number of scenario studies have been performed[104], e.g. by EC-DGXI[105] resulting in narratives of European citizens in the year 2010, in the field of energy by the European Commission DG-XVII[106], and on political and institutional developments by Smith[107].

Different subdivisions of scenarios exist[108]. First, subdivision can be made between ***forecasting*** and ***backcasting*** scenarios, or ***exploratory*** versus ***anticipatory*** scenarios. Forecasting or exploratory scenarios are forward directed, i.e. they explore future consequences of a sequence of assumptions, with or without policy efforts. The majority of recent scenario studies can be characterised as forecasting exercises. Backcasting or anticipatory scenarios on the other hand, are backward directed, i.e. they start from some assumed (desired) final state, and explore the pre-conditions that could lead to this state, including a palette of strategies.

97 Apart from the examples discussed in this paragraph, it is interesting to note that the Dutch Scientific Council for the Government developed a number of scenario-studies on behalf of the Dutch government. Some examples of recent studies are: (WRR 1992; 1998) (van Latesteijn 1999)
98 (IPCC 1990; 1992)
99 See http:// sres.ciesin.org/sres/
100 (Kassler 1994)
101 (WEC and IIASA 1995)
102 (Gallopin et al. 1997)
103 (Robinson 1996)
104 For a comprehensive overview of scenario-studies for Europe during the last decade, see (van Asselt et al. 1998)
105 (EC-DGXI 1996)
106 (EC-DGXVII 1990; 1996)
107 (Smith 1997)
108 See (van Asselt et al. 1998)

Secondly, we can distinguish between descriptive and normative/targeted scenarios. Descriptive scenarios state an ordered set of possible events irrespective of their (un)desirability, whereas normative scenarios take values and interests into account. Current scenario studies mostly have a descriptive character. Some of them are normative or have normative elements, but this is usually not explicitly acknowledged.

Finally, ***trend*** and ***peripheral*** scenarios can be set out against each other. A trend scenario represents extrapolations of past and current trends, while a peripheral scenario includes bifurcations or surprises. Many recent scenario studies are hybrid, in the sense that they are neither trend nor peripheral scenarios. This has to do with the fact that they include deviations of current trends, but these anticipated changes are merely incremental.

Scenarios can in principle be useful tools to:

- ***articulate key considerations and assumptions***: scenarios can help to envision a range of possible futures if we follow a key set of assumptions and considerations;
- ***blend quantitative and qualitative knowledge***: scenarios are powerful frameworks for using both data and model-produced output in combination with qualitative knowledge elements;
- ***identify constraints and dilemmas***: exploring the future often yields indications for constraints in future developments and dilemmas for strategic choices to be made;
- ***expand thinking beyond the conventional paradigm***: exploring future possibilities that go beyond conventional thinking may result in fresh and innovative insights.

Current scenarios are also characterised by a number of deficiencies:

- ***lack of diversity***: scenarios are often developed from a narrow, disciplinary based perspective, resulting in a limited set of standard economic, technological, and to a lesser extent environmental assumptions;
- ***extrapolations of current trends***: many scenarios have a 'business-as-usual' character, assuming that current conditions will continue for decades, excluding surprises;
- ***inconsistency***: sets of assumptions made for different sectors, regions, or issues, are often not consistent with each other;
- ***lack of transparency***: key assumptions and underlying implicit judgements and preferences are often not made explicit. The same holds for the issue of

exogenous and endogenous factors, and to what extent societal processes are autonomous or influenced by policies.

4.3. PARTICIPATORY METHODS

"Participatory methods" is an umbrella term describing approaches for assessment in which non-scientists, such as decision-makers, stakeholders or citizens, play an active role. In the late seventies, Holling[109] proposed the idea of using participatory approaches in assessment efforts. Brewer[110] repeated and rephrased this plea some 10 years later. However, IA practitioners only recently sought to apply such methods.

Participatory methods are thus not new[111]. Focus groups, for example, have been applied in market research since the seventies[112], while consensus conferences were used in technology assessmen[113]. Gaming approaches have been prominently used for training purposes (e.g. military and business games) since the early seventies[114]. Teaching and training games for environmental management have been around since the 80s[115]. There is no major difference in using such methods in IA. However, IA's complexity, interdisciplinary character, and the heterogeneity of societal actors involved present special challenges. The use of participatory methods in IA, therefore, requires substantial adjustment of existing procedures and the development of new tools and methods. Projects like the ULYSSES project[116], the IIASA policy-exercise effort[117], the Mackenzie Basin Impact Study[118] and more recently the COOL-project[119] explore the necessary features of participatory methods for IA. Within the VISIONS project[120], various participatory methods are used in the process of envisioning European and regional futures, which will yield further insights into the strengths and weaknesses of participation of non-scientists in Integrated Assessment efforts.

109 (Holling 1978 (revision 1990))
110 (Brewer 1986)
111 See for recent overviews of participatory methods: (Renn et al. 1995) (Grin et al. 1997) (Joss and Durant 1995) (Dürrenberger et al. 1997) (Coenen et al. 1998). See also: http://www.iadb.org/exr/english/policies/participate/ and http://www.worldbank.org/html/edi/sourcebook/
112 (Cox et al. 1976)
113 For example, on the issue of predictive genetic research (Platform-on-Science-and-Ethics 1995).
114 See, for example, (Hausrath 1971)
115 (Meadows 1985)
116 See Box 1
117 (Parson 1996a)
118 (Cohen 1997)
119 (Berk et al. 1999)
120 (Rotmans et al. 1999; 2000; van Asselt et al. 1998; 1999; Gough et al. 1999; Funtowicz and Pereira 1999). See also http://www.icis.unimaas.nl/visions and Box 2.

Participatory methods for IA differ with regard to the profile of the participants, the goal of participation and the degree of participation. We distinguish three classes of methods:

- policy exercises
- dialogue-methods
- mutual learning methods

Policy exercises build upon the tradition of simulation games. A policy exercise can be described as a flexibly structured process designed as an interface between scientists and decision makers[121], in which a complex system is represented by a simpler one with relevant behavioural similarity, and from which decision-making is part through human participants[122]. In general, a game is set up that represents a negotiation process in which the different teams are responsible for a certain country or region. Policy exercises quite often make use of computer support. A computer model can be used as a consulting device or as tool to convert the negotiated agreements into a new 'state of affairs'.

Policy exercises differ from the other participatory approaches in the following ways: i) the participants play roles, and ii) the participants do not explicitly take part in the assessment process. A policy exercise is a way to get information on human behaviour and policy preferences necessary for the assessment the analysts produce. Two examples of policy exercises in IA[123] are the climate policy-exercises[124] and RIVM's SusClime-exercises[125]. Both efforts made use of IA models, respectively a "tailor-made" version of the GCAM model[126] and a preliminary version of the TARGETS model[127]. Experiences with policy exercises in Integrated Assessment thus far are discussed in Parson[128], and Toth and Hisznyik[129].

The ***dialogue-method*** is applied in cases where the intended users are considered as a source of information beyond behaviour and preferences necessary for the analysts to perform the assessment. The goal of participation is to extract this essential information from the intended users. Within this class, we can discriminate between continuous dialogues, and cases in which the dialogue takes place in a specific phase of the assessment. In the first case, the role of the intended users

121 (Toth 1988)
122 (Parson 1996a)
123 See also (Klabbers et al. 1995; 1996; Mermet 1992; Toth 1997) for policy exercises addressing global change issues.
124 (Parson 1996a)
125 (de Vries 1995)
126 (Edmonds et al. 1994a)
127 (Rotmans and de Vries 1997)
128 (Parson 1997)
129 (Toth and Hizsnyik 1998)

can be described as that of *co-designer*. In adaptive ecological modelling[130], the aim is for the crucial choices to be co-designed by the user community. The epistemic community involving scientists and policy makers in the RAINS project realised that the involved stakeholders actually played the role of co-designer[131]. In cases where the dialogue takes place in the design phase, the role of the intended users is to contribute to the design principles by sketching their wants and needs. This type of dialogue can be described as a user-platform. In earlier work[132], we decribed how a 'dialogue'[133] was intended to serve as a *user-platform*. If the dialogue is part of the final stage, the participants serve as a test-group that helps to determine how the results of the assessment will be brought to the fore. The Delft process around the IMAGE model[134] can be considered as an example of a *test group*.

The principle behind mutual learning is that participation of stakeholders and citizens enriches the assessment by a multiplicity of perspectives, skills and competence. The participants are considered as co-producers of knowledge. They are not selected dependent on whether the assessment is of use, but whether their perspectives, skills or competence complement the scientists' expertise and knowledge.
We distinguish two forms of mutual learning:

- the ***focus group approach***, in which scientists play the role of facilitator and observer, and in which stakeholders are the real participants, and
- the ***interactive approach***, in which scientists are actively involved as participants among other stakeholders like policy makers, business people, and representatives from NGOs.

In the first case, special groups are typically composed of citizens, policy makers and/or other stakeholders who are provided with scientific input. The assessments of these groups are then used in a broader IA process. In interactive analysis[135], problem definitions and proposed solutions are integrated into a joint assessment that makes sense to both stakeholders and scientists. The ULYSSES project involves IA focus groups with citizens (Box 1). The VISIONS project (Box 2) can be considered as a first example of the interactive approach in Integrated Assessment.

130 E.g (Costanza and Ruth 1996; Holling 1978 (revision 1990))
131 (Hordijk 1991a; 1991b)
132 (van Asselt 1994)
133 Analysts and intended users in the policy community did not meet directly, but got informed about each others' perspectives and attitudes via interviews.
134 (van Daalen et al. 1997)
135 (Guba and Lincoln 1989; Kasemir et al. 1997)

BOX 1 The ULYSSES project

While an increasing number of researchers are trying to design suitable computer models for the task of Integrated Assessment (IA), to date there have been severe difficulties in translating the outputs of environmental science into appropriate inputs for policy formation. This does not come as a surprise, as the two worlds -of scientific inquiry and of political decision making, are dissimilar in both their cognitive and social aspects. In this context the European research project ULYSSES, short for Urban Lifestyles, Sustainability, and Integrated Environmental Assessment[136], which ran from 1996 until 1999, is relevant. This project aimed at bridging the gap between environmental science and policy by including a monitored social process in the form of so-called IA-focus groups in the assessment method. Designing an interface between IA focus groups and computer models was the central research task of ULYSSES.

The procedures for public participation in IA developed within the ULYSSES project were tested with regard to issues of urban lifestyles and sustainability. These experiments have been carried out in different European regions. The goal was to shape the participatory procedures in such a way that the cultural heterogeneity within Europe could be taken into account while also maintaining some comparability. Experiences have been gained with IA focus groups in Barcelona, Venice, Zurich, Frankfurt/Rhine-Main, Manchester, Athens and Stockholm.

BOX 2 VISIONS project

"Integrated Visions for a Sustainable Europe", commonly known as VISIONS, is an Integrated Assessment project that will run from 1998 to 2001, under the auspices of DGXII of the European Commission (Research and Development). The project is part of the Fourth Framework Programme, Environment and Climate, Theme 4, Human Dimensions of Environmental Change of the European Community.

see over »

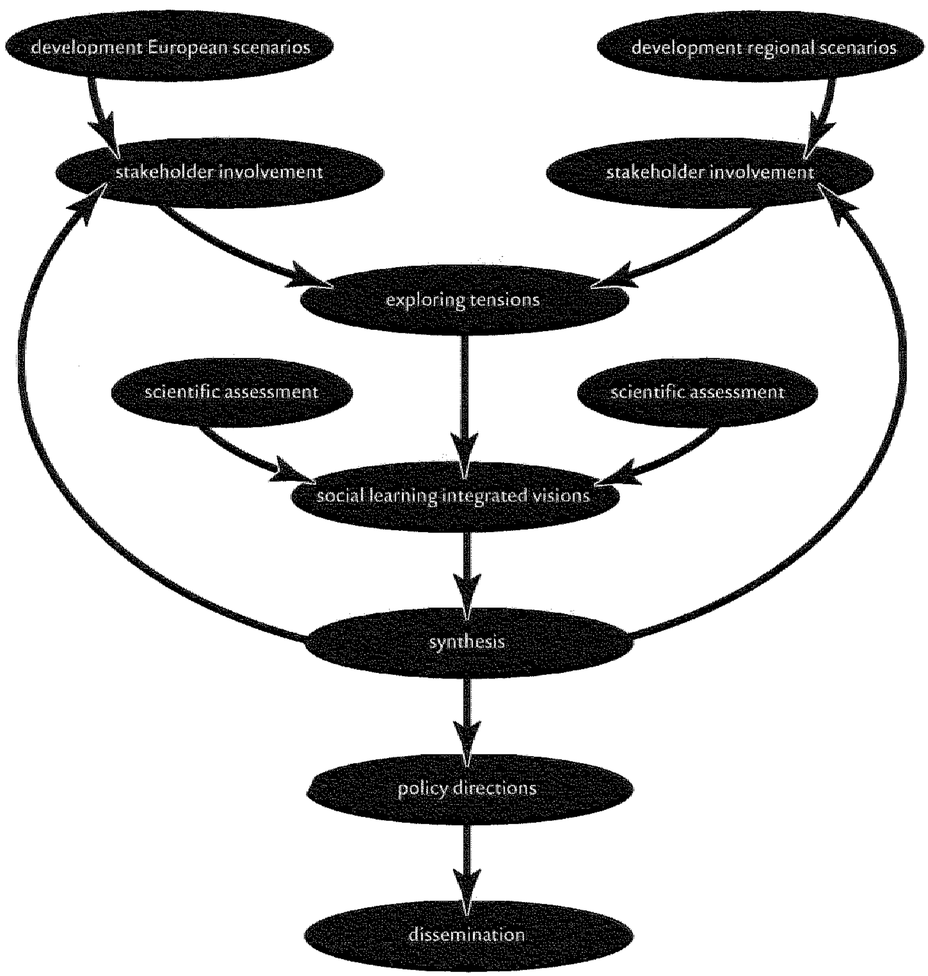
136 (Dürrenberger et al. 1997; Jaeger et al. 1995; Kasemir et al. 1997; 1999a) (Toth et al. 1998) (Dahinden et al. 1999)), see also http://www.zit.th-darmstadt.de/ulysses/

BOX 2

THE MAIN OBJECTIVES OF VISIONS ARE:

- to develop a range of alternative visions, comprising European and regional scenarios for future sustainable development paths, up to 2020 and 2050
- to provide a point of reference and practical tools for key-decision makers and stakeholders
- to raise awareness of sustainable development by increasing the understanding of the many links between socio-economic and environmental processes and improving the assessment of the consequences for Europe from an integrated viewpoint

research methodology



Box 2

Key issues

In order to create a balance between depth and broadness, VISIONS focuses on the following key European policy issues: *equity, employment, consumption behaviour, degradation of the natural resource basis,* in relation to developments in *energy, water, transport and infrastructure.*

Project methodology

Post normal science

The overall research philosophy is provided by "post-normal science", in which scientific process and dialogue is enhanced to include all those who have an interest in or are affected by decisions, associated with the particular issue/set of issues of concern.

Integrated assessment

The overall research activity is that of Integrated Assessment (IA), where a set of assessment tools will be used in an iterative and participatory process of planning for sustainable development.

Research steps

The following concrete research steps can be identified for VISIONS:

- to develop scenarios for Europe and the selected regions
- to integrate those scenarios into a range of *alternative integrated visions* for a sustainable Europe
- to test new and existing *scientific tools* and *participatory methods* for scenario-building
- to develop a *framework for integration* of tools for sustainable development
- to identify and evaluate *consensus* and *conflict* between *multiple perspectives* in alternative scenarios

The visions will be tested by:

- Scientific experts
- State of the art modelling tools
- Participatory methods

see over »

BOX 2

Scenarios

The scenarios will cover a European-wide perspective as well as three selected regions, which are representative for the different types of problems that are relevant within the context of sustainable development, i.e.

- The Green Heart (NL): a non-urban region, threatened by increasing expansion from the surrounding urban areas
- Greater Manchester: a typical industrial region in transformation
- Venice: a flourishing economic region, characterised by tensions between a further economic expansion, degradation of the natural resource base and an increasing deterioration of the water quality

Partners in the VISIONS project are:

ICIS, The Netherlands (co-ordinator); C3ED, France; UMIST, UK; EAWAG, Switzerland; Manchester University, UK; RIKS, The Netherlands; JRC of the EU, Italy; RIVM, The Netherlands; RMC, UK

The set of participatory methods discussed above can be considered to constitute a spectrum with on the one extreme scientists controlling the assessment and on the other methods in which the stakeholder participants perform the core of the assessment assisted by scientists (see Figure 7). There are participatory methods available in which scientists do not participate[137] at all; however, these are not relevant in the context of Integrated Assessment, because it would impair the ambition of building a bridge between science and decision-making.

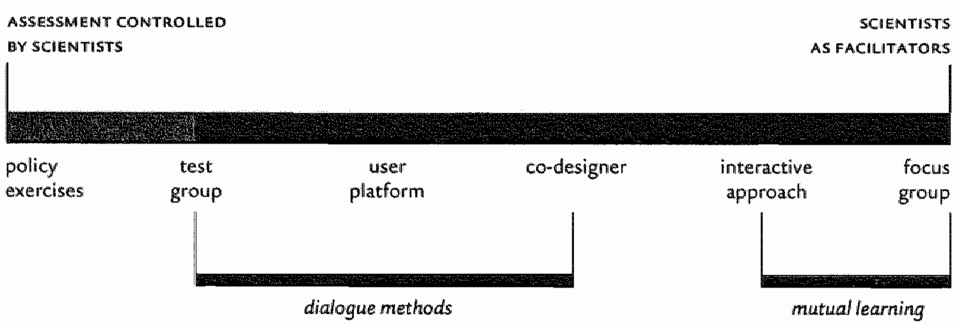


FIGURE 7 Participatory methods

Participatory methods are useful for:

- setting up a communication process between scientists and stakeholders
- structuring the IA process
- integrating public opinion and attitudes of stakeholders into the assessment
- integrating abstract, highly aggregated knowledge with local knowledge
- integrating quantitative with qualitative knowledge[138]

The major weakness is that the use of participatory techniques in Integrated Assessment is in its infancy, which means that there are not (yet) established procedures and work-packages for using participatory processes, whereby making it difficult to judge the quality of participatory-based assessments at this stage.

4.4. TOWARDS AN INTEGRATED ASSESSMENT TOOL-KIT

The issues Integrated Assessment aims to address are far too complex and too diverse to be dealt with by only a single approach. Multiple approaches are needed, employing combinations of analytical methods and participatory processes. The simultaneous use of various methods can improve the quality and adequacy, because each method has its own strengths and weaknesses. This is more easily said than done: in the worst case we end up with the disadvantages of both. Whether choosing an analytical or a participatory perspective, the crux of Integrated Assessment is to provide a framework that can put the methods to work to address the complex issue under concern in a fruitful way. This implies a two-level structure of IA methodology[139] (see Figure 8) in which the base level consists of primary disciplinary elements[140] (such as theories, expert models and data) and primary integration tools (such as checklists, IA-models, scenarios and participatory techniques) (see Figure 8). The methodology used in a particular integrated assessment depends on the issue, the context of the assessment and the requirements of the IA clients. IA frameworks will then differ by the ways and means in which they select, assemble and blend a suitable set of primary elements and tools.

Analytical and participatory methods are thus not, and should not be, mutually exclusive methods for integrated assessment. Models can be used as tools to develop scenarios. On the other hand, models and scenarios can also be the

138 See, for example, (Renn et al. 1995)
139 (Toth and Hizsnyik 1998)
140 Compare (Schneider 1997) for his description of a multidisciplinary toolkit for IA.

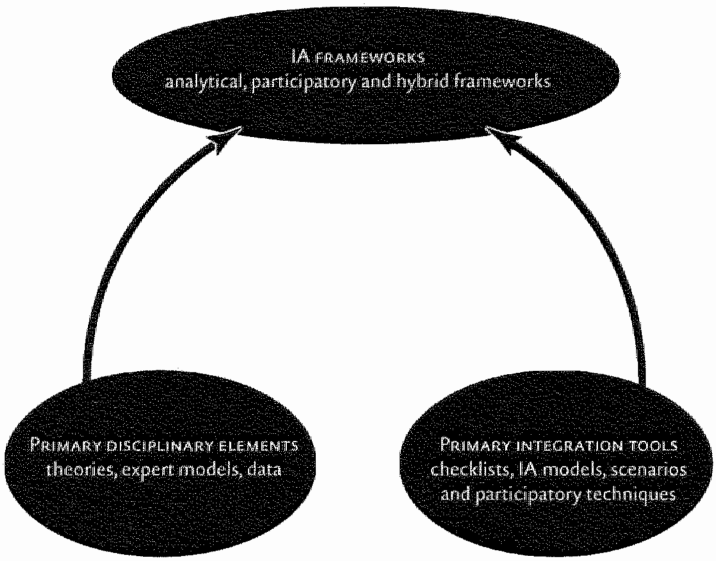


FIGURE 8 IA methodology[141]

result of participatory processes. Dialogue approaches can be oriented towards the development and/or use of IA models. Within policy exercises, models can be used as reference frameworks. In the ULYSSES focus groups, IA models were used as expert input for the group discussions. In mutual learning approaches, models might be helpful for comparing scenarios developed by participants with scientific insights.

A major methodological challenge for IA is to take advantage of the existence of multiple methods. Figure 9 suggests one way how the various methods can be used in a complementary manner:

141 Adapted from (Toth and Hizsnyik 1998)

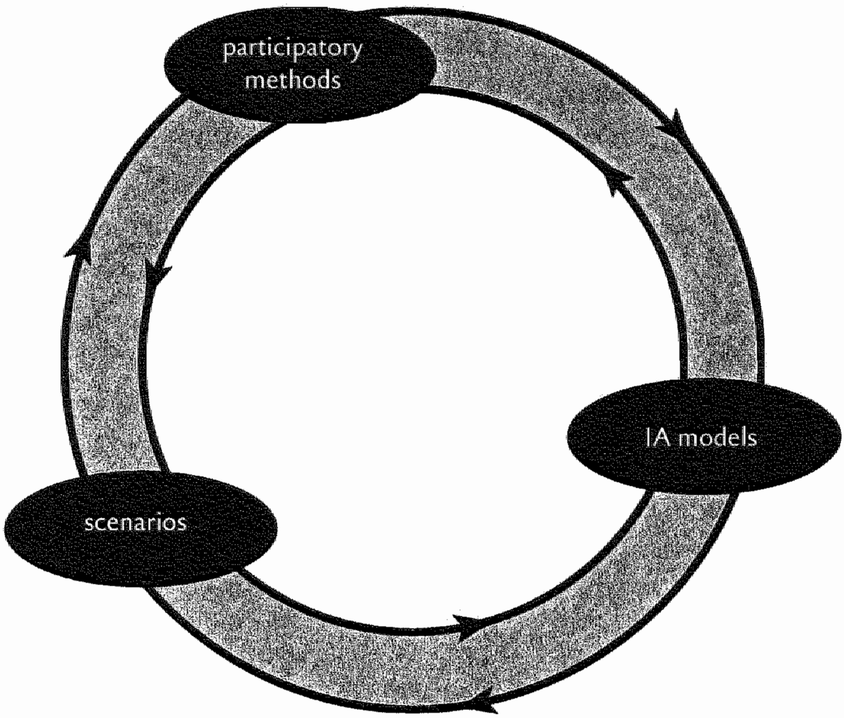


FIGURE 9 IA methods cycle

This cyclic scheme can thus serve as a heuristic to design a variety of sensible procedures using both analytical and participatory approaches. Starting with participatory methods and then turning clockwise, the scheme sketches a project in which participatory methods provide the basis for the development of an IA model that, in turn, is used to develop scenarios. These scenarios are then used as input for the next round of participatory meetings, where the developed models are adjusted, etc. Starting with IA models and turning anti-clockwise results in the following iterative process: an IA model is developed as a multidisciplinary scientific effort and is then used as scientific input to participatory processes in which a variety of scenarios are developed. The consistency and plausibility of these scenarios are then checked using IA-models. These checked scenarios serve as input for participatory processes, etc. The development of European scenarios in the VISIONS project (see Box 2) envisages an anti-clockwise combined use of participatory approaches, scenarios and IA-models starting from participatory methods.

5. Good practice and high quality

An important challenge for IA, and the most crucial one if IA wants to grow into a mature approach, is the development of codes for good practise and quality criteria. Critical reflection on the practice and results of IA activities is not a luxury, but an urgent need[142]. Codes of practise and quality criteria are necessary to evaluate and compare IA studies. Where codes of good practice mainly address the assessment process itself, quality criteria are needed to judge the products associated with IA. An accepted set of codes for practise and quality criteria that enable evaluation and comparison of IA studies will in the end improve the credibility of Integrated Assessment as an approach to decision-support on complex issues.

5.1. DILEMMAS

Why not simply apply standard scientific criteria to evaluate integrated assessments? First, the interdisciplinary nature of IA hampers the application of disciplinary standards on IA. This can be demonstrated at three different levels. First, the ambitions of disciplinary research and Integrated Assessment fundamentally differ. The disciplinary enterprise is focused on new knowledge, while the innovative character of IA is not new knowledge per se. Integrated Assessment aims to provide new and innovative insights through synthesis of available knowledge. Second, because of the multitude of disciplinary processes to be combined in an integrated assessment, simplified representations of disciplinary knowledge are preferable. Notwithstanding the general scientific ideal of parsimony, such a process of simplification by definition does not fully satisfy advanced disciplinary standards. Third, IA by its very nature involves combining different processes usually studied in isolation from other disciplinary fields. However, when the constraints of isolation are removed, there is a variety of ways in which to connect the pieces of disciplinary knowledge. There is neither a unifying theory nor a clear recipe how to integrate the various knowledge elements. An integrated assessment is more than just the sum of its knowledge components, which, in view of the lack of an 'integration theory', adds an artistic component to the endeavour[143].

142 (Ravetz 1997; Rotmans 1998b)
143 Compare (Toth and Hizsnyik 1998)

The critical standards applied to IA can thus not simply be the intersection of the standards from the constituent domains. To do so would reduce all evaluation of the IA endeavour to cheap shots[144] and would by definition ignore the added value of the synthesis. However, disciplinary-based standards are necessary to evaluate the quality of the inputs from the various disciplines on which the integrated assessment builds. The theories, data and expert models used, and the assumptions made should be recognised as valid by the disciplinary community.

Integrated assessment also differs from interdisciplinary research due to its decision-support purpose. If IA is considered as a kind of "decision-aid", it should be tested through use. However, what does "use" mean in the context of IA? And how does one judge that the use of IA improves decision-making? It takes decades or more before the effects of present decisions can be discerned, and that those changes are only partly policy-driven[145]. So if it is difficult to judge the quality of a decision, how can we then recognise if the assessment supports decision-making? IA practitioners[146] argue that studies that correspond to the decision-makers' perceptions and political agenda have a greater likelihood to be considered by decision-makers. But are such assessments better? If so, factors such as political utility and timeliness would overrule scientific criteria. Such criteria deprive Integrated Assessment of going beyond current political interests. But taking the decision support aim seriously, this implies that notwithstanding the above difficulties, we need to find ways to evaluate the 'political quality"[147] of integrated assessments.

Another feature of IA complicates the quality issue even further. Integrated Assessment aims to clarify complex issues. Due to the character of complex issues, every Integrated Assessment study is by definition incomplete and at best only partially integrated. The level of integration[148] may serve as quality criteria, however full integration as yardstick makes any integrated assessment a mission impossible. There seems to be no way to prove that the assessment is correct. The future is likely to be influenced by assessment activities. Assessments may foster decisions that prevent forecasts from taking place. Malthus' fears and the 'Limits to Growth' dooms have clearly influenced political thinking and decision-making. The current state of the world (e.g. no mass starvation nor depleted resources) does not make those past assessments of a poor quality.

144 (Parson 1996b)
145 (Ravetz 1997)
146 E.g. (Robinson 1992) and Rotmans (as cited in (van Asselt 1994))
147 (Robinson 1992)
148 (Schneider 1997)

These dilemmas indicate that the design of codes of practise and quality criteria for IA is not an easy job. It is nevertheless urgently needed in order to be credible in the long term. It is too difficult and would probably even be counter-productive, to formulate strict rules and hard criteria. Nevertheless, we will attempt to formulate rough guidelines and a kind of checklist. It is important to realise that these guidelines and this checklist do not represent the current state of the art. These quality aspects first and foremost aim to provide a heuristic for designing and evaluating IA research.

5.2. ROUGH GUIDELINES FOR PRACTISE

Different authors writing about IA have recently addressed the issue of developing guidelines for practise. Ravetz[149] states that the quality of integrated assessment is assured only by the quality of its production. Risbey et al.[150] emphasise that process-based criteria should be developed. Bailey et al.[151] seek to identify key aspects of good practice in IA. Morgan and Dowlatabadi[152] propose hallmarks of a good integrated assessment. Clark and Majone[153] derived four 'meta-criteria' that capture what practitioners and users have in mind when they cite a particular assessment noteworthy or important. Others like Parson[154], Schneider[155] and Jäger[156] in turn have interpreted and extended these contributions.

It is commonly recognised that good practice primarily depends on craftsmanship. An IA study is designed with a particular function or policy question in mind. To know what to do when and what to leave aside is a crucial part of the craft. In the case of Integrated Assessment, the context, time frame, costs and conditions of use condition 'best'.

The above authors agree that the general functions assigned to IA imply that the IA process should involve a dialogue between users and analysts. Good practice thus means that IA, at least in crucial stages, embraces communication between IA practitioners, stakeholders and the broad audience. This implies that participatory methods are needed in the IA process. Ideally, the various societal actors should

149 (Ravetz, 1997)
150 (Risbey et al. 1996)
151 (Bailey et al. 1996)
152 (Morgan and Dowlatabadi 1996)
153 (Clark and Majone 1985)
154 (Parson 1996b)
155 (Schneider 1997)
156 (Jäger 1998)

participate in all stages of the IA process, but we should keep in mind that this may be too demanding for both the IA practitioners and the stakeholders. Within the VISIONS-project, we observed that it is difficult to get stakeholders 'on board', irrespective of the participatory methods used and the scale of the assessment[157]. Fair management is needed to ensure that the different participants are good discussion partners and that solutions are worked out that do not entirely ignore the interest of anyone across the spectrum of societal actors. Furthermore, stakeholders are not used to this kind of science-society interactions, so the structure of the participatory process and the process facilitators should provide something to go on[158]. In this context, it is extremely important that more experience is gained with participatory methods in IA in order to find out which methods seem to be suitable for what kind of contexts and to develop appropriate procedures and formats for their application.

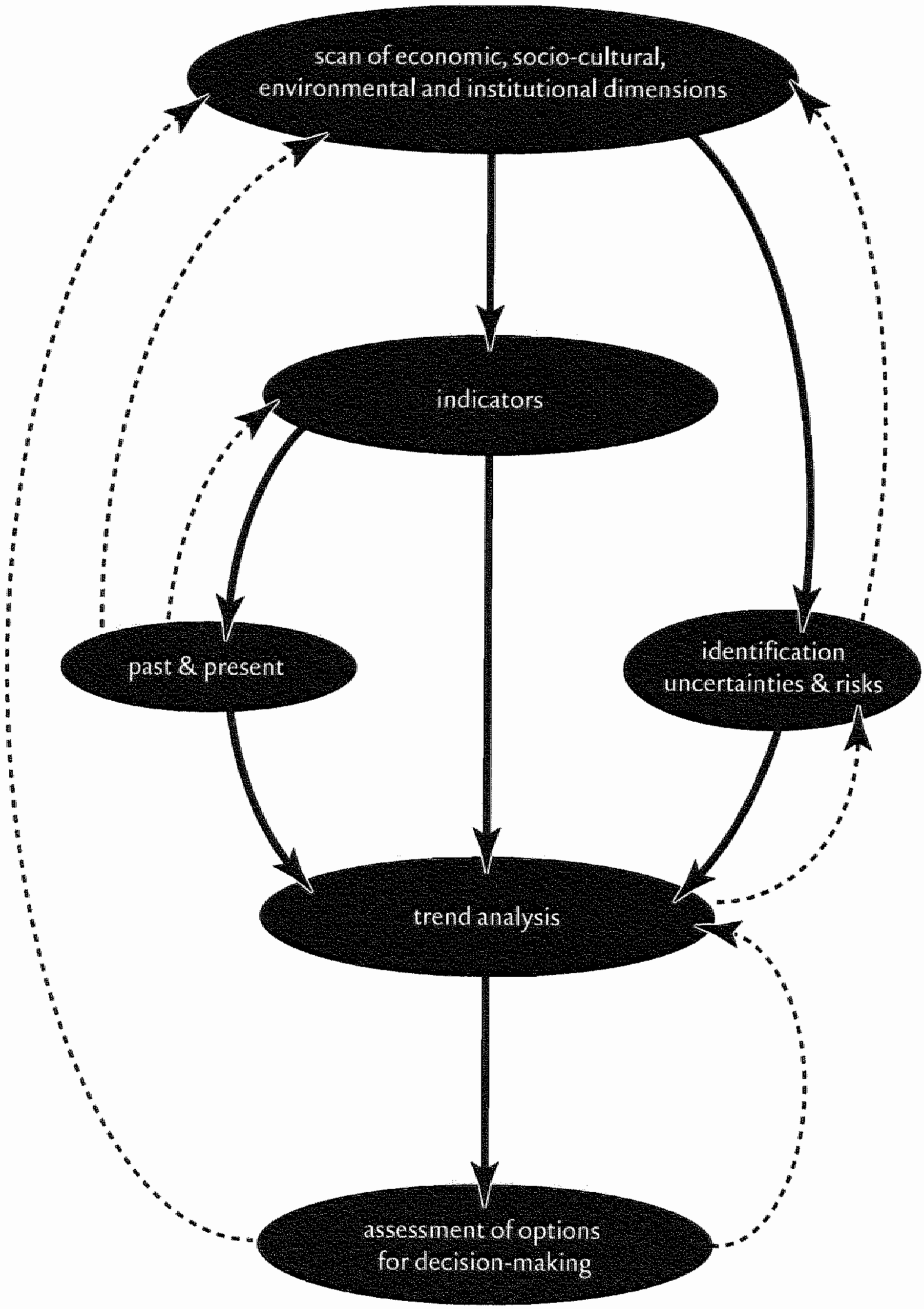
On the other hand, it is commonly felt that IA is more than a participatory process. The analytical dimension, i.e. gathering and synthesising knowledge elements from different disciplines and knowledge domains, is as crucial as the participatory process. Building on the state of the art in IA, we conclude that the following analytical steps are essential in any IA process[159] (see Figure 10) (in italic sources of inspiration and examples that can be turned to):

- A scan of the relevant ***economic, socio-cultural, environmental and institutional dimensions*** to get a first rough outline of the issues and processes that should be considered. This step can be considered as the problem-structuring phase.

  See, for example, Figure 11 for a simple diagram of an integrated perspective on the climate change issues. Within the TARGETS project[160], we made an overview of the global change issues addressed in major studies to select key issues in addressing sustainable development on a global scale[161]. As a first step in our regional assessment of the Province of Limburg, we listed the key economic, environmental and socio-cultural issues as identified in sector-specific studies on Limburg[162].

- Design and selection of ***indicators*** that are crucial for the analysis. Ideally, this step should be taken as a participatory effort. In this context the distinction

157 (Rotmans et al. 1999)
158 See, also, (Rotmans et al. 1999)
159 Compare (Rotmans 1998b), (ICIS 1998; 1999).
160 (Rotmans and de Vries 1997)
161 (Rotmans 1997)
162 (ICIS 1998)



Some likely iterations are indicated by dotted arrows.

FIGURE 10 Flow diagram of assessment steps

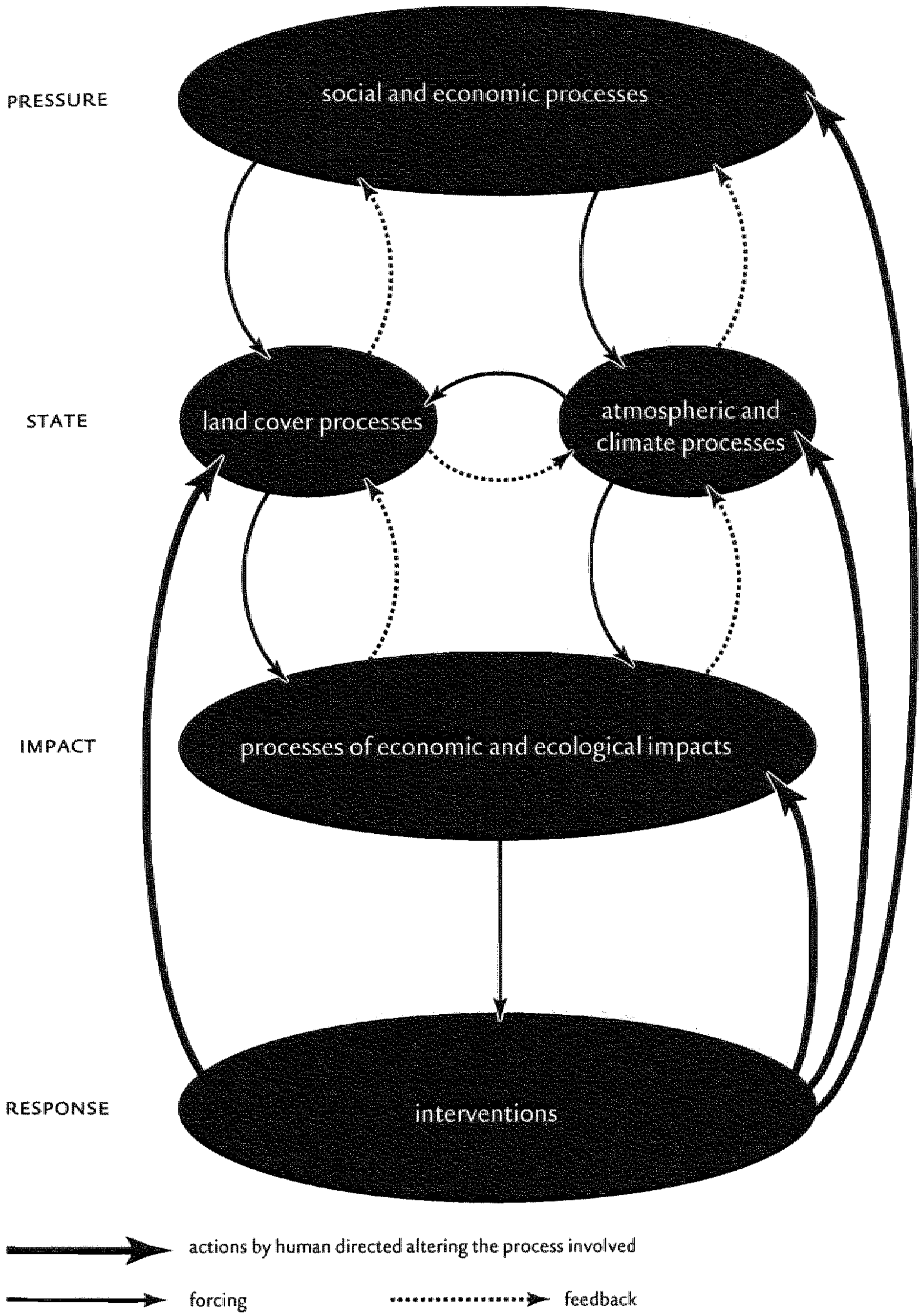


FIGURE 11 A conceptual scheme for an integrated analysis of climate change[163]

163 Source (Rotmans and Dowlatabadi 1998)

between stock and flow indicators is relevant. Flow indicators indicate the short-term changes, while stock indicators describe long-term developments[164].

For an illustration of this step, see the discussion report and the workshop report for the Green Heart case study in the VISIONS project[165] or the report documenting the participatory process with the Province of Limburg in which indicators were designed and selected[166]. See also the IA study on a sustainable future for Canada[167].

- A ***historical analysis*** of the development of the selected indicators, in order to be able to understand the crucial dynamics and to clarify cause-and-effect chains. Part of this step involves an inventory of data pertaining to the key issues and processes to be able to sketch the state-of-the-art.

Interesting example of data inventories are those carried out in the context of VISIONS, both of key characteristics of Venice[168] and of the Green Heart[169]. An example of such a historical analysis can be found in the Trend report of the United Nations, prepared by the Division for Policy Co-ordination and Sustainable Development (DPCSD)[170]. Other issue specific historical analysis can be found in the background documents to the TARGETS-model[171].

- ***Trend analysis*** to get a feel for the future prospects.

See the Trend report of the United Nations, prepared by the Division for Policy Co-ordination and Sustainable Development (DPCSD)[172]. A recent example of such a trend analysis in the context of an IA endeavour can be found in Anastasi et al[173].

- Identification of ***salient uncertainties*** and ***risks***.

Examples of IA studies that explicitly identify salient uncertainties include Lave and Dowlatabadi[174], and Rotmans and de Vries[175].

- Articulation of ***possible futures***.

This can be done by using models (see the wide variety of scenario-exercises by means of IA models for climate change[176]), by means of an intelligent

164 (ICIS 1998; 1999).
165 (RIVM and ICIS 1998)
166 (ICIS 1998)
167 (Robinson 1996)
168 See http://alba.jrc.it/visions
169 (RIVM and ICIS 1998)
170 (UN-DPCSD 1997)
171 E.g (den Elzen et al. 1995; Hoekstra 1998; van Vianen et al. 1994).
172 (UN-DPCSD 1997)
173 (Anastasi et al. 1999a)
174 (Lave and Dowlatabadi 1993)
175 (Rotmans and de Vries 1997)
177 For an overview of IA models for climate change turn to (Parson and Fisher-Vanden 1997; Rotmans and Dowlatabadi 1998)

synthesis of previous trend analysis, or in a narrative manner, either informed by participatory processes (see ULYSSES experience) or as an expert-based exercise (see, for example Smith[177]).

- ***Assessment of insights for decision-making*** in the view of historical developments, the current state-of-the-art, the future outlooks, the salient uncertainties and future risks.

  This step is the most difficult and the most crucial one in any assessment. However, it is difficult to provide case studies, because this step can certainly be characterised as the 'art of integration'. An example in which it is attempted to make the assessment step explicit can be found in Rotmans and van Asselt[178]. The assessment step can involve the evaluation of policy options. Policy analysis offers some good methods for option generation[179].

There is agreement within the IA community that the step of identifying major uncertainties and risks is crucial, but problematic. It is commonly felt that IA lacks the methods or procedures that enable the incorporation of uncertainty into trend analysis in an adequate way and to use the concept of risk in the final assessment. The current thesis aims to provide an in-depth study of the issue of uncertainty and risk in Integrated Assessment. Although uncertainty and risk are just one of the critical quality issues, the current research is thus relevant in the context of good practise.

Notwithstanding the different steps identified above, it is agreed that Integrated Assessment can never be a linear endeavour. This implies that the followed approach should be iterative and cyclical (see also Figure 10). Furthermore, it is important to realise that the distinct steps can be interpreted and performed differently depending on the context in which the assessment effort is carried out[180] and the type of complex issue addressed. The analytical steps above identified serve to outline the analytical dimension of IA.

177 (Smith 1997)

178 (Rotmans and van Asselt 2000 (in press)). This is an assessment based on experiments with the TARGETS model. In order to get a feeling for differences between richer and poorer assessments, compare this assessment with (de Vries et al. 1997), in which the first synthesis of the TARGETS experiments is described. See also (Rotmans and van Asselt 1999)

179 It is beyond the scope of this thesis to discuss the various methods for option generation. See for example van (van Heffen et al. 1999) and (Hoppe 1998).

180 For a discussion on this issue of context, see for example (Hischemöller and Hoppe 1996).

5.3. QUALITY CRITERIA[181]

What applies to the process, also applies to the product: the quality of the products is dependent of the purpose and context of the study in question. It is thus by definition impossible to come up with general quality standards that measure all IAs with the same yardsticks. Nevertheless, it is useful to think about rough rules for assessing the quality of IA studies within the scope of their own purpose.

Building upon Robinson[182], we distinguish three types of quality criteria: i) analytical quality[183], ii) methodological quality and iii) usability[184] that can be defined as follows[185]:

- ***analytical criteria*** concern the credibility of the underlying data sources and theories, the validity of techniques or models used, the level of integration, and the logic of the conclusions.
- ***methodological criteria*** address the quality of the methods and approaches adopted.
- ***usability criteria*** involve the degree of relevancy of the assessment for decision-making.

The latter category is unique and reveals the explicit decision-support aim of IA. For this reason IA-studies are subject to additional criteria that go beyond interdisciplinarity. Analytical and methodological quality are necessary, but insufficient conditions for every IA study. We can thus distinguish between two hierarchical levels[186], i.e. internal quality of the assessment[187] ("have we done a good

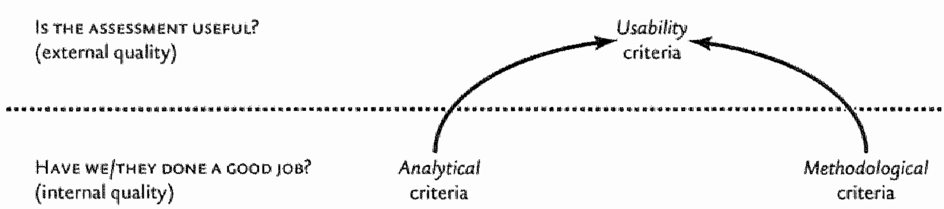


FIGURE 12 Two levels of quality

181 In this effort to propose quality criteria, the Bellagio principles as formulated by the International Institute for Sustainable Development (IISD) (http://iisd1.iisd.ca/) served as another source of inspiration.
182 (Robinson 1992)
183 also referred to as 'scientific quality' (Toth and Hizsnyik 1998) or 'technical adequacy' (Clark and Majone 1985).
184 also referred to as 'practical achievement' (Toth and Hizsnyik 1998)
185 Compare (Rotmans 1998a; 1998b) and (Rotmans and van Asselt 2000 (in press))
186 This issue of levels of quality has been discussed in a wealth of other scholarly papers on quality and methodology. It turned out to be beyond the scope of this thesis to perform a proper literature review.
187 (Clark and Majone 1985) refer to internal quality as "technical adequacy".

job?") and external quality ("is the assessment useful?") (see Figure 12). The aim is a balanced quality judgement, that involving both internal and external quality, would enable us to distinguish between 'better' and 'worse' studies, to separate the sheep from the goats.

In order to arrive at a checklist, it is necessary to investigate what kind of specific items the different types of quality include. On the other hand, we should not aim at an exhaustive checklist. For each type of criteria, we have tried to identify 7 key questions[188].

Analytical quality criteria involve what Risbey et al.[189] call 'discipline-based criteria to evaluate IA components'. An assessment of the analytical quality thus involves addressing[190]:

- What are the data-sources (field data, survey data, laboratory experiments, statistical data, computer simulations, educated guesses, etc.), how credible are they and are the data confirmed by different studies?
- Are the theoretical assumptions derived from state-of-the-art theory, are the concepts and laws used, interpreted and formulated in accordance with disciplinary standards, and are the models used in the assessment calibrated[191] and validated[192]?
- Is there a balance between aggregation and disaggregation, and is it based on a sound protocol?
- Is the adopted time-horizon long enough to capture the relevant time-scales, and how is this long-term perspective related to short-term decision-making?
- Are autonomous processes and processes that are or may be affected by human activities and/or policy strategies distinguished in the assessment?
- To what extent is the study integrated: are the key social, economic and environmental dimensions addressed in a balanced way and does the assessment adequately address mutual interactions as well as positive and negative feedbacks?
- Is the study consistent, are the conclusions supported by evidence and/or logical and plausible argumentation[193], can the results be generalised (either analytically

188 Of course this number is somewhat arbitrary, as any number would be. The general message should be that there has to be a balance between the three types, and for that reason we wanted to have the same amount of issues for each type of criteria. The only 'justification' for 7, may be that this number has the cultural (religious) meaning of representing completeness.

189 (Risbey et al. 1996)

190 Compare (Funtowicz and Ravetz 1990)

191 Calibration is defined as the procedure to gauge the most important parameters in such a way that the model simulations come close to the observations.

192 Validation is defined here as testing model performance.

193 I.e. to what extent are the conclusions compatible with data, model results and qualitative insights?

or statistically) and do the conclusions transcend disciplinary insights and provide innovative findings?

Methodological quality addresses the quality of the Integrated Assessment process and the methods and approaches adopted. Therefore, the guidelines for good practise reappear to a greater or lesser extent as methodological criteria. Questions relevant in this context are:

- Are the research questions and the research priorities appropriate in view of the aims, time frame, costs and conditions of use?
- Does a framework that is integrated and comprises the essential analytical steps as indicated under codes of good practice guide the research?
- Are the chosen analytical and participatory methods and approaches state-of-the-art, appropriate and legitimate in the context of the aim of the study?
- Is the study of an interdisciplinary or multi-disciplinary nature?
- Is the use of disciplinary knowledge elements and the simplification of this knowledge into building blocks for the IA study done in close collaboration with disciplinary experts (disciplinary peer review)?
- What is the level of participation by what kind of stakeholders, and how were they selected?
- How is uncertainty dealt with and are values, preferences and bias made explicit so that it is clear to what extent value judgements influence the scientific conclusions?

Usability addresses the relevance of the IA study for society in general, and decision-making in particular, and the usefulness for disciplinary research in terms of advancing knowledge. As discussed before, it is difficult, if not impossible, to come to a definite judgement taking into account the nature of decision-making processes and the delayed response to actual decisions. However, the key following questions may help to arrive at an indication of the usability of IA-studies:

- Does the problem formulation make sense to the stakeholders and the decision-makers, and does the study address important decision-making issues?
- Are the stakeholders, views and dimensions relevant for the decision-making process taken into account?
- Is the assessment comprehensible to the audience and users, and are the recommendations concrete?
- Is the study useful for disciplinary sciences in the sense that it helps to set disciplinary research agendas?

- To what extent has the IA study been able to address societal concerns and needs, and if, and in what way, do stakeholders and the general public benefit from the integrated assessment?
- Does the study facilitate in any way one or more of the following decision-making processes: framing the issue(s), agenda setting, scenario development, analysis of policy options, evaluation of consequences, identification and exploration of scientific uncertainties or evaluation in terms of equity[194]?
- To what extent is the study effective, in terms of changing, stabilising and/or advancing the relevant debate(s)?
- Is the assessment timely?

The above checklist is summarised in Table 1, where the major items associated with the various quality criteria are listed. Three levels of items can be distinguished, i.e. criteria that hold for any scientific study (normal), criteria pertaining to interdisciplinary research in general (*italic*) and criteria that hold for IA in particular (**bold**)[195].

ANALYTICAL QUALITY	METHODOLOGICAL QUALITY	USABILITY
credibility of data-sources	suitability of research agenda	**value of problem definition**
disciplinary quality of used knowledge elements	*integrated character of research methodology*	**legitimacy**[196]
balance aggregation-disaggregation	choice of methods	transparency
integration of time-horizons	*interdisciplinarity*	*useful to disciplinary science*
distinction between autonomous & policy-driven	*level of collaboration with disciplines*	societal benefit
level of integration	**level of participation**	effectiveness
consistency and 'transdisciplinary' character of conclusions	**uncertainty treatment**	timeliness

TABLE 1 Quality checklist

194 Compare (Parson 1996a)
195 Note that criteria that especially pertain to Integrated Assessment can also hold for particular scientific and interdisciplinary research.
196 (Clark and Majone 1985; Jäger 1998)

6. Challenges

The aim of this chapter has been to set the scope for the thesis by providing a state-of-the-art overview of Integrated Assessment in terms of current practices and challenges for the future. Building upon the above overview, some important conclusions can be drawn:

- Notwithstanding its explicit decision-support aim, the policy relevance of IA is being questioned. The challenge for IA is to investigate how it can be more responsive to the needs of decision-makers.
- There are different analytical methods and participatory methods available or being developed, but IA lacks frameworks that enable practitioners to use different methods in a complementary and sensible way. The need for such frameworks that can guide IA endeavours is commonly recognised.
- The above overview indicates that the treatment of uncertainty and the incorporation of different perspectives in IA are vital issues in the context of quality. It is broadly felt that uncertainty and pluralism are currently problematic issues in IA.
- Integrated Assessment, so far, has not explicitly addressed risks in the assessment effort. It would be interesting to explore which risk approaches can be useful within the context of IA[197].

In view of the above, the goal of the thesis is to provide a significant contribution to Integrated Assessment methodology. The intention of this thesis is to address uncertainty and risk in relation to pluralism. The explicit aim is to explore a framework for uncertainty management and risk analysis that can be used to perform Integrated Assessment in a way that is theoretically sound and practically feasible. As becomes clear from the current state-of-the-art detour in this Chapter, such a contribution to IA methodology would be highly welcomed in view of the quality of IA as an approach to scientific decision-support.

197 See also (Rotmans 1998a; 1998b)

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CHAPTER 3A

Uncertainty[1]

Much has been said and written about what the public expects from science: resolving, or at least reducing, uncertainty. Scientists are requested to give definite answers to societal questions. There are simple and one-dimensional questions that can be unambiguously answered by science, such as effects of smoking on lung functions. However, the majority of urgent societal questions pertain to complex issues, such as increasing poverty, climate change and European integration. Such complex issues involve inherent uncertainty. Scientists are, for example, unable to give confident answers about the magnitude of global climate change or even whether a region will warm or cool. Uncertainty thus has major political and ethical impacts, as the need to decide whether or not to act, as well as what kind of action to take, requires deciding about uncertainty[2].

Uncertainty in science has led to much confusion among the public[3]. Due to inherent uncertainty, scientists come up with different recommendations to decision-making in accordance with their particular argumentation[4]. Confronted with scientific disagreement, the common public reaction is distrust in science. Citizens conclude that scientists contradict each other, and they feel misled[5]. In its extreme form, such emotions may result in the conclusion that science has no value at all. Jasanoff[6] points out that the unproductive response is that scientists are invited to press the evidence to produce levels of precision that cannot be supported. This societal pressure causes that scientists, recognising the uncertainty in their study of (aspects of) complex issues, feel forced to conceal what is unknown or indeterminate.

1 A condensed version of this Chapter has been submitted to Risk Analysis and is also available in the format of an ICIS working paper. (van Asselt 1999)
2 (Silbergeld 1991)
3 (Jasanoff and Wynne 1998; O'Riordan et al. 1997)
4 (von Schomberg 1993)
5 (Beck 1997)
6 (Jasanoff 1991)

The gap between what society expects and what science can provide hampers the interaction between science and society. Facilitating this interplay is the central task of all branches of science for decision-making, including Integrated Assessment. The current Chapter discusses the issue of uncertainty and its implications for decision-support. The aim of the Chapter is to develop concrete ideas for management of

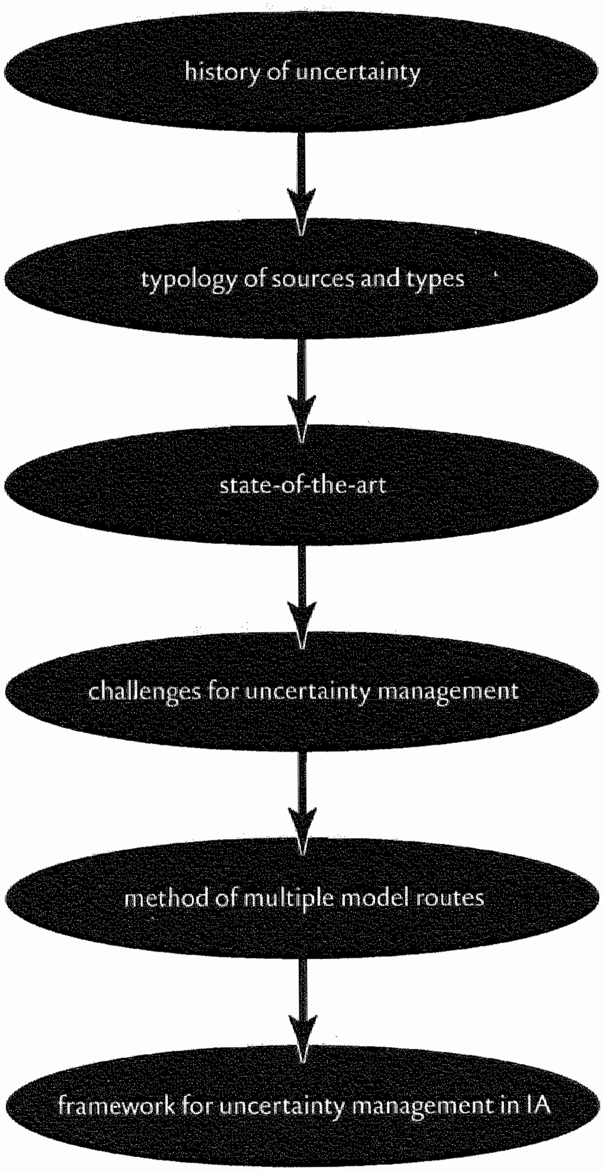

FIGURE 1 Structure of chapter

inherent uncertainty in Integrated Assessment. To this end, the following steps are taken:

- The role of science and the issue of uncertainty are put in a broader, historical context.
- The various types and sources of uncertainty are identified and synthesised into a typology.
- The state of the art in uncertainty analysis applied in Integrated Assessment activities is discussed. The tension between prevalent types and sources of uncertainty and the scope of the current approaches for uncertainty analysis is addressed.
- Crucial challenges for management and communication of uncertainty are identified.
- A new approach to uncertainty management in Integrated Assessment, i.e. perspective-based multiple model routes, is discussed in the context of these challenges.
- A framework for uncertainty management is sketched, which enables us to address the various types and sources of uncertainty in a systematic way.

The structure of our attempt to develop a sound methodology for uncertainty management is summarised in Figure 1.

1. Uncertainty in a historical perspective

What are the tasks and aims of science in the light of the contradistinction certainty-uncertainty? This issue has bothered thinkers and academics ever since intellectual activities are part of society. It is beyond the scope of this Chapter to give a comprehensive overview of the development of ideas pertaining to science and uncertainty since the Greek philosophers. We restrict ourselves to describe milestones in this evolution in a nutshell.

1.1. THE ENLIGHTENMENT

The role ascribed to science as the "provider of certainty" is deeply influenced by the epistemology[7] of what is known as the Enlightenment or the Age of Reason. The

7 For those readers not trained in philosophy: epistemology refers to the human capacity to know, also referred to as "science of science". An attitude towards science is therefore rooted in a particular epistemological stand.

notion 'Enlightenment' came into use by the end of the 18th century[8]. Enlightenment thinking traces back to 17th and 18th century thinkers in Europe, especially in England (Freethinkers, esp. Locke), in France (Encyclopedists, esp. Diderot, Voltaire, Rousseau and d'Alembert) and in Germany (esp. Kant and Hegel). In a certain sense, Enlightenment thinking built upon the theories of Descartes (1596-1650). Descartes' plea for methodological examination of knowledge before the 'forum of Reason'[9] marked a clear break with medieval religious thinking. The Enlightenment movement has carried forward this ideal of systematic investigation. Reason and objectivity are the key values associated with the Enlightenment movement. The imperative is to draw a fixed boundary between the objective realm of facts and the subjective realm of opinions. The conviction is that systematic inquiry using mathematical and quantitative methods will lead to certain knowledge about reality. In other words, science, if conducted in the right way, yields the truth.

Enlightenment thinking grew into what is generally referred to as 'positivism'. Positivism can be defined as the search for, and prediction of, empirical regularities to make universal, true statements. The quantitative method of natural science is the adopted approach to gather objective knowledge. In the positivist epistemology, uncertainty is considered as something unscientific[10]. These positivist absolutisms have dominated science far into the 20th century.

1.2. THE CRISIS OF POSITIVISM

Notwithstanding the dominance of the positivist values in the last three centuries, it is important to realise that these epistemological principles have always been questioned. The most important dissident in the 18th century was Hume (1711-1776). He attacked the thesis that empirical observations and rational investigations lead to true knowledge. His conclusion was that the gap between observations and reality could not be bridged by reason. The pretensions of true knowledge were even challenged within the Enlightenment movement itself. The German variant, of which Hegel (1770-1831) was the most important representative, argued that systematic inquiry leads to knowledge, but not to perfect and complete knowledge.

The first major crisis of positivism was in mathematics. By the beginning of the 20th century, contradictions at the logical foundations of mathematics were revealed.

8 e.g. (Kant 1783)
9 (Bartels 1993)
10 See (Klir 1996)

The emergence of statistical mechanics at the beginning of this century enhanced some serious study of uncertainty and its role in science. In 1905 Einstein proposed his 'new physics', in which the basic concepts of science, i.e. time, space and mass, are relative, instead of absolute, notions. Notwithstanding these developments, positivism remained the dominant paradigm in guiding scientific endeavours.

However, in the second half of the 20th century, the positivist approach to science was more, and more strongly, criticised. The hegemony of the natural science method was questioned from both philosophy and the social sciences. An early publication that also played a key role in this dethroning process is the seminal work "Risk, uncertainty and profit"[11], in which the nature and effects of uncertainty in science are thoroughly discussed. What can be called 'the sceptical crisis'[12] was initiated in the turbulent 1960s. The most extreme antagonists of positivist epistemology, which can be grouped as 'conventionalists' or 'subjectivists', hold that knowledge is nothing but 'conventions' of what given groups of scholars deem to be 'true'. Two influential anti-positivist movements are post-modernism and social-constructivism. Post-modernism originates from philosophy, while social constructivism has its origins in sociological studies of science and technology.

1.3. POST-MODERNISM

Post-modernism[13] can be considered as the most extreme attack on the Enlightenment project. Foucault (1926-1984) and Derrida (1930-) are the most important representatives of this school of thought. They both build upon work of Nietzsche (1844-1900) and Heidegger (1889-1976). Post-modernism denies the possibility of any certain knowledge. Post-modernists question the ability to represent reality in any objective manner. The search for truth is an illusion. The post-modernist argument is that reality is not directly available to us. Facts do not present themselves directly to the investigators. Post-modernists argue that scientists pick and choose among them, guided by ideological presuppositions. Scientists do not discover as the positivists have it, but they invent. Post-modernism furthermore deconstructs central authority, which implies the loss of a central perspective. Post-modernists challenge all endeavours to explain processes and events, and, in doing so, they undermine the traditional claims in both natural and social sciences. If post-modern claims

11 (Knight 1921)
12 (Funtowicz and Ravetz 1993a)
13 See for an overview (Rosenau 1992)

are taken to the extreme, there are no grounds for systematic investigation, analysis and interpretation.

1.4. SOCIAL-CONSTRUCTIVISM

Social constructivism[14] challenges the positivist claim that scientific knowledge can be produced according to purely rational, cognitive factors. Social constructivism claims that the production of science is a social process. Scientific knowledge is constructed and negotiated. Empirical underpinning for this claim is found in historical studies[15] and laboratory ethnographies[16]. Rationality is defined by the beliefs of a specific discipline or scientific community, and thereby socio-cultural. Social constructivist epistemology can be deduced to the following theses[17]:

- What knowledge is produced and how it is to be used are socially driven decisions. Social factors play a large role in the direction of research, the drawing of boundaries between acceptable and unacceptable, relevant and irrelevant research, and so on.
- Key processes in theory building such as consensus formation, assessments of credibility, the acceptance and rejection of theories are entirely social.
- What scientists expect to observe, are able to observe, and want to observe are outcomes of social negotiations.
- There is no single scientific method to which all scientists can refer. Decisions on appropriate methods are influenced by social factors such as rhetoric, politics, disciplinary cultures, and personal reputations.

Social constructivism argues that it is possible to distinguish between valid and invalid scientific statements, but the criteria for making such judgements cannot be derived from an 'abstract and universal faculty of reason'[18], but have to be socially-constructed.

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14 See for an overview (Jasanoff and Wynne 1998; Knorr-Cetina and Mulkay 1983; Pickering 1992). The journal associated with this school of though is Social Studies of Science.

15 E.g. (Barnes and Shapin 1979)

16 E.g. (Latour and Woolgar 1979)

17 Compare (Hess 1995)

18 (Hess 1995)

1.5. FACING INHERENT UNCERTAINTY

Both post-modernism and social constructivism raise interesting questions about truth, objectivity and certainty. They have helped to (re)vitalise discussions about methods, goals and the foundation of science. The main messages propagated by these conventionalist movements are:

- Science is not a purely objective, value-free activity of discovery: science is a creative process in which social and individual values interfere with observation, analysis and interpretation.
- Knowledge is not equivalent to truth and certainty.

The above principles have dethroned the absolutisms that have reigned since the Enlightenment[19].

We have to realise that uncertainty is not simply the absence of knowledge. Uncertainty can still prevail in situations where a lot of information is available. Furthermore, new information can either decrease or increase uncertainty. New knowledge on complex processes may reveal the presence of uncertainties that were previously unknown or were understated. In this way, more knowledge illuminates that our understanding is more limited or that the processes are more complex than thought before. In other words, more knowledge does not mean less uncertainty and vice versa.

Heisenberg explained another dimension of the problematic relationship between knowledge and uncertainty. His uncertainty principle[20] has it that:

> *We could not, in fact, obtain all the information we need, since the act of getting information often changes the phenomena being studied.*

No amount of information will ever be able to entirely eliminate uncertainty. Or as Shackle phrased it in his theory of 'unknowledge'[21]: "There would be no uncertainty if a question could be answered by seeking additional knowledge. The fundamental imperfection of knowledge is the essence of uncertainty". In other words, there are inherent limitations to the reduction of uncertainty[22].

The notion that scientific knowledge is inherently imperfect is becoming more common. The fundamental role of uncertainty in science is more broadly recognised, both in the disciplines reflecting on knowledge and scientific practice, and in

19 See also (Nowotny 1993).
20 (Heisenberg 1962)
21 (Shackle 1955)
22 (Funtowicz and Ravetz 1993a)

the disciplines that aim to describe and explore reality. The interest in uncertainty is enhanced by the recognition that the world around us is becoming more and more complex[23]. There are different causes for this increasing complexity[24]:

- ***increase in scale:*** global and international processes increasingly interact with developments on the national and regional scale, and vice versa.
- ***technological developments***
- ***acceleration of processes***, implying that turnover rates decrease.

The resulting web of social, economic, technological and environmental processes forms a complex system that is beset with new uncertainties.

In such a situation of inherent uncertainty and imperfect knowledge, truth is not what science can deliver to the public. In such cases, "it seems that the only certain aspect of science is that it is uncertain"[25]. The aim of prediction is eroded. On the other hand, if reality were fully indeterminate, there would be no grounds for scientific investigation. The adage that "most phenomena and occurrences have one or more causes" is the basic principle of science. In the light of uncertainty, this implies that plausibility of scientific explanations and claims is the key issue.

Practitioners in science for decision-support in general and Integrated Assessment in particular, realise that uncertainty is and will be central to their endeavours. This increasing interest in uncertainty in the Integrated Assessment community is, for example, revealed by the international workshop on uncertainty organised by the European Forum on Integrated Environmental Assessment (summer 1999).

2. Typology of uncertainty

In order to be able to consider uncertainty as a challenge for science in general and for scientific decision-support in particular, it is necessary to analyse sources and types of uncertainty. Such an understanding of uncertainty is needed to be able to distinguish between highly uncertain and less uncertain issues[26], as well as to understand which types and sources of uncertainty pertain to particular decision-making issues.

23 (Beck 1986; Rotmans 1998a)
24 (Rotmans 1998a); see also Chapter 1.
25 (Rohen 1988)
26 Such a nuanced attitude towards uncertainty, which implies that a distinction can be made between high and low uncertainty, is also found by (Funtowicz and Ravetz 1990) and subsequent publications.

A better understanding of uncertainty and how uncertainty is dealt with analytically is a prerequisite for improved decision-support in situations with high uncertainty. Below various characterisations and classifications of uncertainty are discussed, which are synthesised into a typology of uncertainty.

2.1. TRANS-SCIENTIFIC QUESTIONS

Weinberg[27] addressed uncertainty by identifying societal questions that cannot unambiguously be answered by science and thus 'transcend' science, i.e.:

- Questions that require impracticably expensive or lengthy, or even impossible experiments.
- Questions that refer to human behaviour.
- Questions pertaining to the future.
- Questions that involve value judgements.

These trans-scientific questions are unanswerable due to inherent uncertainty[28]. A closer look at these questions yields which sources of uncertainty complicate scientific investigation. The first type of question refers to cases for which necessary historical records or monitoring systems are lacking to fulfil data-requirements and to cases being too abstract or too demanding to satisfy empirical needs. This holds for example for open systems, such as the global biosphere, which do no allow for controlled experiments.

The second type of question is unanswerable, because the behaviour of human beings does not allow such a strict rationalisation as the behaviour of atoms and molecules does. There is inherent uncertainty with respect to the adaptive and innovative capability of humans.

Questions pertaining to the future, i.e. the third type of question, are unanswerable, because there is always uncertainty in extrapolating current knowledge to new and untried circumstances. For example, natural systems may adapt to changes.

27 (Weinberg 1972)

28 (Funtowicz and Ravetz 1993a) argued that Weinberg's demarcation criterion was one of scale, i.e. the feasibility of a project in relation to existing resources as willed by society. Given more resources or more sophisticated science, "a trans-scientific problem can be rescued for science". They refer to a reply to critics of Weinberg in Science (Weinberg 1973). However, analysing the questions Weinberg identified as trans-scientific in his original publication (Weinberg 1972), we conclude that Weinberg in a second thought did not, or was not longer willing to, realise the fundamental implications of his concept of 'trans-science'.

29 Example builds on statement given by one of the authors of the controversial social cost chapter, i.e. dr. Richard Tol on the International Symposium on Integrated Assessment (Toulouse, France, October 1996), and on personal communication with drs. Arjette Stevens as representative of Greenpeace International participating in the discussions on this IPCC-chapter.

to estimate the social costs of climate change. To that end, estimates of the monetary value of human lives were used to express anticipated loss of lives in dollars. According to these estimates, human life in developed countries is worth more dollars than a human life in developing countries. A similar difference can be observed between the estimates in dollars for male versus female lives. Societal actors heavily attacked this scientific 'answer' to a societal question. Estimating human life involves value judgement that cannot simply be solved in an objective manner in a monetary exercise by economists[30]. This example shows how diversity in values contributes to uncertainty in scientific endeavours. This type of trans-scientific questions shows similarities with what Hisschemöller and Hoppe[31] call 'unstructured problems'.

Issues dealt with in science for decision-making are usually trans-scientific[32]. Although the issue of uncertainty pertains to science in general, our focus will be on the scientific analysis of trans-scientific issues with an explicit decision-support purpose.

2.2. SOURCES AND TYPES OF UNCERTAINTY

It can be argued that uncertainty as such does not exist, but it only exists through human mediation. Whether uncertainty is taken as a factual or as a social construction, it is nevertheless interesting to try to understand the origins of uncertainty. Just as scientists investigate the sources of climate change, we would like to investigate the sources of uncertainty to explain why uncertainty occurs in scientific decision-support on complex, trans-scientific issues. We aim at a comprehensive taxonomy of sources of uncertainty, in the sense that no important class of sources is overlooked. The latter means that any source of uncertainty that cannot be traced to the generic sources of uncertainty should not be found in any empirical decision-support case. A proposed taxonomy of sources of uncertainty can thus in principle be falsified by empirical testing. In other words, it is legitimate to hypothesise that a taxonomy of sources can be universally valid. Our aim is to develop such a universally valid taxonomy that can serve as a benchmark in analysing particular and concrete sources of uncertainty in actual decision-support.

In developing a kind of taxonomy of uncertainty the difference between source and type of uncertainty matters. "Source" refers to the origin of uncertainty, which

30 See (Funtowicz and Ravetz 1994) for a seminal analysis of another monetary exercise that turned out to be controversial in the light of inhe ent uncertainty.

31 (Hisschemöller and Hoppe 1996)

32 Compare (Jasanoff and Wynne 1998)

implies that such a classification is preferably universally valid. "Type" refers to the way in which uncertainty manifests itself in a particular context. The consequence is that any typology of types of uncertainty is by definition context-dependent or method-dependent. A typology of types of uncertainty can help in decision-support endeavours to single out in which step of the analysis, in which part of the model, in which component of the relevant issue, and in which phase of a process uncertainty may be expected. A typology of types of uncertainty can thus never be falsified; its potential usefulness for the quality of the practise of decision-support can only be tested through use and best practise examples.

The aim of our research on the concept of uncertainty is to develop a generic taxonomy of sources of uncertainty and to provide some examples of typologies of types of uncertainty that may be relevant and useful in the context of decision-support in general, and Integrated Assessment in particular.

2.3. SOURCES OF UNCERTAINTY

From the above analysis of trans-scientific questions, it can be concluded that there are various sources of uncertainty prevalent in the science for decision-support. Building upon a recent inventory of classifications of uncertainty[33] and our own review of the scholarly literature on uncertainty, we conclude that on the highest level of aggregation the two major sources of uncertainty are[34]:

- ***variability***, also referred to as 'objective uncertainty'[35], 'stochastic uncertainty'[36], 'primary uncertainty'[37], 'external uncertainty'[38] or 'random uncertainty'[39]: the system/process can behave in different ways or is valued differently. Variability is an attribute of reality.
- ***lack of knowledge***, also referred to as 'subjective uncertainty'[40], 'incompleteness of the information'[41], 'informative uncertainty'[42], 'secondary uncertainty'[43] or 'internal uncertainty'[44]. Lack of knowledge is a property of the analysts' performing the study and/or of our state of knowledge.

33 (van der Sluijs 1997)
34 Compare (Hoffman and Hammonds 1994)
35 (Natke and Ben-Haim 1996)
36 (Helton 1994)
37 (Koopmans 1957)
38 (Kahneman and Tversky 1982)
39 (Henrion and Fischhoff 1986)
40 (Helton 1994; Natke and Ben-Haim 1996)
41 (von Schomberg 1993)
42 (Klir 1996; Natke and Ben-Haim 1996; van Witteloostuijn 1987)
43 (Koopmans 1957)
44 (Kahneman and Tversky 1982)

Uncertainty thus has both an ontological[45] (variability) and an epistemological[46] (lack of knowledge) dimension. As a consequence, there are theoretical and practical limitations to the reduction of uncertainty.

Different sources of variability can be distinguished, i.e.[47]:

- inherent randomness of nature[48] (natural randomness)
- value diversity[49] (cognitive variety)
- human behaviour (behavioural variety)
- social, economic and cultural dynamics[50] (societal randomness)
- technological surprises (technological randomness)

Variability as defined by the above sources goes beyond established seasonalities. Due to variability, reality inhibits inherent uncertainty and unpredictability. As such, it contributes the to lack of knowledge, because due to variability perfect, certain knowledge is unattainable in any event. Variability, especially if it is random, can thus be considered as a source of inherent lack of knowledge.

Lack of knowledge is partly a result of variability, but knowledge with regard to deterministic processes can also be incomplete. There are different degrees of lack of knowledge. A continuum can be described that ranges from inexactness to irreducible ignorance:

- *inexactness*[51], also referred to as metrical uncertainty[52], measurement errors[53], or precise uncertainties[54]. "We roughly know".
- *lack of observations or measurements*: the data could have been collected, but have not been. "We could have known".
- *practically immeasurable*: the data can in principle be measured, but it is not practical to do so (too expensive, too lengthy). "We know what we do not know".
- *conflicting evidence*[55]: different data sets are available and can be interpreted in competing manners. "We do not know what we know".

45 concerning the general properties of objects
46 concerning the human ability to know.
47 compare (Rowe 1994)
48 see also (Morgan and Henrion 1990), also referred to as (unobserved) seasonalities (van Vlimmeren et al. 1991)
49 also referred to as subjective judgement and disagreement (Morgan and Henrion 1990) or moral uncertainties (de Marchi 1995).
50 The need to consider societal and institutional processes as a major contributor to uncertainty due to variability can be inferred from various papers of Funtowicz, Ravetz and de Marchi. See for example (de Marchi 1995; de Marchi et al. 1993).
51 (Funtowicz and Ravetz 1990; Zimmermann 1996). The classical theory of measuring errors postulated by Gauss (1777-1855) has it that every measurement of a physical quantity is affected by measuring errors of a random character, which are unknown.
52 e.g. (Rowe 1994)
53 e.g. (Beck 1987; van Vlimmeren et al. 1991)
54 e.g. (Wallsten 1990)
55 (Zimmermann 1996)

- *reducible ignorance*[56]: there may be processes and interactions between processes out there that we do not observe, nor theoretically imagine at this point of time, but probably in the future. "We do not know what we do not know".
- *indeterminacy*[57]: there may be processes of which we understand the principles and laws, but which can never be fully predicted. "We will never know".
- *irreducible ignorance*[58]: there may be processes and interactions between processes that cannot be (or not unambiguously) determined by human capacities and capabilities. "We cannot know".

The first three degrees of lack of knowledge (i.e. inexactness, lack of observations/measurements and practically immeasurable) are also referred to as unreliability[59]. The latter four degrees are also referred to as structural uncertainty[60] or systematic uncertainty[61].

The hierarchy of sources and degrees of uncertainty is visualised in Figure 2.

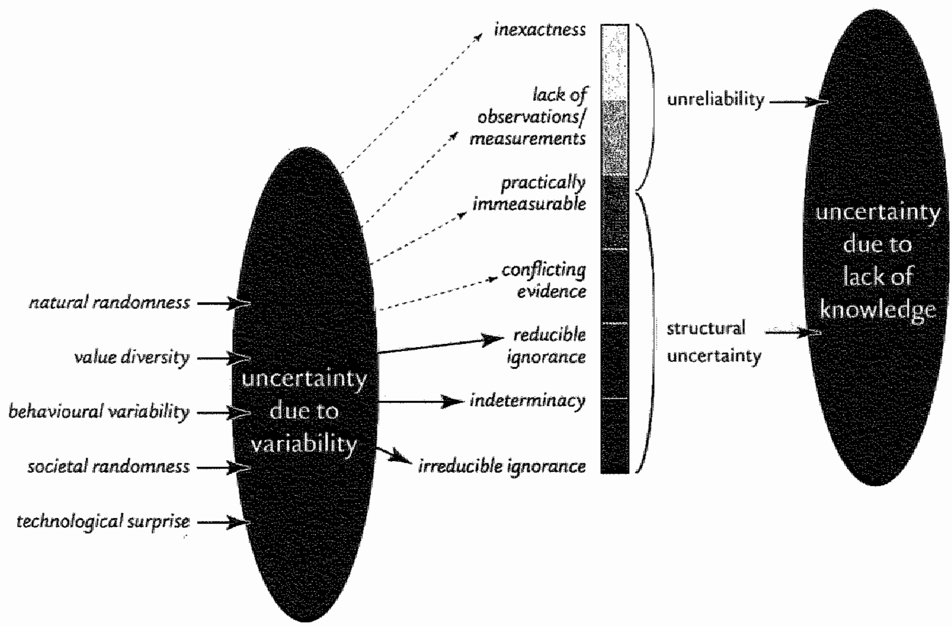

FIGURE 2 Typology of sources of uncertainty

56 (Funtowicz and Ravetz 1990; Wynne 1992)
57 e.g. (Wynne 1992)
58 I owe the distinction between reducible and irreducible ignorance to a fascinating discussion with, among others, Steve Manson, Brian Norton and Jan Rotmans.
59 e.g. (Funtowicz and Ravetz 1990)
60 e.g. (Rowe 1994)
61 e.g. (Henrion and Fischhoff 1986; Morgan and Henrion 1990)

In sum, uncertainty can be defined as the entire set of beliefs or doubts that stems from our limited knowledge of the past and the present (esp. uncertainty due to lack of knowledge) and our inability to predict future events, outcomes and consequences (esp. uncertainty due to variability)[62].

2.4. TYPES OF UNCERTAINTY

Due to variability and lack of knowledge, both our understanding of processes, past and present states of the relevant complex system and our predictive capability in terms of future states are limited. The knowledge of a system or issue is quite often described by means of a model, which can be a theory, a conceptual model, a mathematical model, an optimisation model or a computer simulation model. The latter three types of models can be clustered to 'formal models'. Due to inherent uncertainty, no framing of the issue is neutral, nor are models. However, downplaying the usefulness of models as structuring devices by claiming that modelling by definition denies the essence of uncertainty, as Jasanoff and Wynne[63] do, is throwing away the baby with the bath water. A more constructive approach would be to analyse how uncertainty materialises in modelling.

Uncertainty enters various steps of the modelling process. One way to describe how uncertainty manifest itself in modelling is by means of the following classification of types of uncertainty[64]:

- technical uncertainties
- methodological uncertainties
- epistemological uncertainties

These three types of uncertainty imply different levels of uncertainty as is visualised in Figure 3.

Technical uncertainties arise from the quality or appropriateness of the data used to describe the system, from aggregation[65] (temporal and spatial) and simplification as well as from lack of data and approximation. In other words, technical uncertainties primarily result from uncertainty due to unreliability. Due to lack of knowledge, methodological uncertainties arise. In case of such inherent uncertainty, what analytical tools and methods are appropriate? In view of incomplete understanding of the processes, how does one model causal relationships? What is an adequate frame

62 Compare (Boritz 1990).
63 (Jasanoff and Wynne 1998)
64 (Funtowicz and Ravetz 1989)
65 Also referred to as 'resolution errors' (EnvironmentalResources 1985)

FIGURE 3 Levels of uncertainty

to structure what we know and what is uncertain? How to interpret the uncertainties? Epistemological uncertainties concern the conception of a phenomenon. This type of uncertainty arises from structural uncertainty and variability. The key question with regard to this type of uncertainty is whether the description, theory or model relates to the real, variable world.

In formal modelling, technical, methodological and epistemological uncertainties materialise as[66] uncertainties in model quantities, uncertainty about model form[67] and uncertainty about model completeness/adequacy of the model[68] respectively (see also Figure 4). Parameters, inputs and initial states[69] are uncertain model quantities. Uncertainty about model form comprises uncertainty pertaining to model structure, uncertainties about the functional relationships[70] and uncertainties with regard to the choice of algorithms. Uncertainty about model completeness is the most fundamental and crucial for the quality of the model. Uncertainty about model completeness is addressed in the validation phase[71]. However, complete validation is impossible in case of complex systems due to inherent uncertainty (especially due to ignorance and indeterminacy)[72]. To express the limits to validation exercises, model validation is also referred to as testing model performance[73]. A fourth type of uncertainty relevant in formal modelling

66 For this distinction in uncertainty in model quantities and uncertainty about model form, see (Morgan and Henrion 1990).

67 Compare (Alcamo and Bartnicki 1987; Beck 1987).

68 Compare (Funtowicz and Ravetz 1990; van der Sluijs and Schulte Fischedick 1997; Vesely and Rasmuson 1984)

69 See (Alcamo and Bartnicki 1987; Beck 1987; Morgan and Henrion 1990)

70 Also referred to as 'functional error' (i.e. uncertainty about the nature of the functional relations) (EnvironmentalResources 1985)

71 See (Rotmans et al. 1994) for a discussion on validation in the context of Integrated Assessment models.

72 (Oreskes et al. 1994). (Funtowicz and Ravetz 1993a) argue that due to the materialisation of inherent uncertainty into (mathematical and computer) models, these models are essentially untestable.

73 Note from anonymous reviewer of (Rotmans and van Asselt 2000)

includes so-called model operation uncertainties[74]. These uncertainties occur partly due to the hidden flaws in the technical equipment (especially numerical errors and bugs in hard- and software[75]), but above all due to accumulation of uncertainties propagated through the model[76].

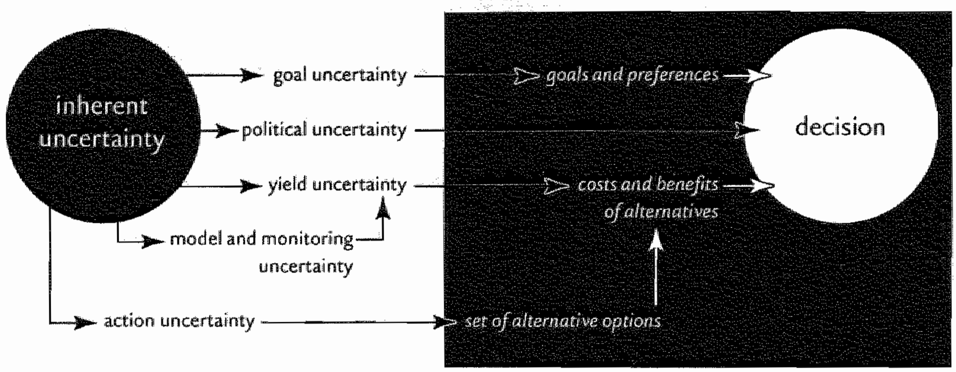

FIGURE 4 Uncertainty in the decision-making process

Another typology of uncertainty relevant in the context of science for decision-support is a classification of uncertainty by its focus in the decision-making process[77] (see Figure 4 and 5). Due to inherent uncertainty, a decision-maker may be uncertain with respect to the composition of the set of alternative options[78] (action uncertainty) and the costs and benefits of those alternatives[79] (yield uncertainty[80]). Model and monitoring uncertainty, i.e. the decision-makers' doubt on the validity of the model and the data sets that they employ, may contribute to yield uncertainty. Another focus of uncertainty relevant in the decision-making process is goal uncertainty[81], i.e. uncertainty or ambiguity about the preferences or goals the decision-maker aims to satisfy. Because there are so many conflicting objectives, priorities and interests, there is furthermore political uncertainty[82] complicating decision-making. Political uncertainty means that the decision-maker struggles with uncertainty as to the political acceptability of options in the relevant decision-forum[83].

74 (Alcamo and Bartnicki 1987).
75 (van der Sluijs 1997))
76 (Beck 1987; van Asselt and Rotmans 1996)
77 (van Witteloostuijn 1986)
78 See also (Scholz 1983)
79 See also (Scholz 1983)
80 According to (van Witteloostuijn 1987), yield uncertainty represents the traditional interpretation of uncertainty in economics as well as psychology.
81 Compare (March 1978)
82 see (Rosenhead 1989)
83 (Bressers and Hoppe 1998).

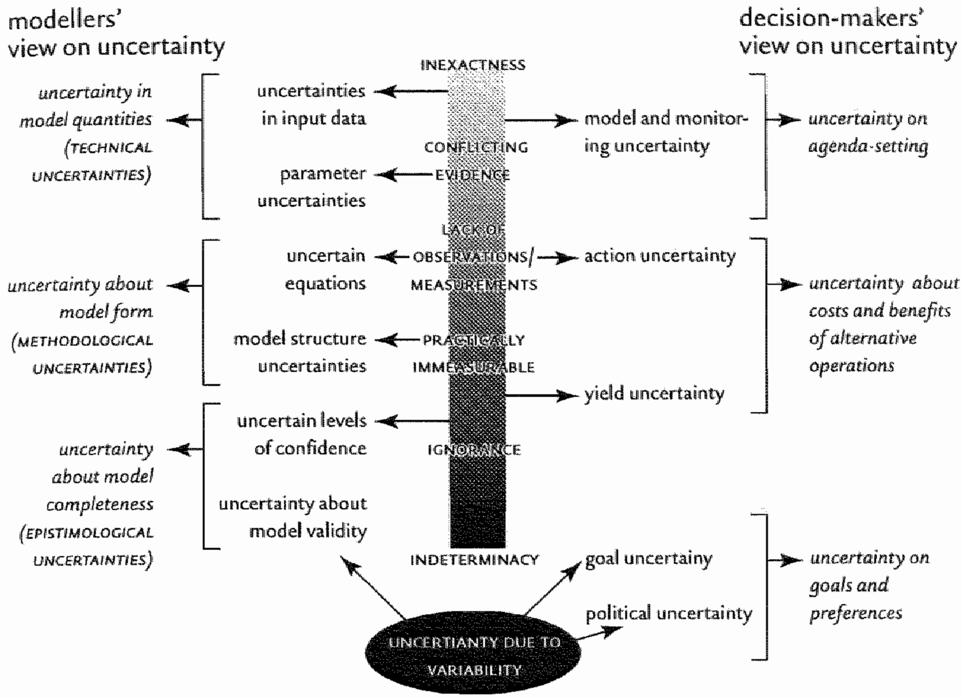

FIGURE 5 Uncertainty in the modeller's and decision-makers view

Various types of uncertainty in decision-making[84] may play a different role in the decision-making cycle[85]. Model and monitoring uncertainties are usually dominant in the ignition and agenda setting phase. Action and yield uncertainties may play a vital role in the assessment phase, while political uncertainties dominate in the actual decision-making process.

2.5. UNCERTAINTY, MEASURABILITY AND SUBJECTIVITY

Some uncertainties are measurable[86] and can be calculated, in the sense that they stem from well-understood systems or processes[87]. These uncertainties generally fall into the categories of technical uncertainties and uncertainty due to unreliability. This implies that either margins (in case of unreliability) or seasonalities can be established, so that

84 See also (van der Sluijs and Schulte Fischedick 1997) for a discussion of uncertainty related to the decision-making cycle.
85 (Hoogerwerf 1989; Winsemius 1986); See also Chapter 2.
86 (Knight 1921) argued that "it will appear that a measurable uncertainty (...) is so far different from an unmeasurable one that it is not in effect an uncertainty at all". He refers to measurable uncertainties as 'risk', however this use of the notion of risk differs fundamentally from the way it is used in this thesis (see Chapter 3B), that we simply refer to this type of uncertainty as measurable uncertainty.
87 Such measurable processes are also referred to as "ergodic processes" (see for example (Davidson 1983)).

the uncertainty can be described quantitatively (either in terms of a domain or as stochastic equation). However, trans-scientific questions by definition inhibit immeasurable uncertainties that are crucial for the analysis. Such immeasurable uncertainties are also referred to as "radical uncertainties"[88]. Radical uncertainties are thus uncertainties that can at best be roughly estimated. Radical uncertainties generally arise due to structural uncertainty and uncertainty due to variability. It is even likely that the most salient uncertainties in the analysis of trans-scientific questions are radical.

Assessment of complex, trans-scientific issues cannot be a purely objective exercise. Due to radical uncertainty, no analysis is possible without a long sequence of decisions based on the analysts' subjective judgement[89]. Subjectivity affects the way analysts deal with uncertainty. It enters the stage already in the conceptual phase in deciding which elements will be included in the assessment, and which will be left out. Decisions in formal modelling involving subjectivity[90] range from which value is used for uncertain parameters to the choice of algorithms, from the treatment of problematic data sets to definitions of functional forms.

Inherent uncertainty thus evokes subjectivity in the assessment process. On the other hand, subjective judgements in the analysis will result in value diversity, which is a source of variability. This implies that an analyst studying and interpreting inherent uncertainty also contributes to inherent uncertainty. Furthermore, it is beyond the human capability to deal with all the phenomena at one time simultaneously. Also in Integrated Assessment, fragmentations are made to describe the physical and social reality. However, these fragmentations are in itself sources of uncertainty, because it is not possible to construct a system that in reality is not influenced by its surroundings, or from which the relationships between the system and the surroundings are completely known or controllable. So the analysts are themselves a source of inherent uncertainty in science[91].

Furthermore, stakeholders participating in the IA process[92] will apply different value systems. So value diversity and associated subjectivity are both a consequence of, and input to, the IA process. The mutual interplay between inherent uncertainty and the IA process is visualised in Figure 6.

88 (Funtowicz and Ravetz 1993a)
89 See (Funtowicz and Ravetz 1990; 1993a; Keepin and Wynne 1984; Lave and Dowlatabadi 1993; Morgan and Henrion 1990; Robinson 1991; Shackley and Wynne 1995).
90 (Pahl-Wostl et al. 1998)
91 (Rohen 1988)
92 See Chapter 2.

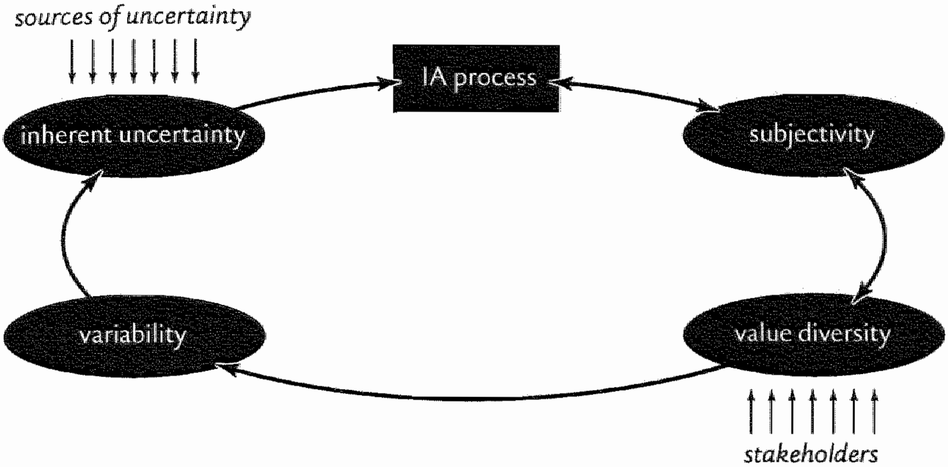

FIGURE 6 Mutual interplay between inherent uncertainty and the IA process

3. State of the art in uncertainty analysis

A better understanding of, and insight in, uncertainty by means of a taxonomy enables structured thinking about how to deal with uncertainty in the analysis of complex issues in general and in Integrated Assessment in particular. In this section, we will discuss methods for uncertainty analysis currently in use, in the light of the above taxonomy of sources of uncertainty.

We can distinguish between quantitative and qualitative approaches for dealing with uncertainty in science for decision-support. Quantitative approaches to uncertainty analysis are used in combination with formal models. In the following, we would like to illustrate quantitative approaches to uncertainty by means of the current practise in Integrated Assessment modelling. Integrated Assessment Models (IAMs)[93] are built to address trans-scientific questions on complex issues. As a consequence, such models describe inherently uncertain systems. Furthermore, as IAMs are end-to-end approaches, they suffer from accumulation of uncertainty propagated throughout the models. Last but not least, the majority of these models are used for forecasting purposes, which introduces another level of uncertainty. In sum, these models inhibit different types of uncertainties that arise from different sources. As a consequence, such models are no truth-machines, but act as heuristic tools for systematic exploration of complex issues.

93 See Chapter 2 for an overview of IAMs.

In view of the above, the logical next question is then 'how is uncertainty managed in IA modelling?'. O'Neill[94] appears to have been the first to call for uncertainty analysis in the context of environmental modelling[95], which is one of the roots of Integrated Assessment modelling. Since then more and more attention is paid how to deal with uncertainty in integrated modelling.

The aim of current uncertainty analysis in Integrated Assessment modelling is to evaluate to what extent particular uncertainties impact upon the conclusions. The standard practise is that uncertainty analysis is performed as a final step in the model cycle. The following approaches are currently used for uncertainty analysis in IA modelling[96]:

- sensitivity analysis
- probability-based methods
- formal scenario analysis
- hedging-oriented methods
- validation

The different approaches will be discussed below, especially in relation to the various types and sources of uncertainty.

3.1. SENSITIVITY ANALYSIS

Sensitivity analysis is the study of the influence of variations in model parameters and initial values on model outcomes[97]. In order to determine whether these variables have a significant effect on the model output, and to determine their relative importance, statistical techniques are usually applied in sensitivity analysis. Some methods for sensitivity analysis are individual parameter variation, differential sensitivity analysis, response-surface method[98] and meta modelling[99]. Standard software packages, employing these methods, are widely available.

The role of sensitivity analysis in the context of uncertainty analysis is to estimate the relative importance of uncertain parameters and initial values on the model output. However, one has to realise that there is not a one-to-one mapping possible from the degree of sensitivity to the salience of the uncertainty. Sensitivity analysis

94 (O'Neill 1971; O'Neill and Gardner 1979)
95 (Hettelingh 1989)
96 Compare (Kann 1998)
97 (Janssen et al. 1990; Rohen 1988).
98 See (Iman et al. 1981; Janssen et al. 1990) for a comprehensive discussion on various methods for sensitivity analysis.
99 See for an example (Braddock et al. 1994).

does nothing more and nothing less, than providing insights of the role of uncertain parameters and initial values in model runs.

3.2. PROBABILITY-BASED METHODS

In economics, engineering and psychology, the probability concept is advanced as the formal representation of uncertainty that can be dealt with in a mathematical manner. Probability is not uniquely defined. The most frequently used probabilistic approach in IA modelling is the Bayesian approach[100], in which probabilities are interpreted as subjective "degrees of beliefs". The information required to apply probability calculus are distributions for uncertain inputs/parameter, which expresses how likely the analyst or group of experts[101] considers a particular value for that variable. The uncertainty expressed in this way is propagated through the model, so that the output variables also feature probability distributions[102] or statistical measures as the 95-percentile (see Box 1). Usually 'intelligent' sampling techniques, generally Monte Carlo techniques[103], are applied to reduce the computing requirements.

Probability-based methods thus give an indication of the likelihood of outputs dependent on the (subjective) likelihood attached to uncertain model inputs/parameters. Probability-based methods solely address uncertainty in model quantities and ignore uncertainty in model structure. In case of lack of knowledge beyond the level of inexactness, it is questionable whether probability distributions can cover the range of possibilities. In practise, modellers apply uniform distributions, because probability distributions are unknown. Furthermore, the method requires a complete covariance matrix, but in many cases the correlations between the uncertainties are unknown[104]. This means that the outputs do not signify the probability of a certain development or event in reality, but merely indicate how the model propagates probability distributions.

100 The fundamentals of the Bayesian approach are explained in: e.g. (Bayes 1763; Marshak 1955; Savage 1962).

101 Examples of IA modelling project in which probability distributions were derived from elicitation processes within a group of experts are: (Morgan and Keith 1995; Nordhaus 1994).

102 See (Dowlatabadi and Morgan 1993) for an example of such a probability-based uncertainty analysis in Integrated Assessment modelling.

103 See (Fedra 1983) for an elaboration of the use of Monte Carlo methods as uncertainty analysis in envrionmental modelling.

104 (Rohen 1988).

BOX 1 Results of probability-based uncertainty analysis

The different outcomes of a large set of model runs performed with probability-based techniques are collected and aggregated in terms of 95-percentiles (see Figure 7 for an example). This range has just statistical meaning; namely it indicates the range that comprises the trajectories of 95% of the outcomes. The remaining 2.5% beyond both the upper and lower bound are considered to be 'outliers' that should not be taken into account. Apart from this statistical meaning the upper and lower bound as well as the range in between do not explain the adopted interpretation of the underlying uncertainties.

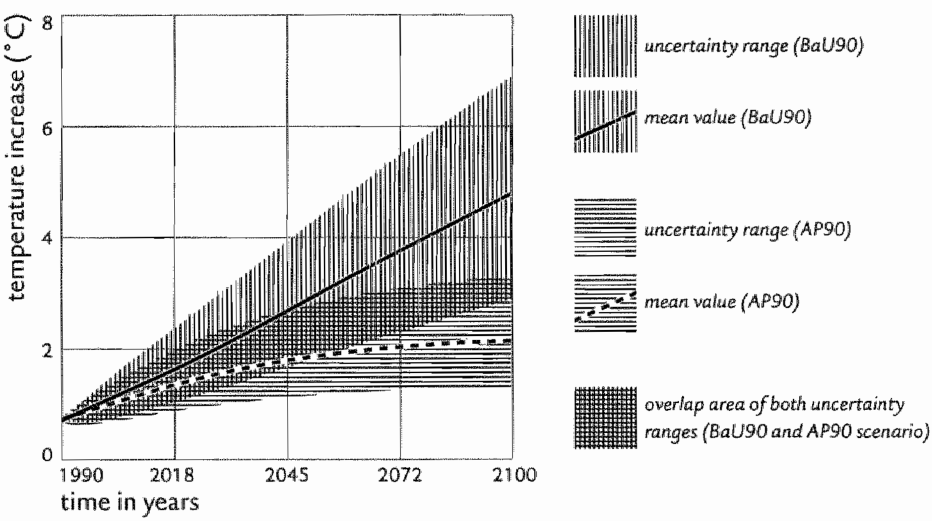

FIGURE 7 Output associated with current methods for formal uncertainty analysis (based on den Elzen 1994)

3.3. FORMAL SCENARIO ANALYSIS

Formal scenario analysis involves assessing sets of different assumptions of possible future states, which are parameterised in the model. Scenario analysis thus implies performing model runs for sets of parameter values and/or time-series, and comparing the results. Scenario analysis aims to investigate interesting, meaningful and varied future states, and in that way in terms of uncertainty analysis it has a considerable advantage above random sampling methods. Table 1 gives an example of the kind of scenario-variables currently used in IA modelling. These variables are central in the scenario-analysis involving the use of different IA-models[105] in the context of the IPCC Third Assessment report process.

Scenario variables
Population (humans)
GNP ($)
GNP/capita ($/cap)
Energy intensity (MJ/$)
Forests (ha)

table 1 Scenario-variables as proposed by scenario-working group in IPCC third Assessment Report process (preliminary version)[106]

In performing scenario analysis, IA modellers implicitly or explicitly draw the distinction between scientific uncertainties occurring in the environmental system and socio-economic uncertainties. The latter are uncertainties occurring in the human system, e.g. with respect to future geopolitical, socio-economic and demographic developments[107]. As the IPCC example illustrates, scenario input sets used in Integrated Assessment modelling merely comprise socio-economic variables. Used in this way, scenario-analysis merely addresses uncertainties in model inputs. In terms of the above distinction, this means that scenarios created in this way assess the consequences of socio-economic uncertainties on projections for the environmental system, but they neglect the scientific uncertainties in the environmental system itself.

Furthermore, scenario-analysis exercises quite often fall in the attractive pitfall to classify one of the scenarios as the most likely scenario or best-guess scenario. In this way the output of scenario-analysis then mask inherent uncertainty, which was originally the starting-point of the analysis.

105 Namely AIM Maria, IMAGE 2, IIASA Message, ASF, MiniCam
106 As presented by Dr. Hugh Pitcher at the Association of American Geographers meeting on Integrated Assessment in Washington D.C. (9-10 July 1998). See also IPCC Open process website: http://sres.ciesin.org/sres/
107 See for example (Rotmans et al. 1994).
108 (Kann 1998)

3.4. HEDGING-ORIENTED METHODS

This class of method is the most recent approach for dealing with uncertainty in Integrated Assessment models. Hedging can be viewed as building contingency plans and responding to opportunities and risks, as they become apparent[108]. Hedging-oriented methods aim to identify strategies, which balance the risks of waiting with premature action[109]. In this type of modelling, the value of decision-variables in the model is determined based on a joint distribution on the possible outcomes that may occur in the next period. This approach does not assume that uncertainty is completely resolved at a certain point in time, but rather that due to progress in knowledge a probability distribution is adjusted. In this approach, the adjustment of probability distributions of the outcomes is central. Such distributions can either be inspired by probability-based methods (see above) or subjectively determined by the analysts. By using outputs derived from probability-based methods, hedging-oriented exercises inherit the disadvantage of solely addressing uncertainties in model inputs. However, hedging-oriented techniques are slightly more sophisticated than the previous methods for quantitative uncertainty analysis, because they do not only address uncertainty in the model, but by incorporating action and yield uncertainties, they also try to keep uncertainties within bounds of credibility for decision-makers. In other words, these techniques are not just about analysing uncertainty; they are about bounding uncertainty[110].

3.5. VALIDATION

It is unusual to place validation approaches under the heading of uncertainty analysis. Validation implies testing model performance. With validation techniques, modellers aim to assess to what extent the model is an adequate representation of reality, and as a derivative to what extent it is in accordance with empirical observations and theoretical insights. In terms of our typology of uncertainty, validation is the analysis of uncertainty on model completeness, which type of uncertainty is caused by ignorance, indeterminacy and variability. In this broader perspective, it is therefore legitimate to consider validation as uncertainty analysis.

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109 (Manne and Richels 1995).

110 (Bressers and Hoppe 1998)

PERSPECTIVES ON UNCERTAINTY AND RISK

Because validation is used in combination with modelling, it is described under formal uncertainty analysis. However, validation may be semi-quantitative and/or participatory. Approaches employed for validation comprise review meetings, comparison with data not used for calibration, comparison with other models and model outputs, and the so-called Strategic Cycling Approach[111]. The latter involves iterative cycling between large-scale and small-scale assessments.

A qualified validation exercise should yield insights in how well the model matches observations and hypotheses. It aims to confirm the model by demonstrating agreement between observations and the model 'predictions', but such a confirmation is anyhow inherently partial[112]. That does not necessarily imply that the model is complete enough or whether it is an adequate representation of reality. Models can only be evaluated in relative terms. Validation exercises, which in principle address the epistemological dimension, are not systematically used to assess and discuss radical uncertainties. The results of validation are generally solely used to 'sell' the model as being scientifically credible.

3.6. QUALITATIVE UNCERTAINTY ANALYSIS

The term 'uncertainty analysis' is generally confined to quantitative approaches. However, there are good reasons to classify qualitative (or narrative) scenario development, interactive problem and uncertainty structuring, and the NUSAP method as uncertainty analysis techniques. These methodologies share a focus on uncertainty and ways of managing it: they do not seek to analyse uncertainty by scientific means alone. Only qualitative scenario-development is currently really applied in the context of Integrated Assessment. Van der Sluijs[113] proposed a procedure for applying NUSAP in Integrated Assessment modelling, but no applications followed so far. Interactive uncertainty and problem structuring is described to offer insight into qualitative uncertainty analysis methods currently available in neighbouring fields of science for policy.

Qualitative scenario-exercises take uncertainties in societal and environmental processes as starting point. The role of scenario-exercises is to imagine how these processes can develop. The ultimate challenge of scenario-development is to manage uncertainty by judging which mutually exclusive images of the future are possible in

111 (Root and Schneider 1995)
112 (Oreskes et al. 1994)
113 (van der Sluijs 1997)

the face of a given amount of knowledge and degree of uncertainty. The concept of scenario as a tool to explore the future came into use since the seminal publication of Kahn and Wiener in 1967[114]. Although many definitions of scenarios circulate, they share the following features[115]:

- scenarios are *hypothetical*, describing possible future pathways.
- scenarios describe *processes*, representing sequences of events over a period of time.
- scenarios consist of *states, events, actions and consequences* that are causally related by the above processes.
- scenarios start from an *initial state* (usually the present), depicting a *final state* at a fixed time horizon.

Qualitative scenario exercises are either developed by means of participatory approaches, or they are expert-based. In this way, scenarios in principle address uncertainty due to variability and lack of knowledge. However, actual scenario-studies[116] are often developed from a narrow, disciplinary-based perspective. Such studies employ in a limited set of standard assumptions, which are implicitly or explicitly treated as certainties[117]. Many narrative scenarios do have a 'business-as-usual' character, assuming those current conditions will continue for decades, thereby excluding variability and hiding ignorance and indeterminacy. Scenarios quite often do not incorporate surprises. Key assumptions and judgements are often not made explicit, so that it is difficult to trace back which salient uncertainties were the starting point for the scenario exercise and how the uncertainties were interpreted.

To illustrate the basic features of ***interactive uncertainty and problem structuring***, we describe two examples of methods that can be grouped under this heading: the strategic choice approach[118] and robustness analysis[119]. The reader should keep in mind that comparable approaches could be found under a variety of headings.

The strategic choice approach can be characterised as an interactive method for representing the structure of complex decision-making problems and the various sources of uncertainty, which make them difficult to resolve[120]. The strategic choice

114 (Kahn and Wiener 1967).
115 (Rotmans 1998b); see also Chapter 2.
116 See for example our evaluation of the last decade of European scenario-studies (van Asselt et al. 1998).
117 The famous economist (Keynes 1937) was one of the first scholars who explicitly stated that scientists tend to substitute certain conventions for the knowledge that is unattainable.
118 This description is based on the overview paper of (Friend 1989). See also (Friend and Hickling 1987).
119 This description is based on the overview papers of (Rosenhead 1989).
120 (EnvironmentalResources 1987; Hickling 1989; van de Graaf 1985) describe examples of the strategic choice approach to high-level national policy-making.

approach involves different stages, i.e. *shaping* the issue in terms of a complex of related problems, *designing* possible courses of action, *comparing* implications of different courses of action and *choosing* a strategy.

Robustness analysis[121] provides a framework to structure problem situations in which uncertainty is high, and where decisions can or must be staged sequentially. It is an approach to identify decisions early in the sequence, which keeps open a range of options for the future. The participatory process of robustness analysis involves *characterising* the decision-problem in terms of sequential stages, *valuation* of alternative initial decisions, *determining* sets of compatible initial decisions and future states, and *selecting* robust initial decisions.

Funtowicz and Ravetz[122] developed the ***NUSAP method*** as a scheme that would enable evaluation of uncertainties in such a way that both the quantitative and the qualitative aspects are addressed. NUSAP stands for Numeral, Unit, Spread, Assessment and Pedigree. The idea is to characterise each part of the analysis in these terms. Numerical, unit and spread are rather familiar concepts and enable to characterise estimate in quantitative terms. Assessment and Pedigree represent levels of uncertainty that go beyond technical uncertainties. They are the most qualitative categories in the scheme. See Box 2 for an application of the NUSAP scheme as a way to characterise uncertainties.

BOX 2 Application of NUSAP

The NUSAP method can be illustrated by means of an example[123], i.e. the economic value of shrimps in the wetlands in Louisiana[124]. A "willingness to pay" method was used to derive an estimate for the annual value per acre, i.e. \$10.85 (rounded of to one digit: 1*10 = 1 E1). The shrimp production estimate was based on a theoretical model relating wetland area to shrimp catch, using statistical data from the National Marine Fisheries and a regression analysis procedure that has high peer acceptance. Pedigree was determined by using Table 2.

see over »

121 Examples of applications of this approach: breweries (Gupta and Rosenhead 1968), chemical plants (Caplin and Kornbluth 1975) and health systems (Best et al. 1986).

122 (Funtowicz and Ravetz 1990)

BOX 2

code	Quality of model/ theoretical structure	Quality of data	Degree of peer acceptance
4	Established theory	Experimental data	Total
3	Theoretical model	Historical/field data	High
2	Computational model	Calculated data	Medium
1	Statistical processing	Educated guesses	Low
0	Definitions	Uneducated guesses	None

TABLE 2 Pedigree matrix

The assessment grade is based on the average codes in the pedigree (i.e. the sum of the codes divided by the maximum grade (i.e. 12)). The full NUSAP representation of the willingness-to-pay estimate for shrimps in the wetlands in Louisiana then holds:

N:U:S:A:P = 1 E1: $/acre/year : ± 10% : 0.7 : (3,3,3)

The willingness-to-pay estimates for menhaden, oyster and blue crab can be represented in the same way. Funtowicz and Ravetz building upon work done by Costanza and colleagues[125] gave the following estimates:

Element	Numeral	Unit	Spread	Assessment	Pedigree
Shrimp	1 E1	$/acre/year	± 10%	0.7	(3,3,3)
Menhaden	6 E0	$/acre/year	± 20%	0.5	(2,2,2)
Oyster	8 E0	$/acre/year	± 30%	0.6	(2,3,2)
Blue crab	1 E0	$/acre/year	± 40%	0.6	(3,2,3)

TABLE 3 NUSAP representation of elements of fishery in wetlands in Louisiana

Funtowicz and Ravetz used these grades to determine the NUSAP score for the total commercial value of fishery on these four kinds of fish. Numeral is the sum of the numeral of the components, i.e. N:U = 2.5 E1 : $/acre/year. Its Spread is defined as the weighted average of the percentage spreads of the elements, i.e. total sum of Numeral multiplied by Spread of the components divided by Numeral of fishery:

(1E1 * 0.1 + 6E0 * 0.2 + 8E0 * 0.3 + 1E0 * 0.4)/ 2.5 E1 = 0.2 = ± 20%

see over »

123 (Funtowicz and Ravetz 1990) p. 195-197
124 Building upon research done by (Farber and Costanza 1987) and (Costanza et al. 1989).
125 Ibid.

BOX 2

and the grade for Assessment is determined as the weighted average of its component grades, i.e. total sum of Numeral multiplied by Assessment per component divided by Numeral of fishery:

$$(1E1 * 0.7 + 6E0 * 0.5 + 8E0 * 0.6 + 1E0 * 0.6) / 2.5\,E1 = 0.6$$

So the NUSA(P) representation for the total commercial value of fishery in wetlands of Louisiana according to these calculations holds:
N:U:S:A = 2.5 E1: $/acre/year : ± 20% : 0.6

The advantage of the NUSAP-method is that it enables to characterise the quantitative, the qualitative, and the subjective aspects of uncertainty in a formal way. The disadvantage is that it concentrates on uncertainty in variables and it does not address uncertainty in relationships between different variables. Furthermore, notwithstanding its usefulness to roughly characterise salient uncertainties, performing a comprehensive NUSAP is probably a rather time-consuming effort. Last but not least, the question is how to interpret the results. NUSAP produces a judgement of the analysis in terms of "how (un)certain are the underlying sources?". But does this imply that an analysis that solely includes uncertainties with low spread and high grades on assessment and pedigree is 'better' than an analysis that includes uncertainties with high spread, and low grades on assessment and pedigree? Van der Sluijs[126] interprets NUSAP in the context of Integrated Assessment modelling in this way, with the implication that modellers who restrict themselves to 'hard' data and certain equations are 'rewarded' with a high NUSAP grade. The consequence is that from this NUSAP perspective uncertainty-avoiding behaviour of the positivist scientist turns out to be the 'best' strategy. However, NUSAP has been developed in the context of post-normal science that argues that uncertainty is inherent in Integrated Assessment and that it should be at the heart of the analysis. So it can never be the intention that NUSAP reinforces the positivist paradigm. So apart from the practi-

126 (van der Sluijs 1997)

cal limitations to NUSAP, there is a fundamental question how to use this approach as tool for uncertainty analysis.

3.7. LIMITS

Because uncertainty is multi-dimensional, it is unlikely that a single approach will suffice to capture all the salient forces of uncertainty[127]. Different approaches address different types and sources of uncertainty in different ways. If we use the above classification of types of uncertainty in modelling, Table 4 summarises which types of uncertainty are analysed by the discussed methods. Table 5 summarises which sources of uncertainty can be addressed by the above approaches. We make the reservation that not all methods in any application are currently used to such a full extent. In Table 5 NUSAP is not mentioned, because it is actually a method to articulate sources of uncertainty and the degree of uncertainty in the components of the analysis.

A complementary use of various methods is needed in order to be able to provide a comprehensive insight into the extent and the scope of uncertainty. Such combinations of uncertainty analysis methods are applied in Integrated Assessment modelling. For example, as follows from the description above, hedging-oriented

uncertainty		**method**
uncertainty in model quantities	uncertainties in input data	• sensitivity analysis • probability-based methods • formal scenario-analysis • hedging-oriented methods • NUSAP
	parameter uncertainties	• sensitivity analysis • probability-based methods • hedging-oriented methods • NUSAP
uncertainty about model form	uncertain equations	• sensitivity analysis in the form of meta-modelling
	model structure uncertainties	*no methods*
uncertainty on model completeness	uncertain levels of confidence	• NUSAP
	uncertainty about model validity	• validation

TABLE 4 (ABOVE AND RIGHT) Methods of uncertainty analysis in terms of types of uncertainty

127 (Boritz 1990)

methods are combined with probability-based methods. Sensitivity analysis is quite often used to filter out those uncertain parameters that will be subjected to probability-based uncertainty analysis. Exploratory modelling[128] is an example of an approach that explicitly aims to incorporate a combination of the above methods in order to address uncertainty explicitly. In its general form it combines sensitivity analysis with both quantitative and qualitative scenario approaches and it is usually applied in a participatory set-up.

However, even if the available methods for uncertainty analysis are combined in a systematic manner, crucial sources and types of uncertainty are ignored as become apparent in Table 4 and 5. The current methods suffer from the fact that they only address uncertainties in model quantities and neglect the structure of the model itself. In doing so, significant uncertainties are 'exogenised' and thereby become invisible[129]. Current uncertainty analysis techniques thus merely address technical uncertainties. Furthermore, sources of variability are difficult to address with the current methods. Scenario approaches in principle allow inclusion of behavioural variability and societal randomness, however in practise this is seldom the case. As can be concluded from Table 5, there are no methods available yet to deal with value diversity and technological surprise in Integrated Assessment.

output
• role of uncertainties in input data in model run • propagation of probabilities in input data to outcomes • effects from uncertain socio-economic inputs on outcomes • assessing effects uncertainty reduction in input data • insight in the qualitative and quantitative nature of the uncertainty in the inputs
• role of uncertainties in parameters in model runs • propagation of probabilities in parameters to outcomes • assessing effects uncertainty reduction in parameters • insight in the qualitative and quantitative nature of the uncertainty in the parameters
insights into crucial equations
insight in the level of confidence in terms of the quality of the underlying sources
insights in model performance

128 (Bankes 1994; Lempert 1996; Lempert and Bonomo 1998)
129 (Wynne 1992)

source	method
Inexactness	• Probability-based methods • Formal scenario-analysis
Lack of observations/ measurements	• Probability-based methods • Formal scenario-analysis • Hedging-oriented methods
Practically immeasurable	• Probability-based methods • Formal scenario analysis • Hedging-oriented methods
Conflicting evidence	• Formal scenario-analysis • Hedging-oriented methods
Ignorance	• Validation • Qualitative scenario-development • Interactive problem and uncertainty structuring
Indeterminacy	• Interactive problem and uncertainty structuring • Qualitative scenario-development
Natural randomness	*Stochastic modelling*[130]
Value diversity	*no methods*
Behavioural variability	Scenario-approaches
Societal randomness	Scenario-approaches
Technological surprise	*no methods*

TABLE 5 Potential of discussed methods in addressing different sources of uncertainty

At the moment, uncertainty is not at the heart of scientific assessment. Notwithstanding modellers' claims, in the practise of Integrated Assessment modelling, uncertainty is treated as a marginal issue that could unfortunately not be resolved yet. Uncertainty is treated as if it were an additional physical variable[131], as a mathematical artefact. Current uncertainty analysis techniques implicitly inherit positivist thinking; i.e. these methods remain ambiguous as to the acknowledgement of subjectivity and inherent uncertainty. Uncertainty analysis merely involves evaluation of the impacts of 'certain uncertainties', i.e. uncertainties for which estimates or probability distributions are available. The more fundamental, and probably the most salient, uncertainties are ignored. As a consequence, formal uncertainty analysis is in a sense hiding inherent uncertainty.

On the other hand, the inevitability of uncertainty is increasingly recognised in the IA community. But the formal uncertainty analysis techniques applied originate from principles that are incompatible with this recognition of inherent uncertainty.

130 Not mentioned thus far, because it is too specific to treat it on a similar level as the other uncertainty analysis methods.
131 (Funtowicz and Ravetz 1993a)

The available formal techniques do not allow addressing inherent uncertainty adequately. The use of qualitative methods for uncertainty analysis in Integrated Assessment is relatively rare. Only qualitative scenario-development is used, but in a very limited manner. The present situation in IA can therefore be characterised by the tension between objectivity and truth as guiding principles for actual uncertainty analysis on the one hand and the recognition of the inevitable uncertainty on the other hand[132].

To date, there is no alternative crystallised portfolio of methods that enables conscious integrated assessors to deal adequately with inherent uncertainty in their daily practise. There is no ready-made kit of tools, recipes, techniques and models available.

The above evaluation teaches us that as uncertain situations become more imminent, the ability to analyse uncertainty decreases[133]. We conclude that:

> *Uncertainty analysis lacks a tool-kit that enables to address salient technical, methodological and epistemological uncertainties in an adequate manner as the central activity in scientific assessment*[134].

As a consequence of the above inconsistency between epistemological principles and the tools and methods used, it is even more difficult to discuss the relative value of scientific insights with societal actors. Current methods give them no indication regarding the magnitude and the sources of the underlying uncertainties, with NUSAP as notable exception. The way scientists handle uncertainty affects the manner in which they communicate lack of knowledge and variability to the public[135]. Furthermore, scientists fail to translate uncertainty into notions that are understandable by non-scientists, and vice versa. Such communication problems in explaining uncertain results and in interpreting characterisations of uncertainty are referred to as "translational uncertainties"[136].

132 (Funtowicz and Ravetz 1994) provide an interesting case-study of the kind of contradictions that yield from this tension between epistemology and practise.

133 Compare (Rowe 1994)

134 Compare (Dovers and Handmer 1992) who argue that "If science relies on the existing toolkit of ideas and approaches (to deal with uncertainty and risk, mva), then it will fail the urgent demands of policy". Compare (Ermoliev 1993) who argues that in order to encourage decision-makers to act in face of inherent uncertainty "we need appropriate tools to explicitly treat the uncertainties involved".

135 (O'Riordan et al. 1997)

136 (Rowe 1994)

4. Towards uncertainty management

If we do not change the way uncertainty is treated in science for decision-making, uncertainty is a problem that has the potential to sap the role science may play in facilitating decision-making processes. Uncertainty can also be considered as a challenge, and as an invitation to develop new approaches. Suggestions for how science may play a relevant and useful role in society within its inherent limits are provided in the scholarly literature under denominators as trans-science, realism and post-normal science. These attempts share that they aim to reconcile the notion to improve the scientific basis for decision-making (which is actually a remainder of the positivist model of science)[137] with the constructed character of that scientific basis (which is the central claim of the conventionalist model of science) [138].

The aim then has to shift from analysing the impact of uncertainty on the conclusions to treating uncertainty as intrinsic and key facet of the issue under concern. Uncertainty should not longer be treated as marginal issue or a closing entry in the analysis, but it should be at the heart of the assessment[139]. In this perspective, science is no longer understood as steadily advancing certainty of knowledge. Science for decision-making is conceived as a search process that aims to provide insights that facilitate conscious acting in an uncertain world. This implies a switch from the technical discourse of problem-solving and definite answers, to puzzling and insights. In order to mark this shift in orientation, the notion 'uncertainty-management' is introduced[140].

Uncertainty management should encompass the various types and sources of uncertainty in an adequate manner. Due to inherent uncertainty, bias is pervasive in the analysis of trans-scientific issues. It is expert judgement, but judgement nevertheless. For example, Lave and Dowlatabadi[141] argued that the actual estimates of the effects of climate change on people and the environment "depends on whether one is optimistic, moderate or pessimistic". An important step towards uncertainty management is the acknowledgement of irreducible subjective diversity in science[142].

137 See (van der Sluijs and Schulte Fischedick 1997)
138 Phrasing inspired by (Jasanoff 1990). See also (Nowotny 1987) (Funtowicz and Ravetz 1993a).
139 (Funtowicz and Ravetz 1993a)
140 (Funtowicz and Ravetz 1990) use the notion of uncertainty management to mark this switch, however without explicitly defining it.
141 (Lave and Dowlatabadi 1993)
142 Wording inspired by Hadi Dowlatabadi, personal communication.

Funtowicz and Ravetz[143] argue that quality assurance[144] and the fostering of skills necessary for this are crucial elements in uncertainty management. The issue of quality assurance is usually ignored in dealing with uncertainty. And it is furthermore not well understood that uncertainty and quality are two distinct attributes. High quality does not imply low uncertainty and vice versa. Information of lesser certainty may be yet of good quality for its intended function. Building upon Funtowicz and Ravetz[145], quality can be defined as "the totality of characteristics of a particular process-product combination that bears its ability to satisfy an established use". In the context of uncertainty management, quality implies that the salient uncertainties crucial for the decision-making process are considered and that legitimate interpretations of these uncertainties are brought to the fore.

Uncertainty management can then be defined as an approach to decision-support that reasons from inherent uncertainty and that provides a framework in which the salient uncertainties are used as building blocks to arrive at insights relevant for the decision-making process. The ultimate aim of uncertainty management is to facilitate the search for the most robust alternative. Robust implies that the identified strategy is one that appears to trigger a favourable future, that seems to avoid highly undesirable ones, and that is flexible enough to be changed or reversed if new insights emerge[146].

In the following, we aim to provide concrete suggestions for uncertainty management. To that end, we will suggest approaches for selecting salient uncertainties, i.e. the key items of the analysis, and we will argue how a pluralistic approach enables to deal with value diversity and subjectivity in an adequate and constructive manner.

4.1. APPROACHES TO SELECTING SALIENT UNCERTAINTIES

Probably, it is not worthwhile investing serious efforts in analysing uncertainties of lower salience, as long as the more salient ones remain. So the first step towards uncertainty management is a heuristic that enables to select the most salient ones. Checklists have been proposed to rank uncertainties in terms of salience[147]. In earlier work[148], we proposed to use magnitude, degree and time-variability as indicators of importance:

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143 E.g. (Funtowicz and Ravetz 1990). They summarise their approach to quality assurance as the 'p-4 approach', i.e. four components have to be considered: the purpose, the person, the process and the product.

144 See also Chapter 2.

145 (Funtowicz and Ravetz 1990) (Funtowicz and Ravetz 1993b)

146 Compare (Collingridge 1980) (Colglazier 1991)and (Lempert and Bonomo 1998).

147 See for example (de Marchi et al. 1993)

148 (van Asselt and Rotmans 1995)

- ***magnitude***: the relative contribution of the specific uncertain component to the uncertainty of the full analysis.
- ***degree***: the range of uncertainty of a specific component of the analysis.
- ***time-variability***: whether the rate of uncertainty is fluctuating over time.

The three indicators can be used to assess the components of the analysis in a qualitative way[149]. Using Table 6 the components can be classified as uncertainties of low, middle and high importance.

magnitude	degree	time-variability	importance
large	high	high/medium/low	HIGH
large	medium	high/medium	
large	low	high	
medium	high	high/medium	
medium	medium	medium	
large	medium	low	MEDIUM
large	low	medium/low	
medium	high	high/medium/low	
medium	medium	medium	
small	high	high/medium	
medium	medium/low	low	LOW
small	high	low	
small	medium	high/medium/low	
small	low	high/medium/low	

TABLE 6 Classification of importance[150]

As argued in the section on formal uncertainty analysis, sensitivity analysis may be useful in this ranking effort. Inspired by post-normal science reasoning, Van der Sluys[151] proposed a participatory sensitivity analysis that can be used in a selection process (see Figure 8).

We have to realise that due to the nature of uncertainty, ranking the most salient uncertainties is always a judgmental exercise, notwithstanding the usefulness of checklists and techniques for sensitivity analysis for doing it in a systematic way.

149 I.e. for each indicator we used three classes, i.e. *small*, *medium* and *large* for magnitude, and *low*, *medium* and *high* for degree and time variability. Magnitude is weighted highest, then degree and than time-variability.

150 Source: (van Asselt and Rotmans 1995)

151 (van der Sluijs 1997)

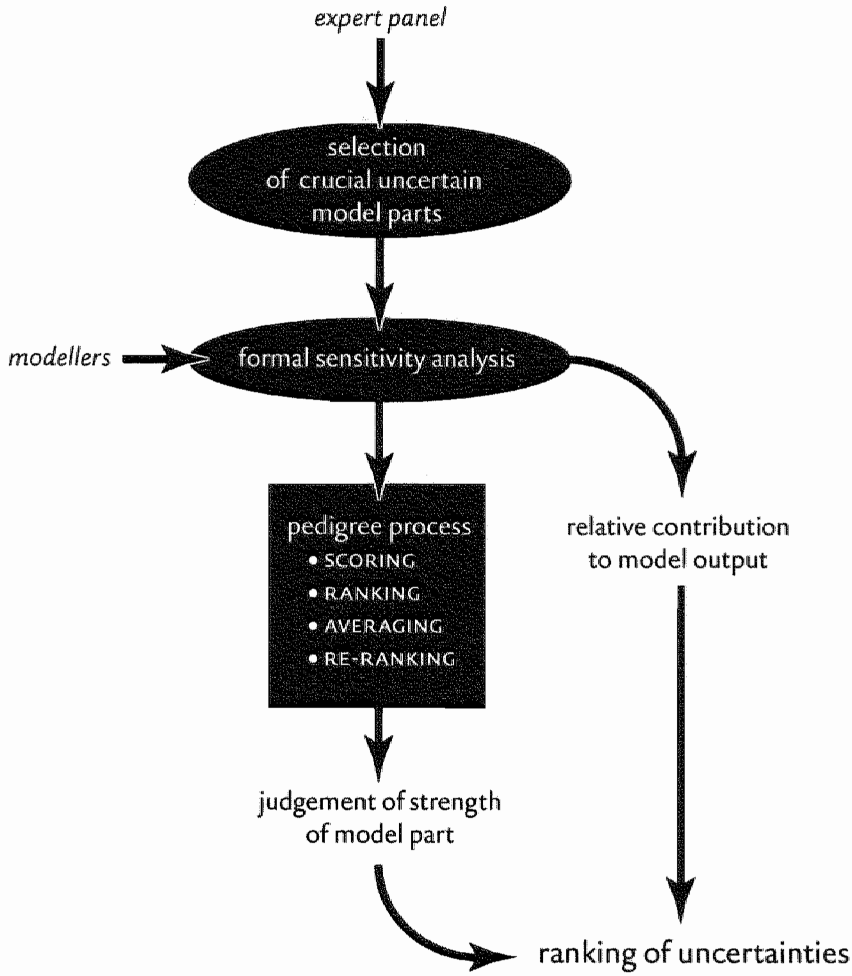

FIGURE 8 Participatory sensitivity analysis as derived from van der Sluijs (1997)

4.2. SUBJECTIVITY, CONTROVERSY AND PLURALISM

In case of value diversity, scientific disagreement and controversy are persistent. Scientific disagreement on its turn encourages controversy, because it enables different stakeholders to arrive at competing scientific conclusions[152]. Furthermore, scientific consensus on trans-scientific issues has often been wrong[153]. Due to inherent uncertainty, controversy should not be treated as something that should or could be avoided. In face of inherent uncertainty, scientific consensus is not a substitute for

152 See (Jasanoff 1990)
153 (Colglazier 1991)

knowledge[154]. Controversy involves counterfactual arguments that articulate uncertain and inadequate knowledge[155]. Controversy between schools of thought and types of knowledge are signals of inherent uncertainty. Taking this into account, controversy can be used in a constructive manner to identify disagreement, and thereby different interpretations of the underlying uncertainties. Analysis of controversy is one way to grasp uncertainties and different legitimate perceptions composed of facts and coloured interpretations of uncertainty[156].

Since the 1970s, procedural suggestions have been made to deal with scientific disagreement and inherent controversy. The common denominator is that scientific controversy should be openly admitted. In the 1970s, the idea of a Science Court was launched[157], i.e. an occasional body analogous to a law court, where scientists from different fields would reach consensus on the basis of the best available evidence and the most plausible argumentation. Weinberg[158], for example, argued that a type of adversary procedure seems to be the best alternative, involving face-to-face confrontation, juxtaposing experts and counter-experts, and opportunity for cross-examination[159]. The idea did not develop into standard practise, but it is still an inspiring analogy in the Integrated Assessment community[160].

Reasoning from value diversity and subjectivity, we argue that a science has to accept the differences in perspectives, and utilise them consciously as resource. This requires willingness to open the scientific black boxes and to consider their internal construction[161]. In line herewith, we argue that uncertainty management should be pluralistic. This implies that uncertainties are considered from different legitimate perspectives in order to articulate multiple manifestations of a problem[162]. Such an approach is in line with the insight from social psychology[163] that biased interpretations are seldom fully arbitrary, but tend to relate to frames, value-systems or perspectives.

Regarding the controversy that transcends science and affects society, scientists can no longer deal with these issues alone. In such cases, not only the perspectives prevalent in the scientific community count. In addressing such unfamiliar issues sci-

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154 See, for example, (Keynes 1937), (Lave and Dowlatabadi 1993))
155 (von Schomberg 1993)
156 Compare (van Eeten 1999)
157 See (von Schomberg 1993) for a discussion on the concept of Science Court.
158 (Weinberg 1972)
159 See also (Weinberg 1972)
160 For example, during the meeting on Integrated Assessment organised by the American Association of Geographers (July 1998, Washington) Schlessinger suggested that an alternative way of dealing with controversy would be an analogy to the Supreme Court. Furthermore, in the original proposal for the ULYSSES project (Jaeger et al. 1995). The wording IA-juries was used to refer to the role of participatory Integrated Assessment.
161 (Wynne 1992)
162 Wording is inspired by Khalid Saeed, Symposium Environment, Energy and Economy: A sustainable future, Rome, 12-13 October 1998.
163 E.g. (Tversky and Kahneman 1974; 1980; 1981)

entists are like amateurs, with a training that is useful, but without a secure framework. Science is challenged to become conversant with mature citizens and to address certain of the public's legitimate demands. Knowledge then becomes alive by the force of conflict and contradiction[164]. It is argued that the different parties in the participatory processes should be granted equal power, and function like an externally 'extended peer-community'[165]. This implies that uncertainty management involves participatory processes including scientists, decision-makers, stakeholders and the general public[166].

In such a participatory process, qualified scientists possess unique knowledge and useful skills. According to Weinberg[167], scientists can and should inject some intellectual discipline into the, often chaotic, trans-scientific debates by:

- making the contestants (more) aware of the consequences of any decision and of alternatives,
- showing them what the implications are in terms of other values,
- ensuring that they are aware of the values implied in their choices.

It is beyond the scope of this Chapter, to discuss participation in depth[168]. We touch upon it, because it is an important feature of uncertainty management. In our attempt to sketch a framework for uncertainty management in the remaining of this Chapter, participation will be included as one of the constituting characteristics, without going into much details of implementation.

4.3. CHALLENGES FOR UNCERTAINTY MANAGEMENT

In sum, the state-of-the-art review of current methods for uncertainty analysis and scholarly thoughts on uncertainty management teaches us that the challenges for uncertainty management are:

- to develop methods for addressing methodological and epistemological uncertainties.
- such methods for uncertainty management have to be pluralistic (i.e. including different perspectives, expertise and counter-expertise).
- to seek ways for participatory uncertainty management.
- quality assurance is central to uncertainty management.
- to find ways to communicate uncertainty in a way understandable to non-scientists.

164 (Funtowicz and Ravetz 1993b)
165 (Funtowicz and Ravetz 1990; 1993b)
166 See, for example, (von Schomberg 1993) (Funtowicz and Ravetz 1993b), (Nowotny 1993), (O'Riordan et al. 1997)
167 (Weinberg 1972)
168 See Chapters 2, 3B and 5 for a more extended discussion on participation.

5. Perspective-based uncertainty management

Attempts have been made to incorporate multiple perspectives in Integrated Assessment modelling[169] as a way to assess the most salient uncertainties, both as manifested in model quantities and in model structure. Such a pluralistic approach implies that an IA model does not merely include one (hidden) perspective, but comprises a set of perspectives. Our contribution to this endeavour has been the development and application of 'multiple perspective-based model routes'[170]. In this approach uncertainty is "marked" and communicated by different interpretations according to different perspectives. A perspective is reflected in choices concerning model inputs, parameter choices, model structure and equations. In this way, experimenting with the model implies choosing among perspective-dependent options. A perspective-based model route is thus a chain of interpretations of the salient uncertainties coloured with the bias and preferences of a certain perspective. In this way, uncertainty and subjectivity are not hidden, but are made explicit.

In the following pages the method of perspective-based model routes is described. The methodology of model routes has been developed within the scope of RIVM's research project[171] 'Global Dynamics and Sustainable Development' that involved the development of the Integrated Assessment model TARGETS, which is an acronym for Tool to Assess Regional and Global Environmental and health Targets for Sustainability. To a certain extent the method is tied to, or constrained by, features of the TARGETS model[172]. For that reason, we first describe this particular method for pluralistic uncertainty management by means of the application to the TARGETS model. Secondly, we will use the experiences and lessons learned to draw the contours of pluralistic uncertainty management.

5.1. PERSPECTIVES

The first step in developing the model route strategy has been to define the concept 'perspective'. The definition of perspective adopted in this thesis holds:

169 E.g. (Lave and Dowlatabadi 1993), (van Asselt and Rotmans 1995; 1996), (Rothman et al. 1998 (in press)) and (Biggs et al. 1998 (in press)).

170 (van Asselt et al. 1996; van Asselt and Rotmans 1995; 1996; 1997)

171 (Rotmans and de Vries 1997; Rotmans et al. 1994)

172 See, for example, (Geels 1996) for a discussion how model choices framed the multiple model route strategy.

> *A* PERSPECTIVE *is a* COHERENT *and* CONSISTENT *description of the* PERCEPTUAL SCREEN *through which (groups of) people* INTERPRET *or make sense of the* WORLD *and its* SOCIAL DIMENSIONS, *and which guides them in* ACTING.

A perspective thus comprises both a worldview (i.e. how people interpret the world) and a management style (i.e. how they act upon it)[173].

Involving the endless number of individual preferences to account for variety in perspectives would turn any pluralistic endeavour into a mission impossible. Furthermore, some social scientists argue that the variability in values can be covered by a limited number of value combinations[174]. The challenge then is to find a typology of perspectives that sufficiently covers the pluralism in value-systems. To implement the concept of multiple perspective-based model routes, such a typology should satisfy the following conditions:

- It should be social scientifically credible.
- It should be structured in a systematic manner.
- It should be generic, i.e. applicable to different temporal and geographical scales and different levels of aggregation.
- Each perspective should comprise both a worldview and a management style.

Unfortunately, the social sciences do not provide a ready-to-hand, generally accepted typology of perspectives that is independent of time and scale. Social sciences have it that people think and act on the basis of a 'situation-logic'[175]. Generic typologies would violate this broadly shared conviction. For the development of TARGETS, a top-down approach has been chosen whereby the analysis addresses the global level. Taking genericity as opposed to the specificity social sciences presumes as the aim, a typology of global top-down perspectives is needed. However, social sciences usually prefer a bottom-up perspective in understanding actual pluralism[176]. As far as our knowledge extents, no credible typology is available that explicitly addresses the global level and that mirrors the top-down perspective adopted in the modelling effort. The challenge left to us was to find a systematic typology of perspectives that includes both a world view and a management style dimension, that can be considered to be credible in social sciences and that is phrased in sufficiently general terms to allow application to the

173 A similar distinction can be found by (Sabatier 1987).
174 (Rayner 1987)
175 Wording inspired by Hoppe, personal communication.
176 See, for example, (Roe 1998).

global level and the diversity of issues covered in the TARGETS model (i.e. population & health, economy, energy, food, water and environmental change).

Cultural Theory as developed by anthropologists and widely used in political science, has been a basic source of inspiration. Cultural Theory does not represent social science as a whole. We realise that its scheme is rigid and that it cannot fully take account of the real world variety of perspectives. The typology associated with Cultural Theory is nothing more, but also nothing less, than an attempt to systematically address the complex issue of different perspectives at a rather general level. As any model it is merely a limited and defective reflection of reality. However, in spite of the lacunae and inconsistencies, we did not find a typology that better satisfied the criteria mentioned above[177]. In the context of our aims, it seems therefore legitimate and reasonable to use the types put forward in Cultural Theory to characterise the spectrum of perspectives and to use the associated typology to implement multiple perspective-based model routes in Integrated Assessment models. In Van Asselt and Rotmans[178], we have attempted to motivate that this typology served our purpose and that it was a legitimate choice in this particular context to chose Cultural Theory as heuristic. Furthermore, it falls beyond our competence, as is also argued by our colleagues Parson[179] and Risbey *et al.*[180], to test Cultural Theory. Although Cultural Theory is controversial, it is a theoretical model that has passed the test of peer review and that is used by social scientists. So apart from the criticism, there are also social scientific scholars arguing that Cultural Theory provides an enriched framework for the perceptions of the various participants in trans-scientific issues[181]. It is up to social science experts[182] to test its validity. Parson's[183] remark pertaining to the limits of IA in connection to disciplinary research is relevant here:

> *IA cannot be held liable for the general incompleteness of relevant knowledge. (..) IAs can help - they may reveal or characterise the need, motivate the research effort, perhaps even provide hints about fruitful ways to proceed- but they cannot do the job.*

With our work, we have tried to encourage social scientists to develop typologies that enable IA practitioners to apply the concept of perspective-based model routes

177 In (van Asselt and Rotmans 1999) we provide an overview of other general typologies that have been considered, e.g. acting perspectives by (WRR 1994). Ethical positions by (Coward and Hurka 1993) and (Dotto 1993), and views on sustainable development (de Vries 1989)).
178 (van Asselt and Rotmans 1996; 1997)
179 (Parson 1996)
180 (Risbey et al. 1996)
181 (Funtowicz and Ravetz 1993b), (Jaeger et al. 1999), (O'Riordan et al. 1997), (Hoppe and Peterse 1998), (Pendergraft 1998)
182 For example, in the way as done by (O'Riordan et al. 1997), (Marris et al. 1997)), (Grendstad and Selle 1997), (Jaeger et al. 1999)
183 (Parson 1996)

in a way that does justice to both empirical observations and social science theorising. Crucial in our effort was to develop a strategy that enabled practitioners to take account of pluralism (and thus of inherent uncertainty and subjectivity) in IA modelling. In this context, we will use the application of cultural theory-based in the TARGETS model first and for all to illustrate pluralistic uncertainty management.

In the present context, we thus limit ourselves to a brief description of the three active perspectives (see Box 3), i.e. hierarchist, egalitarian and individualist, which have been used as stereotypes to develop multiple model routes that represent fundamentally different, but legitimate perspectives. The hierarchist, egalitarian and individualist are considered as extremes. The resulting spectrum that these extreme stereotypes define comprises a variety of less extreme, or rather hybrid, worldviews and management styles.

BOX 3 Cultural Theory's typology of perspectives[184]

EGALITARIANS hold that all humans are born 'good', but that they are highly malleable. Just as human nature can be 'corrupted' by bad influences, it can be positively guided by an intimate relationship with nature and other people. Self-realisation lies in spiritual growth rather than in the consumption of goods. The egalitarian worldview implies a risk-averse attitude. The associated management style can therefore be characterised as preventive. With regard to the capitalistic economic system, drastic structural social, cultural, and institutional changes are advocated. The egalitarian has it that nature is very fragile. Small disturbances may have catastrophic results. Any man-made change is likely to be detrimental to the environmental system. Nature is in a delicate balance. Activities that are to a greater or lesser extent likely to harm the environment should be abandoned.

For the INDIVIDUALIST, human nature is based on self-seeking behaviour. Human beings are considered to be rational self-conscious agents seeking to fulfil their ever-

see over »

184 Key sources on Cultural Theory are: (Douglas 1969; Douglas and Wildavsky 1982) (Douglas 1982) (Rayner 1984; 1991; 1992) (Schwarz and Thompson 1990); (Thompson et al. 1990). Some recent papers on Cultural Theory that are interesting in the present context are: (Pendergraft 1998), (Proctor 1998), and (O'Riordan and Jordan 1999). See also (van Asselt and Rotmans 1996; 1997).

BOX 3

increasing materialistic needs. Individualists hold that changes in principle provide opportunities for human ingenuity that will be revealed through market mechanisms. The individualist can be characterised as risk seeking. Eventual highly unlikely negative consequences of human activities will be resolved by technological solutions. The management style of the individualist can therefore be described as adaptive. Seen from an individualist perspective, nature is very robust. Anthropogenic perturbations, even if they are large, will do no more than result in mild and harmless disruptions. The individualist considers humans the centre of the universe, while nature is seen as providing resources that are there to be exploited.

HIERARCHISTS consider humans to be born sinful, but that they can and should be educated by good institutions. The role of management is to prevent serious problems by careful control, i.e. by keeping the system within its limits. This management style of control can be associated with a risk-accepting attitude. Hierarchists believe that nature is robust within certain limits. Nature is able to cope with small disturbances. However, as soon as a threshold is passed, anthropogenic disturbances pose a threat to the functioning of nature. The hierarchist can be associated with an attitude towards the relationship between man and nature in which the mutual dependency between humans and nature is stressed. A balance between human and environmental values has to be ensured.

Cultural Theory describes 4, and at times even 5, perspectives, i.e. hierarchist, egalitarian, individualist, fatalist and hermit. The first three perspectives, are also referred to as 'active perspectives', because they share an action oriented world view and management style, although they fundamentally differ with regard to the type of action and the effectiveness thereof. Because the TARGETS model envisioned policy action, the fatalist and the hermit were not of primary interest. For simplicity reasons, those two were not included in the perspective-based model route application to the TARGETS model[185]. However, in a project that ran parallel to the TARGETS project in which we have tried to model different types of consumer and consumer behaviour, the fatalist perspective was explicitly taken into account[186].

see over »

BOX 3

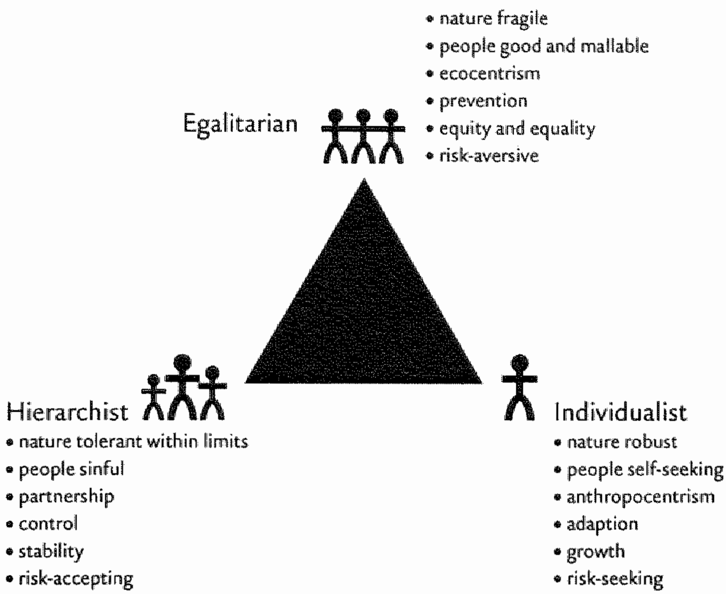

FIGURE 9 Main features of perspectives

5.2. MULTIPLE MODEL ROUTES

Model routes consist of chains of alternative formulations of model relationships and model quantities. Implementing model routes in an Integrated Assessment model is a collaborative and iterative effort involving at least modellers, analysts, disciplinary experts and Cultural Theory experts. The various implementation steps are summarised in a flow chart (Figure 10).

In the following sections, we will illustrate the implementation steps by referring to aspects of the application in TARGETS[187].

185 See also (van Asselt and Rotmans 1996; 1997).
186 (Jager et al. 1995; 1999;)
187 See (Rotmans and de Vries 1997) for a comprehensive overview.

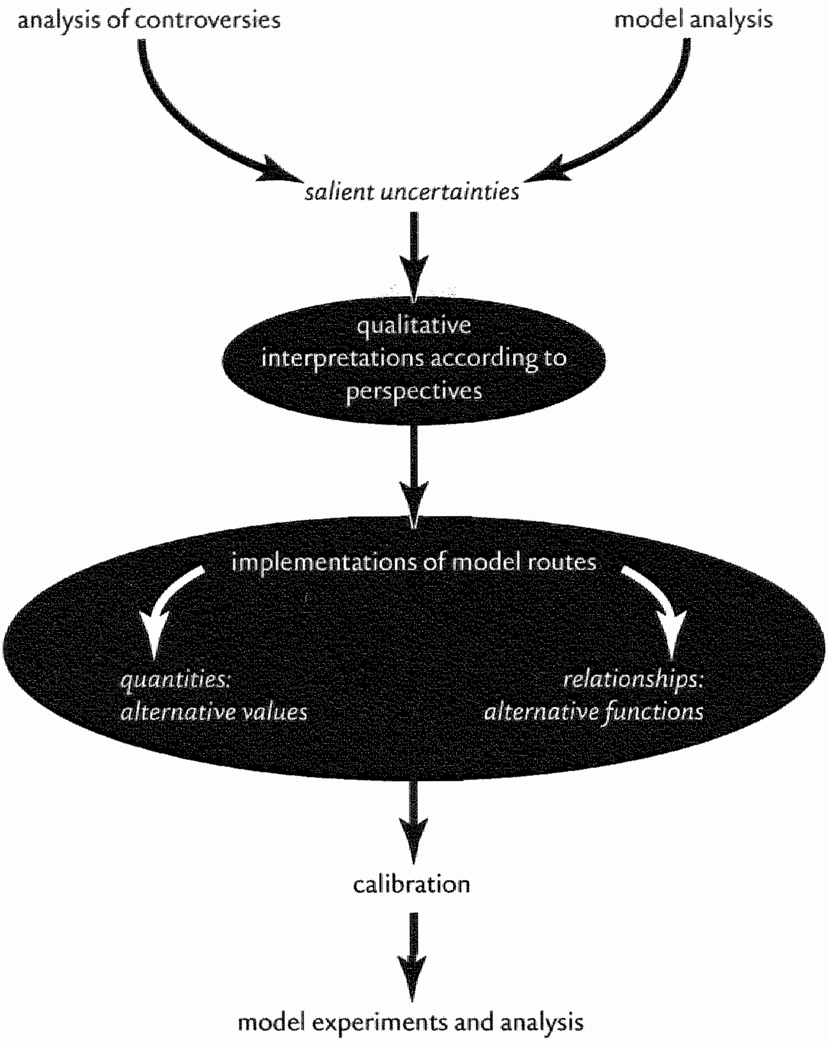

FIGURE 10 Flowchart of methodology of multiple model routes

STEP 1 ANALYSIS OF CONTROVERSY

In the previous section, it was argued that the analysis of controversy could be a way to identify salient uncertainties. The first step in the multiple model route method builds upon this argument. Relevant scientific debates are analysed in order to identify the major controversy within the scientific community. To give an example: the key question that underlies the controversy in the climate community can be summarised as:

Is the global climate disturbed in a serious and irreversible way; and if so to what extent, at what rate of change and with what regional pattern, and what are the human and environmental consequences?[188]

This question includes all the controversial elements around which the actual controversy abounds. The above question can therefore be considered as embracing and representing the major controversy in the climate community.

The next step is to unravel this controversy in terms of facts, hypotheses and uncertainties. To this end, a study of the scientific literature and intensive collaboration with experts is needed. Crucial in this step is to decide which literature is included, in other words whose opinions are considered, and what falls beyond the inventory. In the present application, the heuristic guideline was to restrict the inventory to official publications in peer reviewed media and to research reports that were seriously considered in such official publications (e.g. the Greenpeace scenarios on energy as produced by the Stockholm Environment Institute[189]). This explains why Simon's controversial opinion[190] is considered and why Böttcher's opinion[191] is left out. Constraint by this heuristic, the inventories performed in the context of the TARGETS reveal fundamental uncertainties underlying the debate in the scientific community as discussed in official scientific bodies.

STEP 2 MODEL ANALYSIS

The inventory of the salient uncertainties enables to identify which model components are necessarily influenced by subjective judgement. All model choices on inherent uncertainties by definition represent a particular interpretation of uncertainty. By going back and forth between the inventory of uncertainties and the model, a list of crucial model components that involve subjectivity is produced. Sensitivity analysis is used to check how critical these model components are for the assessment activities. Based on this evaluation, the most salient uncertain model components are selected.

This step can be illustrated by means of the example of the analysis of the water submodel in the TARGETS model. As a result of the above procedure, water scarcity, potential water supply and water demand were selected as the key uncertain issues in forecasting whether the world population can be provided in the long term

188 (den Elzen et al. 1997)
189 (Lazarus 1993)
190 Examples of peer-reviewed publications in the scientific literature: (Simon 1980; 1981)
191 No publications on his controversial opinion on climate change in scientific journals.

with sufficient and clean fresh water without threatening the ecological functions of water. In an iterative process between the water modeller and the analyst, the following model components were selected[192] as being crucial in terms of inherent uncertainty and its impact on the model output:

MODEL STRUCTURE

- Modelling of water scarcity
- Modelling of water quality

EQUATIONS

- Water supply-cost curves
- Water demand equation (esp. in terms of growth and price elasticity)

MODEL QUANTITIES

- Diffusion of technology
- Fraction consumptive water use
- Climate sensitivities of ice sheets and glaciers

STEP 3 QUALITATIVE INTERPRETATIONS

The next step involves defining alternative interpretations of the uncertain model components reasoning from the above framework of perspectives. The perspectives were used to develop mutual coherent sets of responses on the following questions that represent the salient uncertainties addressed in the TARGETS model:

- What level of economic growth is desired?
- What are the limits to population growth and what are the major driving forces?
- What determines health?
- How will technology develop in the energy sector?
- What is the role of feedbacks in the climate system?
- What are the determinants of water demand and supply?
- What will the future diet be?
- What is the area land available for agriculture and what will the quality of arable land be in view of global change?
- What policy measures are preferred?

Qualitative descriptions of the perspective-based interpretations of the salient uncertainties should be the result of intensive and iterative dialogue. Table 7

192 See (Hoekstra et al. 1997)

summarises the participatory-developed interpretations for the hierarchist, individualist and egalitarian perspective, in terms of both world views and management styles as was used to implement the perspectives in the TARGETS model[193].

	Hierarchist	Egalitarian	Individualist
economy	• moderate desired economic growth	• low desired economic growth	• high desired economic growth
population & health	• physical limits • family planning programs as driving force • health as human capital • health services	• environmental and social limits • societal developments as driving force • health as human asset • social-economic and environmental health determinants	• no limits • individual possibilities as driving force • health as consumption good • ageing
energy	• moderate technology development	• environmental technology	• energy-efficient technology
climate	• amplifying effect of geophysical feedbacks • moderate cooling of aerosols	• strong amplifying effects of geophysical feedbacks	• radiative effects are strongly dampening effects
water	• supply oriented • stable runoff as potential water supply • medium response to climate change	• demand oriented • clean fresh water stock as potential supply • high response to climate change	• market oriented • no limits • low response to climate change
land & food	• present diet • 3.3 Gha arable land • middle recuperative power of degraded land	• vegetarian diet • 2.8 Gha arable land • low recuperative power of degraded land • negative effect of temperature increase	• American diet • 3.8 Gha arable land • high recuperative power of degraded land • positive CO_2 fertilisation effect

TABLE 7A Perspective-descriptions in terms of worldview

193 As synthesised from the various publications on the TARGETS model, see (van Asselt 1997).

	Hierarchist	Egalitarian	Individualist
population & health policy	• family planning • anti-abortion* • selective health care policy (cure)	• human development (esp. education for women) • legislation of abortion* • comprehensive health care policy (prevention)	• legalisation of abortion* • market-oriented health policy
energy policy	• no carbon tax • moderate R&D programs for new energy supply and efficiency options	• carbon tax towards 500$/tC in 2020, constant afterwards • R&D programs on renewable resources	• no carbon tax
water management	• increasing charges on water	• water-taxing • active policy on public water supply and coverage • R&D programs on small-scale technology	• market pricing of water • high-tech R&D programs if water gets scarce (e.g. desalination)
land management	• reforestation policy • agricultural planning (incl. irrigation, fertilisers, deforest-ation, reforestation)	• eco-forestry (e.g. reforestation) • eco-agriculture (less clearing, no fertilisers)	• protection of wood sector • intensive agriculture (incl. genetic engineering)

* the issue of abortion turned to be very difficult to interpret in terms of the different perspectives. With reference to the Roman Catholic Church, which can be considered as an exemplar of hierarchic culture, the hierarchist is interpreted as anti-abortion; while with reference to China, which can in a certain way also be considered as a hierarchist culture, the hierarchist is interpreted as pro-abortion. This was the most evident example we encountered of ambiguity of Cultural Theory, also by Cultural Theorists themselves (personal communication with Steve Rayner and Michael Thompson).

TABLE 7B Perspective-descriptions in terms of management style

The above descriptions were used as starting point in the implementation of multiple model routes in the TARGETS model.

STEP 4 IMPLEMENTATION OF MODEL ROUTES

The crucial next step involves translation of these qualitative descriptions into model terms. In the case of model quantities, this means that alternative values have to be determined. This is achieved by estimating inputs and parameter values so that they reflect the interpretation from this perspective. If the scientific literature provides a range of quantitative estimates for a parameter or input, this range can be used to arrive at reasonable model choices. In case no specific quantitative estimates are available, the team has to decide upon representative quantitative values.

In the case of uncertain relationships, functional forms need to be reformulated. This means changing the function, or deleting, adding or changing the function's arguments. Notwithstanding their mathematical simplicity, such changes are fundamental in a conceptual sense. Alternative formulations change the dynamics of the system. Ideally, different equations are provided by the scientific literature, which can be assigned to the perspective-based interpretations of the underlying uncertainty. In practise, it is rather likely that alternative interpretations are not spelled out in the literature in explicit mathematical terms. In this case, modellers and experts have to study the perspective-based interpretation of the uncertain issue and search for an adequate translation into model terms.

Figure 11 schematically represents different perspective-based model formulations in the water submodel in TARGETS[194]. Another example of different functional forms is the relationship between net primary production and global mean temperature in the biogeochemical cycles submodel. This relationship is modelled as a parabolic function in both the hierarchist and egalitarian model route, where it is a continuously increasing function in the model route representing the individualistic perspective. An example of alternative quantities in perspective-based model route is the value for the CO_2-fertilisation factor β, which ranges from 0 (i.e. no effect) in

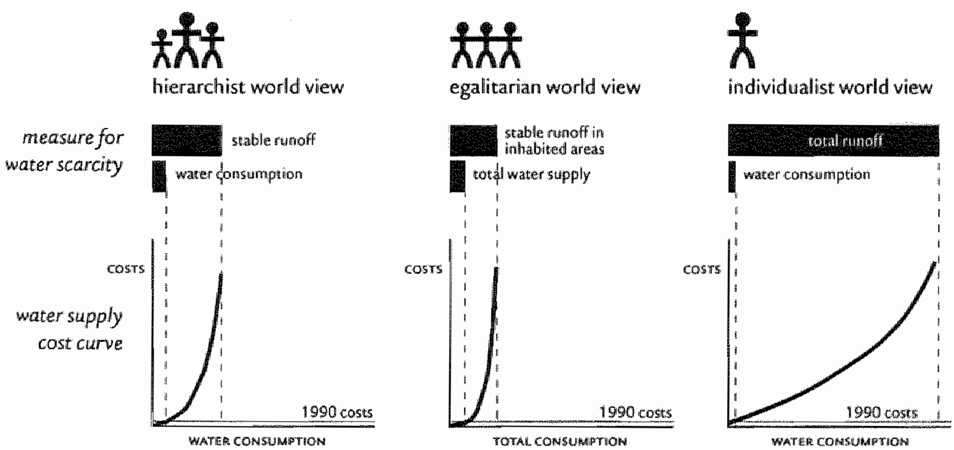

FIGURE 11 Schematic representations of perspective-based formulations in water submodel

194 (Hoekstra et al. 1997; Hoekstra 1998)

the egalitarian model route, to 0.7 (i.e. substantial effect) in the individualistic model route. In this case, a range was provided in the scientific literature[195].

STEP 5 CALIBRATION

The multiple model routes have to represent historic trends and should match available data. However, we should realise that the data is not always hard, but may contain uncertainties. The TARGETS model runs from 1900-2100, which allows for calibration on historical evidence. Each model route is calibrated on historical data[196], in which effort we took uncertainty bounds into consideration. Figure 12 illustrates that notwithstanding the fundamental differences between the three model routes in the land and food-submodel of TARGETS, the historical trajectories calculated with each model route correspond with the actual historical development, while the future pathways differ significantly.

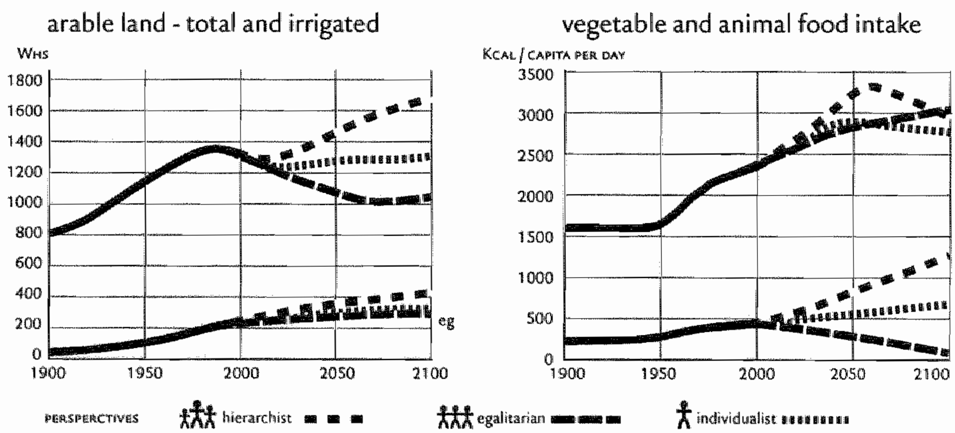

FIGURE 12 Historical similarities and future divergence

STEP 6 MODEL EXPERIMENTS

The implemented and calibrated model routes allow for systematic experimentation. To this end, the distinction between world view and management style is relevant. Matching the management style of each perspective to its respective worldview is a

195 (van Asselt and Rotmans 1995) (den Elzen et al. 1997)

196 See (Rotmans and de Vries 1997) for the description of the calibration procedures employed.

technique used to assess the utopias. A utopia is a world in which a certain perspective is dominant and the world functions according to the reigning worldview.

We realise that the concept 'utopia' is normative and that use of the concept is highly controversial. It is beyond the scope of this thesis to provide a well-founded underpinning that does justice to the state of the art in political philosophy[197]. In this Chapter, we restrict ourselves to a short motivation why we think 'utopia' is a proper label for this particular kind of experiments. A utopia is a description of an ideal future. In that sense, it is a kind of scenario, but one that is a highly normative. A utopia reasons from a radical model of society and nature that serves as a blueprint of the future. Utopias are characterised by the trust that the imagined future will be without problems. In political philosophy, utopias are considered as a kind of thought experiments, that are logical and internally consistent[198]. As discussed before, each perspective involves a certain worldview and a certain management style. From the viewpoint of a particular perspective, a human and an environmental system mirroring the adopted world view and management style would yield the preferred future. The utopian experiments that we propose to carry out with an IA model thus reflects the basic characteristics associated with the utopian tradition.

In the philosophical tradition, dystopias, or anti-utopias[199], describe terrifying visions of the future. In terms of our dichotomy, dystopias describe either what would happen to the world if reality proved not to resemble the adopted world view following adoption of the favoured strategy, or vice versa, i.e. where reality functions in line with one's favoured world view, but opposite strategies are applied. Thus in terms of model experiments, dystopias are scenarios involving mismatches between worldviews and management styles (Figure 13).

future according to management style	future according to world view: HIERARCHIST	EGALITARIAN	INDIVIDUALIST
HIERARCHIST	utopia	dystopia	dystopia
EGALITARIAN	dystopia	utopia	dystopia
INDIVIDUALIST	dystopia	dystopia	utopia

FIGURE 13 Utopias and dystopias

197 See (de Geus 1996), (Crombag and van Dun 1997), (Achterhuis 1998) for recent in-depth and critical studies on the 'utopia' concept.
198 See, for example, (de Geus 1996).
199 (Kumar 1991)

This way of generating scenarios is rather crude. The above scheme was used for the first set of scenarios. Building upon the insights gained, we systematically explored scenarios in which the model routes varied per submodel; for example in the population and health submodel the world view was egalitarian and the management style hierarchist, while the energy submodel featured the hierarchist perspective for world view and management style and the other submodels were entirely put on the individualistic model route. Furthermore, we have also experimented with changes in perspective over time in developing scenarios[200].

The result of performing utopian and dystopian model experiments is a flow of outputs representing various pathways into the future. There are different strategies for analysing these projections. One way is to evaluate whether the outcomes differ significantly from previous qualitative or model scenario studies. The next step then involves explanation of these differences. Box 4 provides an example of such an assessment. In this example population projections generated with multiple perspective-based model routes are compared with the authoritative population projections of the United Nations.

Box 4 Comparison of perspective-based population scenarios with UN projections[201]

The spectrum emanating from the three utopias generated with the population submodel of TARGETS runs from 7.9 to 13.0 billion people in 2100 for population, while the life expectancy projected for 2100 varies between 76 and 86 years. Comparison of our projections with the current UN projections[202], of which the 2100 values range from 6.4 billion in the low projection to 17.6 in the high projection, shows a smaller range provided with perspective-based model experiments.

Why do the perspective-based projections significantly differ from the ones provided by the UN? First of all, the utopian projections all assume that the fertility transition succeeds, it is only the onset and the transition rate that differ among the three perspectives. By the end of the 21st century the utopian projections

see over »

200 See e.g. (van Asselt and Rotmans 1996) and (Janssen 1996)
201 This analysis is based on (Hilderink and van Asselt 1997)
202 (UN 1993; 1995)

BOX 4

perspective-based projections versus UN-projections
without food, water and environmental constraints

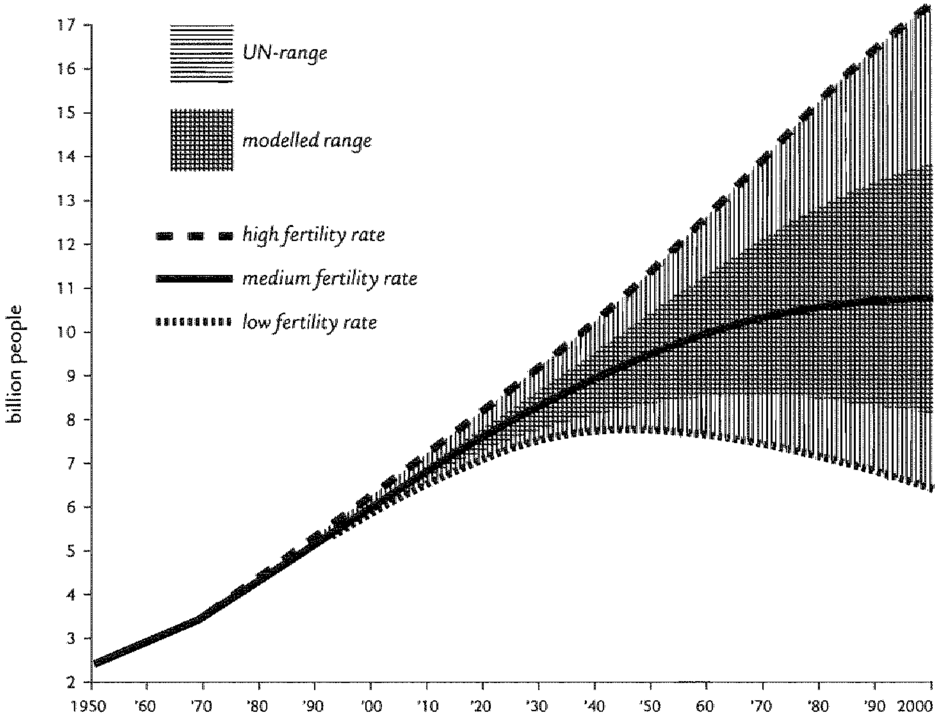

FIGURE 14 Population projections with TARGETS compared to UN range

show a fertility level approaching replacement level (2.1 children per woman), which eventually causes stabilisation of the population on the condition that the mortality level also stabilises. In designing their scenarios, the UN chose fertility levels which are taken constant for the next 50 to 100 years. Their assumptions with regard to fertility levels for the second half of the next century vary between 1.6 in the low-fertility case to 2.6 in the high-fertility case. The high UN projection thus comprise of futures in which the fertility level is far above replacement level, and thus yields a higher population projection than our utopian projections reveal. Secondly, the population and health submodel in TARGETS accounts for the recognised mutual relationships between fertility and mortality. The assumptions with respect to food, water and environmental circumstances underlying the utopian population projections reason from a secure food supply, access to clean fresh water for

see over »

BOX 4

everyone and moderate environmental changes. The result is that the major health determinants, i.e. food security, safe drinking water supply and health services, evoke in any perspective an epidemiological transition towards low mortality levels. A low mortality level implies a high life expectancy, which, in turn, increases the level of human development, stimulating a decrease in fertility level[203]. On the other hand, a lower fertility level causes a smaller increase in the population, thereby enhancing the availability of resources per capita, which in turn results in better health conditions. These causal relationships imply that high life expectancy excludes a high fertility level for the world at large. The perspective-based projections therefore do not comprise a scenario that describes a large excess of births over deaths for a healthy population. The high UN projection seems to presuppose such an implausible development.

The low UN projection provides a picture in which the population declines very fast, i.e. a decline of 1.4 billion in 50 years during the second half of the 21st century, which corresponds to an average decline of 30 million persons per year. None of the utopian projections show a decline that can be compared to such a fast decrease. The rapid and huge decline in population as described in the low UN projection presupposes an excess of deaths over births. None of the stages of the demographic transition features a situation in which the crude death rate exceeds the crude birth rate. In other words, the low UN projection assumes a very low fertility level (i.e. a global average of 1.6 children per woman as early as 2050, which is supposed to remain constant for the next 50 years) and/or an extraordinary situation featuring very high mortality levels. One can probably imagine a large number of deaths due to famine and severe water shortages. As said before, the utopian projections do not account for grave lack of food and water[204]. Other potential factors that influence mortality, such as wars and natural disasters, are ignored in our model due to them only accounting for a negligible part of the total mortality. When, for example, the Gulf War, and wars in Rwanda, Sudan, Uganda, Angola and Liberia raged in 1990, only a mere 0.6% of the total mortality could be attributed to wars[205].

203 See (Niessen and Hilderink 1997)

204 We did such experiments (see (Hilderink and van Asselt 1997)), but also in these cases the lowest bound of the UN range could not be reproduced.

205 (WorldBank 1993)

Another way to analyse the model experiments, is to concentrate on differences between the various utopias. Do they significantly differ and are the differences counter-intuitive? What do these differences teach us about possible futures? Box 5 illustrates this kind of comparison by means of an analysis of the integrated utopian experiments.

BOX 5 Comparison of utopias[206]

Figure 15 presents the three integrated utopias in 2100. The differences between these scenarios are salient. Whereas the individualistic utopia has the highest-pressure values and the highest social and economic impact values for the selected indicators, the state of the environment is the least deteriorated, and water and energy prices are lowest. The reason is that this is a world of abundance and resilience: energy, land and water resources are huge and the environmental system is supposed to be quite insensitive to human disturbances. The egalitarian utopia shows the opposite picture: at much lower pressure and impact levels, and despite rather radical response measures, parts of the environment, notably land and climate, are in worse shape. The hierarchist utopia has high energy-related indicators, which means that this scenario symbolises an energy-intensive future. The environmental impacts are considerable, i.e. the environment is more deteriorated than in the individualist utopia, however less than in the egalitarian one.

The intriguing aspect that arose from the simulated utopias briefly described above, is that these utopias are not strictly utopian: not all is rosy, as expected beforehand. This is due to the variety of choices over widely differing issues, which has to be internally consistent. The internal consistency may result in counter-intuitive trends that contain positive and negative trends. This observation is also interesting from a philosophical point of view. Critics from the utopian tradition[207] argue that the realisation of any utopia does not bring the ideal society it imagines. Also in this sense, the label 'utopian experiments' seems to be adequate in our context where these experiments show those tensions.

see over »

206 This analysis is based on (Rotmans and van Asselt 1999)
207 See for example (Crombag and van Dun 1997)

BOX 5

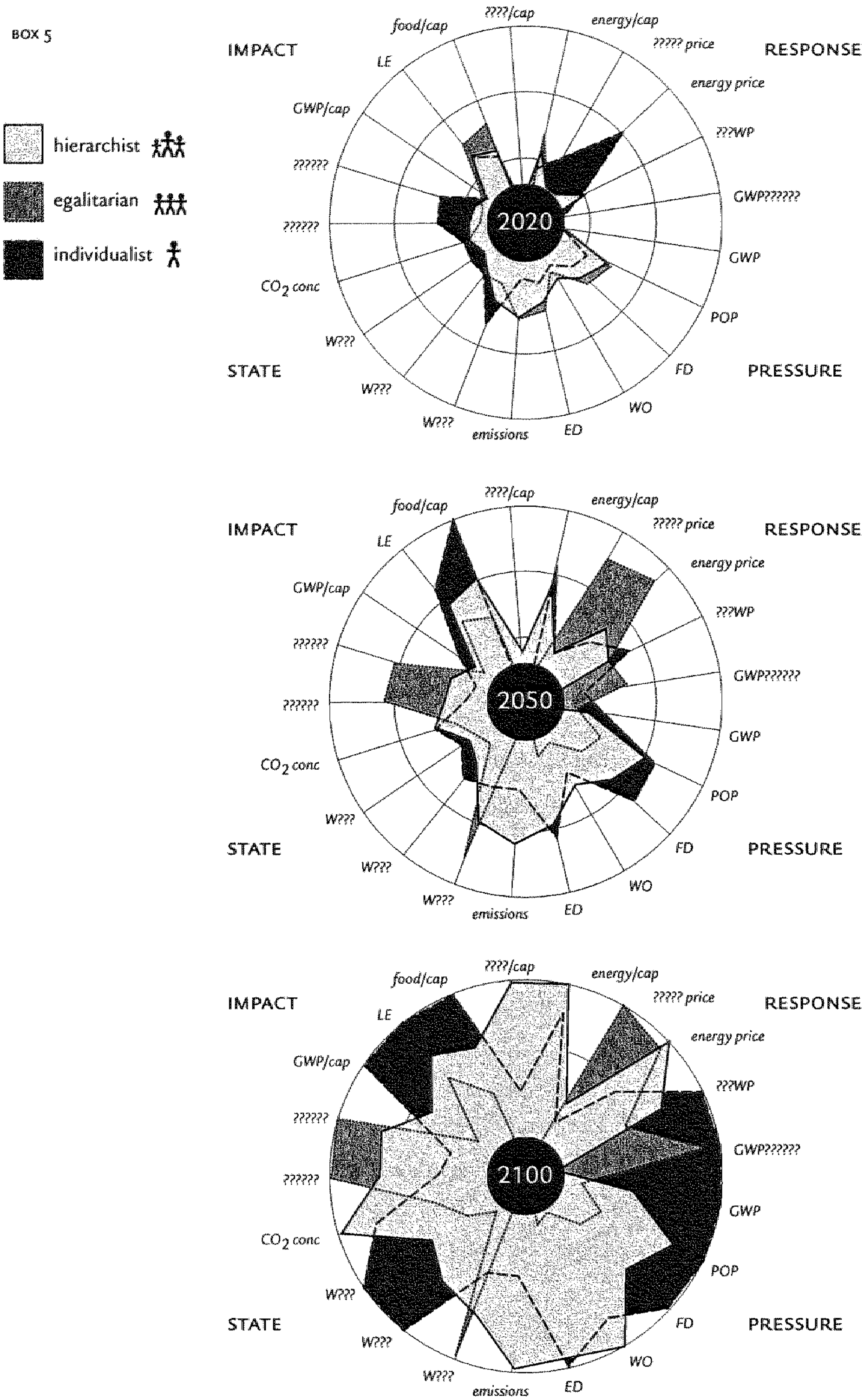

FIGURE 15 Multistar representation of the three utopias over time

By means of multiple model routes, we create a set of model runs that spans the space of possible arguments, constrained by what is known[208].

5.3. LESSONS LEARNED

The method of perspective-based model routes is tied to formal modelling and is framed by the features of the TARGETS model. What did we learn from applying pluralistic uncertainty management in IA?

Whether right or not, the most eye-catching element of our approach was the choice of our typology. In some cases the controversial character of Cultural Theory was probably used to discredit the pluralistic approach where as in fact it seemed to be dismissed for deeper reasons. Nevertheless, this experience yields that although a typology is primarily a means to express pluralism, the level to which the typology is acceptable is crucial for the usefulness of the actual assessment. Our recommendation would be that the way in which the choice for a typology is made or the process in which a set of perspectives is developed is participatory in order to ensure that the perspectives are familiar and valid to at least the users of the assessment. Furthermore, we would like to challenge social scientists to engage in this endeavour. Such engagement is needed in order to guarantee that the variety of perspectives covers to a sufficient extent the plurality observed by social scientists. Only with help of social scientists could such a perspective-based approach go beyond superficiality[209].

The experience with TARGETS yields that it is difficult both for colleague integrated assessors, for other scientists, for the policy audience and the public at large to interpret the results. With hindsight this is not surprising if we evaluate the learning processes that took place within the TARGETS team over the course of three years. It is such a fundamental different way of dealing with knowledge and uncertainty that it takes time to understand both the principle and the outcomes, and to grasp how such insights can be used for decision support. We have underestimated the revolutionary aspect of our approach. Participating in the process seems to enhance the capability to deal with the outcomes. However, not all the intended users can participate in the development process, even not in case of a participatory set-up, so it is necessary to put a lot of effort in communicating the insights in transparent and understandable ways. To that end also new ways of summarising the insights are

208 Wording inspired by Rob Lempert, personal communication.
209 See also Chapter 4.

needed. Traditional representations are not suitable for communicating non-traditional outcomes.

The way perspective-based model routes were implemented was very science-oriented. We just allowed scientific interpretations of salient uncertainties. For some of them it can be argued[210] that scientific knowledge of the relevant issue is necessary to arrive at a valid interpretation of the given uncertainty. However, many of the uncertainties involved in the analysis were trans-scientific and implicitly or explicitly deal with societal developments, human behaviour or value diversity. One of the major lessons of the experiences with TARGETS is that such a trans-scientific exercise should be participatory in order to allow a mutual learning process in which those uncertainties and risks are selected that are salient in societal terms.

6. Framework for uncertainty management

Building upon our efforts to deal with inherent uncertainty in Integrated Assessment modelling as reported in the previous section, we can envision a framework for uncertainty management that is both pluralistic and participatory. The first step in such uncertainty management would be to unravel controversies on trans-scientific issues. The next step is to identify salient uncertainties, and to colour them according to different perspectives. The different interpretations of the salient uncertainties can then be used to envision alternative futures, either by means of modelling or by means of scenario-exercises. The concept of utopias and dystopias, and variations on this basic scheme, can be useful in exploring tensions and conflicts in a participatory manner. The next step is then to synthesise the knowledge encountered in this systematic exercise of exploring uncertainty into robust insights and recommendations for decision-making.

The above describes a systematic procedure for exploring uncertainty in a participatory manner. Roughly speaking, two strategies for performing the different steps can be distinguished[211]:

210 See for example, (Ermoliev 1993).
211 Compare (Rotmans 1998b); see Chapter 2.

A SUPPLY-DRIVEN STRATEGY

- the controversies are defined building on literature review and document analysis.
- salient uncertainties are identified by means of sensitivity analysis or systematic ranking exercises to articulate expert judgement.
- scientists prepare different internally consistent perspective-based interpretations reasoning from an inventory of different scientific opinions[212], a typology or building upon analysis of prevailing perspectives (e.g. using questionnaires, discourse analysis, Delphi-methods[213], etc.)
- the participants in the process enrich and extent the qualitative interpretations and suggest which ones (or combinations) are interesting from a societal point of view.
- participatory assessment of the future in terms of utopias and dystopias ('what-if'-exercises).

A DEMAND-DRIVEN STRATEGY

- the controversies are framed in a participatory process.
- the salient uncertainties associated with the controversies are identified.
- the participants colour the uncertainties, either by means of group processes or by a systematic analysis of the individual perspective-based interpretations of uncertainty the number of qualitative descriptions is reduced to a manageable number.
- scientists check the qualitative descriptions in terms of consistency and whether they do not contradict established facts.
- the identified perspectives are used to assess the future.

The above descriptions are just meant to illustrate how pluralistic uncertainty management might be set-up. Variations and combinations are imaginable.

The framework for participatory pluralistic uncertainty management is summarised in Figure 16.

212 (Nordhaus 1994) for example used different opinions on climate change from natural and social scientists to express the variability and divergence in opinion in order to assess the uncertainty range associated the estimate of the economic impact of potential climate change. See also (Morgan and Keith 1995) for a comparable approach.

213 (Bithas and Nijkamp 1996) plead to use a Delphi type of methodology in the context of environmental assessment to arrive at instances of uncertain causal relationships.

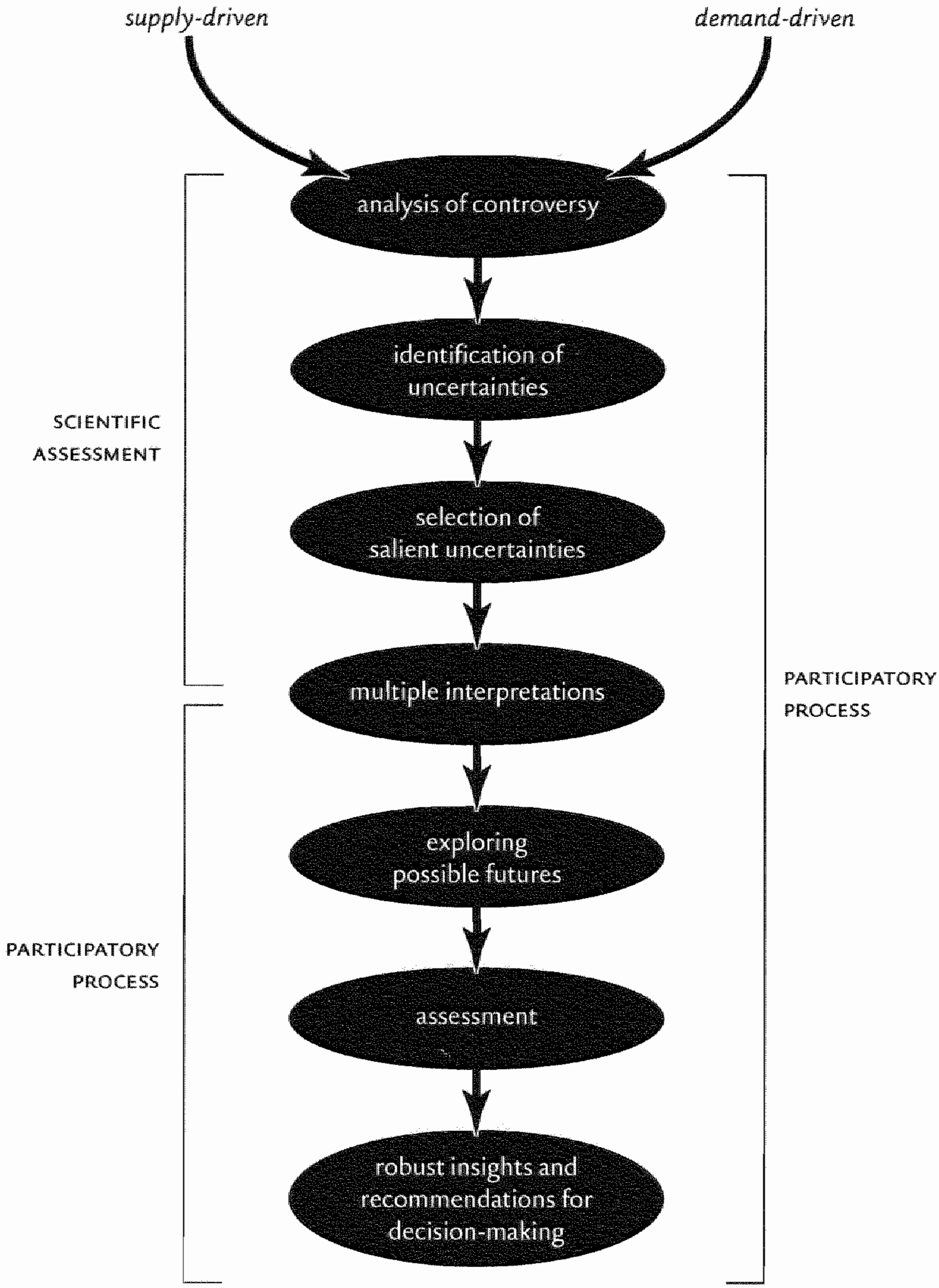

FIGURE 16 Framework for participatory pluralistic uncertainty management

In this way, uncertainty is at the core of the assessment, and remains there. This approach has considerable advantages compared to existing approaches in uncertainty analysis:

- Pluralistic uncertainty management focuses on the most salient uncertainties.
- This approach is able to address sources of uncertainty that are not addressed by other methods for uncertainty management, esp. conflicting evidence and uncertainty due to variability.

However, notwithstanding its advantages pluralistic uncertainty management is not a panacea. Other methods of uncertainty analysis can serve as complementary tools to allow for a more comprehensive evaluation of uncertainty. In the above description we already suggested how scenario approaches could be applied in the framework of pluralistic uncertainty management. Furthermore if applied in the form of modelling, the combination with sensitivity-analysis or probability-based methods could enable to evaluate uncertainty due to inexactness compared to other sources of uncertainty.

7. Conclusions

Regarding complex issues, it is important to include a number of alternative views of the future in an analysis, because due to inherent uncertainty, one can never be sure which view is correct. In this Chapter we have tried to go beyond the abstract and general notion of uncertainty by identifying sources of uncertainty. The taxonomy of uncertainty as proposed in this Chapter enables to characterise uncertainty, and thereby renders it more tangible. The hypothesised generic validity of this taxonomy can in principle be tested empirically. A sound empirical testing is beyond the current thesis, but it may become a leitmotiv in future research.

Building upon the insight into uncertainty, the present Chapter outlines an approach pluralistic uncertainty management. This approach builds on epistemological principles advocated under denominators as trans-science, realism and post-normal science, which accept uncertainty as being inherent to knowing.

The use of multiple model routes in the IA model TARGETS is discussed as a first application of the idea of pluralistic uncertainty management in Integrated Assessment. By means of this example we wanted to illustrate the potential of the pluralistic approach to uncertainty management. In this way, the methods and building blocks provided in this Chapter may be of help for integrated assessors to recognise uncertainty and to deal with it in their research efforts in an adequate manner. The challenge is to test the soundness of the approaches in concrete studies of complex issues. We hope that the example of perspective-based model routes in the TARGETS model illustrates that the framework we propose can in principle be implemented. As this example illustrates, this type of uncertainty management has the potential to yield new and challenging insights on complex issues: insights that will be informative and highly relevant for societal decision-making.

The aim of the following Chapters is to use the proposed insights on uncertainty in an effort to arrive at methodological improvements of decision-support on complex issues. From the analysis provided in this Chapter, we can conclude that key notions for such an endeavour are[214]:

- PLURALISM
- PARTICIPATION
- ROBUSTNESS

214 The same notions materialise from addressing the above aim of this thesis from our overview of the state-of-the-art in Integrated Assessment (Chapter 2) and our review of risk analysis (Chapter 3B).

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Risk

Risk refers to debates about the possibility that something might go wrong. Risks are rooted in human behaviour[1], or in natural surprises or extreme events (also referred to as external risks). The notion of 'risk' traces back to the 13^{th} century[2]. The word 'risk' is derived from the Italian word 'rischiare' that has its origins in the Greek notion 'rhiza' which literally means 'root' or 'cliff'. This word got the metaphorical meaning of everything that sticks out, and thereby can constitute a danger. The word risk circulated in Italy in the context of insurance against the loss of shiploads coming from the Orient through, for example, storms or piracy. The notion of 'risk' is still used in the context of insurance, but apart from that it has become a widely applied, often used and ambiguous notion. It is used in the field of business, technology, health, politics, sport, games, and even in love. 'Risk' originally had a negative connotation, as something dreadful (for example, in the case of nuclear energy). It is now also used positively, namely as a challenge (for example, in the case of stock exchange) or even as a kick that one is seeking (for example, bungy-jumping)[3].

1 (Gezondheidsraad 1996)
2 The historical description of the use of the notion of 'risk' is based on (Jungermann 1993) and (Gezondheidsraad 1996)
3 The latter two examples do not build on extensive scientific research, but are derived from common life experience.

Apart from this common use, risk is also used as a concept in scientific analysis for decision support. An early example of this kind of analysis[4] dates back to the introduction of electricity at the end of the 19th century: men like Edison and Thomsom made the first assessments concerning the risks associated with the use of electricity[5]. Since the early 1970s[6], risk analysis has become an established field of research. It was originally rooted in engineering and decisions sciences[7]. During the seventies the notion of 'risk' was mainly confined to the natural sciences. Probabilistic risk assessment was the dominant method. The rise of risk analysis is strongly connected with the nuclear energy controversy[8] and a number of technological accidents[9], esp. the Bhopal accident in India (in 1984) and the Chernobyl disaster in the former USSR (in 1986). Since the 80s, 'risk' has gained importance as a concept in assessment activities[10], esp. in technology assessment[11]. In the 1980s, efforts have been made to define 'tolerable risks'.

The notion of risk is still central to societal debates on technology. Nowadays, all undesirable side-effects of modern technology are subsumed under the notion of 'risk', whether these are associated with a single system (e.g. a technological site) or product (e.g. an airplane, a medicine), technological innovations (e.g. gene-technology) or large-scale projects (e.g. water reservoirs, airports)[12]. The last decade, the concept of risk is also increasingly used to refer to environmental hazards, like ozone depletion and climate change[13]. Risk analysis is furthermore becoming part of assessment activities for the purpose of environmental policy making[14]. Since the beginning of the 90s, it is advocated to use the concept of risk to address general aspects of decision-making in modern society[15]. These recent developments seem to onset a trend in risk analysis to extend beyond a specific case.

Contemporary risk analysis can be described as the scientific approach to risk for public policy making on technological, environmental and health issues[16]. It now

4 It can be argued (see for example (Clark 1980) that societal risk assessment has a history as long as humans' efforts to explain, manipulate and cope with their fears and the unknown, so back to the beginning of humankind. In our description we focus on risk analysis as scientific effort as it developed during the 20th century.
5 (Carlson and Millard 1987)
6 See for a more comprehensive analysis of the history of risk analysis, for example, (Mazur 1980)
7 (O'Riordan 1982)
8 (Jungermann 1993)
9 (van Eijndhoven 1991)
10 (O'Riordan 1985)
11 (Conrad 1980; Douglas and Wildavsky 1982; van Eijndhoven 1995)
12 (Jungermann 1993)
13 See, for example, (Swart 1994)
14 (Jungermann 1993)
15 (Kämper 1998)
16 In line with the risk analysis literature, risk analysis is considered as the umbrella term encompassing all systematic efforts to identify, estimate, evaluate and manage risks. Risk assessment and risk management are thought about as being activities within risk analysis.

has become an active field involving disciplines as diverse as mathematics, statistics, epidemiology, toxicology, biology, engineering, technology studies, system analysis, environmental sciences, law, psychology, decision sciences, sociology, anthropology, geography, history, economics, management science, policy sciences and philosophy. Notwithstanding the involvement of so many disciplines, we can doubt whether the risk community is in fact interdisciplinary in the sense as expressed by Schneider[17]: "Interdisciplinary implies an original combination from the integration of multidisciplinary ideas or methods that permits explanation or assessment not achievable of un-integrated application of multidisciplinary ideas or tools". There is a clear tendency to treat the issue of risk from the perspective of one's own discipline and speciality[18]. There is not (yet) a universal definition of risk: the Society for Risk Analysis tried to arrive at an accepted unique definition of risk, but so far without success. It may therefore not be surprising that there is no common paradigm that integrates the different aspects of risk and that guides risk analysis.

This Chapter explores the risk concept and its relevance for decision-support on complex, incompletely known societal issues. The aim is to sketch a framework for integrated risk analysis. To that end, the following steps are taken:

- the debate in the risk community is analysed
- an attempt is made to explore whether, and if so, how the partial contributions of the different schools of thought can be synthesised into one framework, that may provide the basis for a new, integrated form of risk analysis

We do not stop here, but continue with exploring the features of such an integrated risk analysis. In this effort, we will argue in this Chapter that it is necessary to:

- classify risk
- (re)define risk
- develop methodologies that enable multiple risk assessments
- explore guidelines, tasks and tools for participatory processes
- design formats for risk statements

Building upon three decades of risk analysis, we will try to take the above issues a step further to concrete suggestions how to implement integrated risk analysis. The structure of our search towards an integrated form of risk analysis is summarised in Figure 1.

17 (Schneider 1997)
18 (Conrad 1980), (Jasanoff 1993)

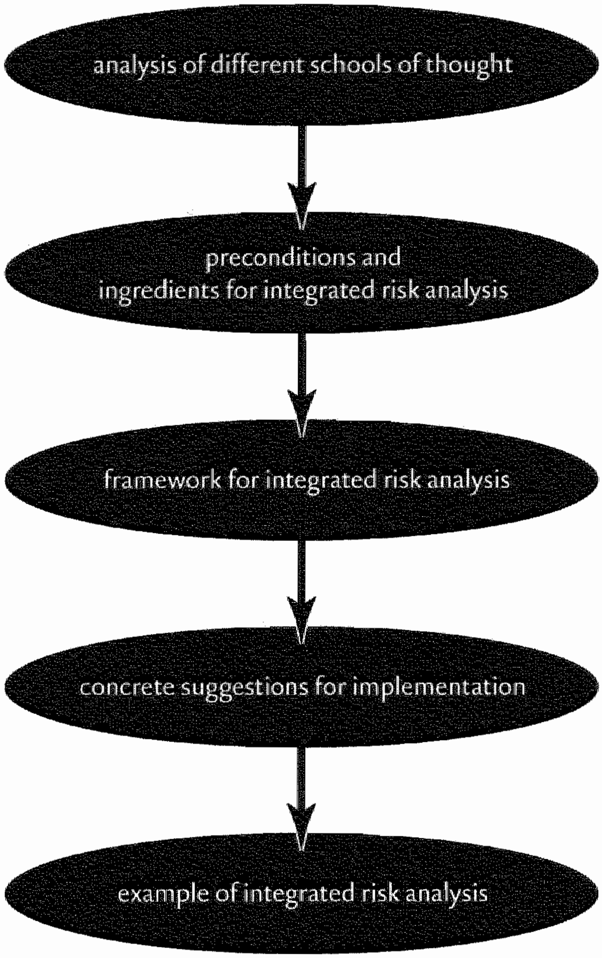


FIGURE 1 Structure of Chapter

1. The risk debate

Analysis of the scholarly literature on risk yields that there used to be a serious division of opinion concerning fundamentals. The risk community is still somewhat fragmented, although attempts are made to bridge the gaps. Out of the scholarly literature, two key issues emerge that underlie the differences of opinions, i.e.:

- How to define risk?
- How risky are modern hazards?

On each question, roughly two extreme positions can be identified. In the discussions pertaining to defining risk, the objectivists and constructivists[20] can be distinguished[21]. Concerning the second issue, we find scholars holding the position that hazards have increased and are increasing versus those that argue that modern society is only more sensitive to risk. Both discussions have implications for risk analysis activities: thus far they have prevented the development of a common cognitive framework that can guide risk analysis and that would enable to compare specific risk analyses in terms of quality. It can be argued that the diversity of approaches is useful, because each framework has its pros and cons. On the other hand, a common basis would help to advance to a mature scientific method[22].

It is beyond the scope of this Chapter, to provide a full account of all positions and viewpoints in the risk debate. For the sake of brevity and simplicity, we therefore limit ourselves to describe the extreme positions in a rather black and white manner, in order to highlight the major controversy. We aim to discuss the range of opinions by means of sketching the extreme, probably somewhat charicatural in view of the current state-of-the-art, positions related to the two controversial issues. Such an analysis can provide a basis for exploring the question whether, and if so, how the partial contributions can be synthesised.

1.1. THE DEBATE ON RISK DEFINITIONS

Risk is not a physical substance that can be directly measured. Risk is a kind of attribute ascribed to the unknown future: the real dangers and hazards are only known afterwards[23]. Risks exist only in the artificial world of risk analysis. Risk is a construct. The central question that underlies the debate on risk definitions is whether it is a construct that can be defined univocally, or whether it is a social construct, that is given a meaning through social processes.

We can distinguish between formal and informal definitions of risk. Formal definitions generally stem from especially statistics and economics. In most formal definitions, risk is defined as some function of probability (i.e. the likelihood of consequences) and negative utility (the seriousness of the impacts)[24]. An example of a

20 This labelling is in accordance with the terminology as proposed by (Linnerooth-Bayer and Thompson 1997)

21 This divergence of opinion is also described in terms of the quantitative versus the qualitative approach (see, for example, (Jasanoff 1993)), or the naïve positivists versus the cultural relativists (Shrader-Frechette 1991), or the seperatist versus sociological view ((Mayo and Hollander 1991)

22 See for example (Jasanoff 1993)

23 (Douglas and Wildavsky 1982; Vlek 1990)

24 (Hendrickx 1991)

formal definition is the one applied in the safety literature, in which risk is defined as the probability of an adverse future event multiplied by its magnitude[25]. Apart from these singular definitions, so-called 'combination functions' (i.e. aggregates of singular measures) have been proposed to assess risks[26], such as the 'probability-weighted sum of possible undesired consequences'. An example of an informal definition is 'the set of undesired consequences associated with a certain activity'[27]. Informal definitions appeared in response to the vague sense that what is experienced as being risky may be not fully or not adequately grasped by formal definitions[28]. Informal definitions are generally proposed by social scientists or by societal actors in actual risk debates.

Empirical research on risk perception[29] shows quite convincingly that the risky events "that kill people, are not necessarily the ones that anger and frighten citizens"[30]. In other words, a gap between scientific estimates and risk estimates of lay people is observed. To discriminate between the 'scientific definition' and the 'lay perception', the distinction between 'objective' and 'perceived' risk was explicitly introduced by Starr[31], who is generally considered to be an important scholar belonging to the so-called 'objectivist' school of risk analysis. 'Objective risks' then are the "real, actual, objective, measurable risks that obey the formal laws of statistical theory"[32]. 'Perceived risks' are "subjective risks inaccurately perceived by non-experts"[33]. Differences between objective and perceived risks are attributed to simple misperceptions, biases or plain deviousness[34]. With reference to the confined finding in psychological research that citizens often overestimate involuntary risks, the objectivists have it that perceived risks are inherently wrong. In the same line of reasoning the distinction is made between 'risk assessment' and 'risk management'[35]. Risk assessment is considered as the "hard" analysis that measures the "real" risks[36]. It is the process of estimating the risks associated with an activity, practise or substance[37]. Risk management comprises the "soft" administrative and political procedures to

25 See, for example, (Adams 1995)
26 See (Vlek 1990) for a comprehensive overview.
27 (TweedeKamer 1989)
28 (Vlek 1990)
29 See, for example, (Burger 1988; Fischer et al. 1991; Fischhoff et al. 1981; Jungermann and Slovic 1993; McDaniels et al. 1996; Renn 1984; Slovic 1987; Slovic et al. 1982; Weinstein 1984; Wynne 1982)
30 (Sandman 1987)
31 (Starr and Whipple 1980)
32 as quoted from Chapter 5 of the 1992 British Royal Society report on risk assessment (RoyalSociety 1992).
33 Ibid.
34 (Otway and von Winterfeldt 1982a)
35 The distinction was introduced in the early 80s by the US Research Council (NationalResearchCouncil 1983) and was elaborated on in (Russel and Cruber 1987).
36 Ibid.
37 (Mayo and Hollander 1991)

deal with risks[38]. It is the process of deciding what to do about such risks[39]. The vast and sophisticated literature in this objectivists' paradigm[40] assumes that the right expert calculations would be enough to settle questions about worthwhile risks.
There are two major types of criticism on the above objectivists' paradigm:

- criticism within the framework sketched by the objectivists
- fundamental criticism on the objectivists' basic principles

Both types of criticism will be discussed below.

First, the measurability of the two components, i.e. probability and damage, is questioned, because of the unreliability of historical records[41], uncertainty with regard to cause-effect relationships[42], and the absence of an agreed scale for measuring the magnitude of damage[43]. According to the Bayesian school of thought[44], probability is not a property inherent to the event, but a statement expressing an observer's judgement that it will occur. "There is no 'correct' probability that resides somewhere in reality"[45]. Probabilities are thus subjective "degrees of belief"[46]. So if probability is inherently subjective, experts' risk estimates are not neutral and objective.

It is furthermore argued that it is controversial which probable events should be considered: only the major negative outcome(s), or all imaginable outcomes, whether positive or negative, direct or indirect effects?[47] Merely casualties, deaths and material damage, or also environmental impacts, and social effects like social anxiety or even political and social disorder?[48] How far to go in considering higher-order consequences?[49] How to treat partial contributions to impacts, such as rendering people more susceptible to other risks?[50] And even if it is decided which damages to consider how to combine the relevant probabilities and magnitudes of damage into an overall risk estimate? A generally accepted aggregation rule is lacking[51], and can probably anyhow not be established definitively.

38 The distinction was introduced in the early 80s by the US Research Council (NationalResearchCouncil 1983) and was elaborated on in (Russel and Gruber 1987).

39 (Mayo and Hollander 1991)

40 see for example (Hafele 1976; Lowrance 1976; Starr 1969; Starr and Whipple 1980)

41 See (Adams 1995) for a comprehensive discussion and illustrative examples.

42 Examples can be found in (Somers 1995). See for a discussion on the different types and sources of uncertainty relevant for risk analysis (Morgan and Henrion 1990).

43 See, for example, (Adams 1995) and (Jungermann and Slovic 1993). (Fischhoff et al. 1984) illustrate the difficulty of choosing a unit to express the damage by bringing different choices found in the risk analysis literature to the fore. The units of damages range from annual death toll to the loss of life-expectancy.

44 Detailed discussions of the Baysian view of probability can be found in (Bernardo and Smith 1994; de Finetti 1974; Hacking 1975; Lindley 1973; Savage 1954)

45 (Otway and von Winterfeldt 1982b)

46 (Morgan and Henrion 1990)

47 (Hendrickx 1991)

48 This enumeration is taken from the list of risks associated with gene-technology as compiled by (van den Daele 1991)

49 (Fischhoff et al. 1984)

50 Ibid.

51 (Hendrickx 1991)

Besides, social scientific research, especially psychometric studies, shows that individuals on the one hand tend to discard low probabilities[52], but, on the other hand, explicitly take the catastrophic potential (i.e. high damage cases) into account[53]. Empirical research on risk perceptions indicates that citizens seem to be more worried about cases with large effects at once (such as accidents in a nuclear plant), then repeated occurrences with little damage (such as accidents with electricity at home). The definition of risk as probability times effects is thus questioned, because it does not allow to discriminate between 'low probability – high damage' and 'high probability – low damage' situations[54]. These specifics of the human mind and psychological processing have to be considered in risk analysis.

This way of thinking about risk that can be derived from the above criticism on the objectivists be characterised as the subjective perspective on risk. This point of view can be considered a kind of middle position between the objectivists and the constructivists.

Furthermore, social scientists from a wide range of disciplines argue that the formal definition of risk as a function of probability and negative utility is not able to cover crucial psychological and social dimensions. From this point of view, risk analysis does not supply socially relevant results that can inform and facilitate societal decision-making on risk. Psychologists[55] argue that risk analysis should address issues like the potential of catastrophe, the location of the impacts and contextual factors, such as voluntariness and the possibility of control as well as the cause of the risk (natural versus human-induced)[56]. In line with empirical findings on how individuals rate risks, risk estimates should be higher if a single occurrence leads to enormous impacts (in terms of deaths, for example), if one is personally likely to lose out and if the risks are human-induced and not attributable to specific societal actors. Risk estimates should be lower if one voluntarily runs the risks, and if one can control it. Anthropologists[57] argue that risk estimates should comprise fairness considerations such as trust, liability distribution and consent. Other qualitative factors added by social scientists include organisational affiliations, community dynamics, institutional context, ideology and social interactions. For this reason, alternative

52 e.g. (Tversky and Kahneman 1974; 1980; 1981)
53 (Jungermann 1985; Jungermann and Slovic 1993) (Slovic 1987; Slovic et al. 1985) (Fischer et al. 1991; Fischhoff et al. 1984) (Vlek 1996; Vlek and Stallen 1980)
54 (Kaplan and Garrick 1981; Vlek and Stallen 1981)
55 See footnote 53.
56 (Jungermann and Slovic 1993)
57 (Rayner 1992; 1987) (Johnson, 1987)

definitions of risk are proposed such as 'lack of perceived controllability' that stems from social psychology and decision-theory[58]. The sour conclusion is that "the most powerful method of science, i.e. experimental observation, is inapplicable to the estimation of overall risk in exactly those instances where public policy most demands assessments of risks"[59].

The second type of criticism mainly stems from social studies of science and technology and fundamentally criticises the basic assumptions of the objectivists' paradigm. It questions whether risks are measurable and objective at all. 'Risk measurement' is inherently problematic because risk refers to the future, and we cannot collect future data. Interpretation and judgement of today's hard facts are needed to determine their relevance for the future[60]. Besides, selecting risk measures is complicated, because different measures of the same hazard exist and the same measure can lead to different perceptions[61].

In this 'constructivist'[62] school of thought which fundamentally questions the objectivists premises, one finds arguments like "there is not an objective definition of risk. There are only different definitions which are, dependent on the problem and the context, more or less appropriate"[63]. It is argued[64] that risks are socially constructed, so there is no valid way of drawing the distinction between objective and perceived risks. According to the constructivists, risks are inherently subjective[65]. Mary Douglas' paper 'Environments of risk'[66] first introduced the idea that the definition and perception of risks are rooted in social and cultural conditions[67]. The constructivists have it that multiple legitimate risk definitions exist due to a wide variety of psychological factors, and social and cultural circumstances. They argue that any form of society and every individual produce their own selected view, which influences the choice of dangers worth attention. Constructivists therefore have it that risk analysis never should be an exercise performed by scientists alone. Societal stakeholders should participate in the risk analysis. According to the constructivists, participatory processes are an integral part of risk management.

58 see (Vlek 1990) for a comprehensive discussion
59 (Weinberg 1981)
60 (Slovic et al. 1985)
61 (Slovic 1991)
62 (Linnerooth-Bayer and Thompson 1997)
63 (Jungermann 1993)
64 e.g. (Adams 1995; Beck 1986; Douglas 1969; Douglas and Wildavsky 1982; Thompson et al. 1990) (Wynne 1980)
65 One of the first discussion on the concept of subjective risk can be found in (Rowe 1977)
66 (Douglas 1969)
67 See also (Douglas and Wildavsky 1982)

In Table 1 the main characteristics of the objectivist and the constructivist ways of reasoning are summarised just as to indicate the variety of opinions in the risk community.

objectivists[68]	**constructivists**[69]
Science is value free (i.e. positivism).	Science is entirely social (i.e. social or cultural relativism)
Distinction between objective and perceived risks.	Risk is a social construct. There is no objective definition of risk.
Objective risks are measurable in terms of probability and utility.	Risk analysis should involve qualitative factors that are difficult to measure.
Risk assessment and risk management have to be separated.	Risk assessment and management are inseparable activities in which value differences are at the core.
Right expert calculations can settle risk issues.	Participatory processes are needed to manage risk issues.

TABLE 1 Characteristics of the two major schools of thought in risk analysis

1.2. THE DEBATE ON THE RISKINESS OF MODERN HAZARDS

The question whether contemporary hazards and dangers are larger than in the past is explicitly debated within the sociological segment of the risk community[70], but it does have some impact on the community as a whole. The debate has been framed roughly by two extreme positions[71]. The first point of view[72] holds that past generations were threatened by much more direct hazards and did not worry about it. In this perspective, a critical mass of citizens has become more sensitive to risk. Modern society seems to have become unusually risk-aware and does no longer accepts vital risks as belonging to fate or destiny[73]. As a result, risk issues have gained an enormous importance in modern society and have become foreground phenomena[74].

The majority of the scholars in the risk community have it that the increasing complexity of modern technological society leads to severe risks[75]. This second point

68 or naïve positivists or seperatists (see footnote 21)
69 or cultural relativist or sociological view (see footnote 21)
70 (Kämper 1998)
71 (Krohn and Kruecken 1993)
72 see for example, (Whipple 1985)and (Douglas and Wildavsky 1982)
73 (Lübbe 1993)
74 (Vlek 1996)
75 see, for example, (Kasper 1980; Nelkin 1982)

of view can be characterised as the "Risk Society"[76] school of thought. In the wake of the German sociologist Ulrich Beck[77] these scholars argue that humanity has moved, slowly and almost unnoticed, into a society shaped by risk and hazard. The nature of risks has changed in a significant way. The crucial contemporary risks are human-created, i.e. large-scale nuclear, chemical, genetic and ecological hazards. In this view, present-day concerns about industrial pollution, radiation and the side effects of new drugs and chemicals are not comparable to concerns about pollution and impurity in less industrial societies[78]. The modern risks and hazards "surpass traditional human boundaries"[79] and "transcend the capacity of our senses"[80]. With this poetic expression Beck implies that, because of the global, long-term and universal character, contemporary risks cancel out our conventional notions of space, time and social differences. According to this point of view, increase in risk is inherent to economic, scientific and technological progress. Due to size and nature, current and future threats are substantial.

In line with the issue concerning the riskiness of modern risk, the question arises 'how important are risks for modern governance?' According to Beck, risk permeates society. The crises in the modern world root in the inability to deal with modern risks: society deals with these omnipresent 'normal accidents'[81], normal in the sense of inherent to modern industrialism, as if they are excesses. Conventional institutions and organisations are specialised in denying risks and hazards, instead of being prepared for the 'largest assumable accident'[82]. Beck characterises this situation as 'organised irresponsibility'.

The consequence of this 'institutionalised non-management' is that society may come into a negative spiral to the extent that it has nothing left to go on. The post-modern, nihilistic phantom might then become reality. Several authors[83] examine how societal mechanisms rooted in organised irresponsibility evolve, and how these processes on their turn impact upon society. A central issue is the role of scientific expertise. On the one hand, because of the 'transcending' character of risk, society heavily relies on scientific expertise. On the other hand, scientific experts just address probable risks. But, as for example the Tsernobyl-disaster showed, there is a wide gap

76 (Beck 1986)
77 See e.g. (Beck 1986; Beck 1992; Beck 1995; Beck 1996; Beck 1997a; Beck 1997b) See also introductions to Beck, e.g. Lash and Wynne (1992), and (Hajer and Schwarz 1997).
78 See for example (Kaprow 1985; Winner 1982)
79 (Vlek and Stallen 1981)
80 (Beck 1992)
81 (Perrow 1984)
82 (Beck 1992)
83 (Beck 1986) and following publications, (Jasanoff 1991; Slovic 1991)

between 'safety' and 'probable safety'. "The calculations of experts remain true, even if some nuclear plants explode"[84]. The failure of scientists to indicate uncertainty in an understandable manner not only deprives society of needed information, but it will also lead to distrust towards science[85]. In the same time, the effort to bring an unattainable level of technical rationality to decisions that are fundamentally subjective and political will weaken trust in governmental institutions as well[86].

It is a complex interplay of various societal mechanisms rooted in organised irresponsibility that may cause society to stumble into this negative spiral. Apart from the vicious cycle described above, Beck argues that we now live in an 'uninsured society'[87]. The common strategy in case of uncertainty is collective agreements as insurance. However, due to the complexity and the nature of contemporary risks, the foundations of the established risk-logic are undermined[88]. According to Beck, this results in the strange situation in which the legal system regulates every detail of technically controllable *small* risks, but implicitly legalises *large-scale, global and universal* hazards. Paradoxically enough this implies that the more hazards increase, protection decreases. As a consequence, the 'everything-under-control' mentality will either result in the return of insecurity or to rigid bureaucratic control that invades all aspects of life. Proponents of this point of view argue that to get out of this vicious circle, new institutions and arrangements are needed to deal with risk and uncertainty in a more intelligent way.

1.3. THE RANGE OF SCHOLARLY VIEWS

T range of opinions had severe implications for risk analysis activities. Over the last 25 years, the different points of view had fervent advocates and fierce proponents in and outside the risk community[89]. With the result that there is neither agreement over appropriate methods for risk analysis nor acceptance of the outcomes of public processes. As a consequence measures of risk tend to fall into two categories[90]: i) those that aim to calculate the risk of a process or a project, and ii) those that rely upon the perceptions of those assessing the risks. Measures of the first type employ

84 (Beck 1997b)
85 (Slovic 1991)
86 (Jasanoff 1991)
87 Ibid.
88 Ibid.
89 It is beyond the scope of this thesis to provide a detailed and comprehensive overview of the history risk analysis and a adequate review of all definitions and approaches. For a recent state-of-the-art review see (Stern and Fineberg 1996). The aim of this Chapter is to highlight the main controversy and its implications.
90 (Kasper 1980)

experimental evidence, long term experience, and/or sophisticated analytical calculations to describe actual risks or project potential risks. This type of measure can be associated with the objectivist school of thought. Measures of the second type tell us what people think the risks of a particular activity are. This type of measures is advocated by constructivist risk analysis.

Till the 90s the 'objectivist' perspective has dominated risk analysis, as can be concluded from the publications of prestigious bodies like the US Academy of Science[91] and the UK Royal Society[92] in the midst of the 80s. This resulted in a mechanistic approach to decision-making whereby "too great an emphasis is placed on quantification"[93]. The objectivist' view has come under increasing attack. As a result, the majority of risk-analysts now seem to agree on the following premises[94]:

- experts perceive risk differently from lay men
- risk analysis is not a purely objective process: facts and values merge frequently
- cultural factors affect the way people assess risk

This shift signifies that the supremacy of the objectivist school is weakening. However, that does not mean that the constructivists have taken over. According to critics of the constructivist approach, many constructivsts mainly criticise the objectivists' way of doing it, without providing alternatives[95].The constructivist school is criticised for going a step too far by downplaying the value of scientific and analytical methods, and scientific knowledge in general, in assessing and evaluating risks[96] Those critics argue that risks are not merely social constructs. At least some hazards are real, and many of these are measurable, though within limits. According to the critics, not all disagreement about risk is entirely political as the constructivists suggest. Methodological and conceptual disagreements are often at stake. The constructivists deny the existence of objective grounds for criticising and scrutinising risk judgements. The critics argue that although no risk estimate is value free, some are more warranted than others. Not all risk attitudes can be justified. A critical scientific overview can indicate what the data do and do not say about a certain risk and what is biased by political and/or cultural values[97]. In other words, "one can admit

91 (NationalResearchCouncil 1983)
92 (RoyalSociety 1992)
93 (Somers 1995)
94 (Jasanoff 1993)
95 (Vlek 1990)
96 e.g. (Mayo and Hollander 1991; Shrader-Frechette 1991)
97 (Mayo and Hollander 1991)

that risk judgements are not perfect and yet claim that it is possible to reason about them"[98] against the background of such a scientific overview.

What we see at the moment is on the one hand an increasing recognition of the constructivists' criticism on the objectivist framework. This can be observed from discussions in the scholarly journal Risk Analysis and from proceedings of conferences on risk assessment[99]. On the other hand, analysis of the contents of, for example, the Journal on Risk and Uncertainty, shows that the objectivists' paradigm is still playing a role in actual studies on risk for decision-making. Signs that the issues raised by the constructivists are recognised within this part of the risk community follow from attempts to address the issue of inherent uncertainty in a mathematical way. For example by bringing Bayesian statistics and subjective probability functions[100], or fuzzy sets into risk assessments.

The risk community[101] is facing the dilemma that uncertainty takes away the security of science and that conflicts are inherent to risk issues. On the basis of our analysis of the scholarly literature on risk, we conclude that:

> *the risk community is confronted with the challenge to reconcile the limitations of scientific analysis, the special characteristics of the human mind, and social and cultural factors into one coherent umbrella paradigm.*

2. Towards an integrated risk analysis

The relevance of the Risk Society concept in the broader context of risk analysis is that it reveals that risk management is essential to the governance of the complex society-environment system. As a result, the fact that an integration of the available knowledge on risk analysis is lacking[102] has severe consequences for decision-making about risk[103]. One approach to decision-making, reasoning from the objectivist paradigm, is to ignore public opinion and to insist on using solely calculated estimates of risk. But the result of such an approach is dissatisfaction on the part of the public, which in the long run may undermine the legitimacy of democracy. The other extreme, which can be associated with the constructivist point of view, is no more palatable: it may

98 (Shrader-Frechette 1991)

99 For example, the conference on integrated risk assessment in Australia (Melchers and Stewart 1995), and the annual meetings of the Society for Risk Analysis (see http://www.sra.org/)

100 for example, (Morgan and Henrion 1990)

101 It should be explicitly noted that the risk community does not only 'house' pure constructivists and objectivists, but that it is increasingly common to recognise the differences in opinion and to aim to benefit from both approaches (Passchier, personal communication).

102 See also (Gezondheidsraad 1995)

103 This section builds upon (Kasper 1980)

get stuck in satisfying public opinion in not-in-my-backyard type of discussions, and thereby deprive society of potential social, economic and environmental benefits.

Both positions err: roughly speaking, objectivists overemphasise facts and underestimate values, while constructivists overemphasise values and underestimate facts[104]. In doing so, constructivists reduce all risk judgements to social constructs, and objectivists reduce all risk estimates to scientific calculations. If risk analysis is serious about the decision-support, it has to provide a form of risk analysis that addresses both 'fact' and 'value'[105]. The aim of systematic risk analysis is to support intelligent decision-making out of knowledge of the known and critical analysis of the uncertainties. The alternative to systematic risk analysis is governance inspired by fear of the unknown.

Notwithstanding the criticism on the actual practise of risk analysis, both proponents and opponents generally agree that the risk concept comprises a promising selection and evaluation instrument for policy strategies. The underlying argument holds that it is important to explore the subject of risk analysis in order to improve the quality of decision-making[106]. The acceptance or rejection of risky activities[107] requires a dynamic decision-making process based on assessments made under uncertainty[108]. Risk analysis should enable society to consider trade-offs. To avoid that society will crawl in a sea of irrationality[109], it would therefore be interesting to explore an "integrated approach to thinking about risk analysis"[110], in order to arrive at "a framework that is both pragmatic and rational to help us cope with a largely irrational world"[111]. Without such an integrated approach to risk analysis, the knowledge of risks "will remain fragmentary and will serve at best as an imperfect guide to (..) decision-making"[112]. In other words, there seems to be a societal need for a new 'risk-logic' and a new form of risk analysis. What we need is a framework in which alternative risk judgements can be developed, compared and criticised in terms of

104 (Shrader-Frechette 1991)

105 Using the value-fact difference is highly controversial in post-modern times. In this thesis, we use the two notions to express a continuum ranging from proven evidence to hypothesis, from weak to strong knowledge, or from certain to uncertain. We do not use it to distinguish between objective and subjective (as the positivists and objectivists do), because also 'facts' are filtered and valued differently. In other words, we accept that the facts and values merge, and we value 'facts' and 'values' equally as relevant piece of knowledge, but we would like to be able to differentiate between, and to be nuanced about, different kinds of knowledge. Such a middle position is in science-philosophical literature on risk referred to as "scientific proceduralism" (Shrader-Frechette 1991) or the meta-scientific view (Mayo and Hollander 1991) and can also be found in scholarly literature associated with post-normal science (e.g. (Funtowicz and Ravetz 1992a; 1992b; 1993a; 1993b; 1994)). Compare Chapter 1 on research perspective and Chapter 3A on uncertainty.

106 Starr and Whipple (1980)

107 Where we should realise that also inaction can be risky (Douglas and Wildavsky 1982).

108 (Vlek 1990)

109 (Beck 1996)

110 (Jasanoff 1993)

111 (Somers 1995)

112 (Jasanoff 1993)

coherence, completeness, plausibility and transparency[113]. Such a framework should allow for critical scrutiny of the uncertainties involved[114].

An integrated framework for risk analysis should comprise a consistent theoretical framework and sound methods to deal both with 'facts' and 'values' in estimating risks. The ultimate challenge is to find ways to cope with the surprising world around us. The necessary approach to risk analysis accepts the inevitability of incomplete knowledge, seeks to accommodate the unknown and aims to coexist with uncertainty and surprise. So, integrated risk analysis should be designed in such a way that it uncovers facts and uncertainties and illuminates alternative judgements. An integrated approach to risk should enable us to reach robust[115] conclusions, which in turn would help us to recognise, address and manage risk-conflicts[116]. In other words, integrated risk analysis may help society to avoid 'unmanageable risk conflicts'[117] by identifying and creating public support that couples scientific facts with societal values and aspirations.

The search for an integrated approach towards risk is currently in the phase of individuals signalising the necessity for an integrated approach to risk analysis[118], building relevant networks and searching for research commitments and funds[119]. In this context, the following part of the present Chapter aims to provide a methodological contribution to this search. Our starting-point is that the various current approaches to risk capture a different, and only partial, aspect of the complex and multi-dimensional reality[120]. For example, recognising the social context and societal substance of risk does not deny the value of formal sciences and approaches. The challenging task is to deduce those partial aspects that together can provide a basis for integrated risk analysis. To that end, we have to determine which requirements such an integrated risk analysis should satisfy:

- the process of risk analysis should be one that assures real involvement of scientists and stakeholders (i.e. decision-makers, the general public, non-governmental organisations and the economic actors)
- both 'facts', 'values' and alternative judgements should be illuminated

This means that the following issues discussed in the risk literature are relevant in

113 Ibid.
114 (Mayo and Hollander 1991)
115 (Clark 1980)
116 (Jasanoff 1993)
117 (Beck 1992)
118 (Funtowicz and Ravetz 1992a) (Jasanoff 1993) (Gezondheidsraad 1995; 1996) (Vlek 1996)
119 (Linnerooth-Bayer and Thompson 1997)
120 (Jasanoff 1993)

our endeavour: i) social, psychological and physical aspects of risk, and ii) the need for participation.

2.1. THE NEED FOR AN INTEGRATED RISK NOTION

Key insights with regard to the quantitative risk aspects and how to calculate them can be found in the objectivist scholarly literature. The complementary value of public risk perceptions to scientific risk estimates[121] is that the underlying conceptualisation of risk is much richer than that of the experts and reflects legitimate societal concerns that are typically omitted in risk estimates[122]. In lay perceptions, qualitative, indirect and long-term damages are taken into account[123]. As a result, societal aspects of risk can be derived from the social and behavioural research on risk perception. It is surprising how little objectivist risk analysts thus far have tried to benefit from the insights the state-of-the-art in social and behavioural research on risk provides. It is equally surprising that expert knowledge, experience and creative imagination about the future usually fall outside the scope of decision analysis of risk issues as practised in the social sciences[124]. Objectivist risk studies concentrate on scientific risk assessment, while psychometric studies focus on public risk perceptions. Policy sciences and technology assessment explicitly attempt to integrate scientific knowledge on facts and uncertainties, and public values and judgements. Building upon these efforts, the challenge is thus twofold. First, to use the complementary aspects of risk as addressed by both objectivist and constructivist literature. And second, to phrase the notion of 'risk' in such a way that it implies integration of various pieces and types of knowledge and the judgements of facts, uncertainties, and values into risk estimates and assessments.

Empirical research on risk perception shows that different 'fundamental moods of thought'[125] exist that result in specific expectations concerning the riskiness of hazards. Some expectations are relatively permanent[126]. Especially these seemingly stable expectations have a profound effect on risk perception[127]. Such 'beliefs' about risks[128], which can be interpreted as a priori risk attitudes, are embedded in general

121 See also (Vlek 1996) who is arguing that perceived risk dimensions and the formal definitions can be considered as supplements.
122 (Slovic 1991)
123 (Jungermann and Slovic 1993)
124 See, for example, (Vlek and Stallen 1981)
125 (Slovic et al. 1985)
126 (Kahneman and Tversky 1982)
127 (Kahneman and Tversky 1982)
128 (Cotgrove 1981)

social orientations, such as short or long time horizons, and concentration on losses or gains[129]. At the highest level of abstraction these general social orientations can be described as worldviews[130]. The variety in risk attitudes is usually described in terms of risk avoiding, risk taking, and risk accepting[131]. These a priori risk attitudes in turn structure the way in which the uncertainties, accompanying a specific risky issue, are perceived[132]. This is not to say that risk attitudes of specific actors are deterministic and do not vary in time. However, it does mean that various biases result in different risk perceptions. The definitions of risk vary greatly, depending upon the chosen perspective. So 'risk' cannot have a generally shared meaning. Cultural variety implies inherently differing perspectives towards the interpretation of risk. Especially so-called 'cultural theorists' argue that each cultural group has its unique way of looking at the world. Social and cultural risk analysts have attempted to account for pluralistic interpretations of risk. Anthropologists, for example, have devised a variety of classificatory schemes that reduce the range of cultural variation to a number of useful types. Grid-group analysis, which evolved from Douglas and Wildavsky's pioneering book 'Risk and culture[133], is such a scheme that has received prominence in social and cultural risk analysis since .

Furthermore, social and cultural analysis as well as the subjective probability school indicates that scientists cannot free themselves entirely of biases. A degree of subjectivity is inherent to risk assessment. As Fischhoff *et al.* explain: "in risk analysis, research requires the exercise of judgement. It is expert judgement, but judgement nonetheless"[134]. Not only about what is but what ought to be in the future[135]. Experts slide bias into the calculations unobserved[136]. Both scientific knowledge and value judgements are involved in the scientific assessment of risk. Case studies on decision-making on risks[137] reveal diverging interpretations and conflict among experts. Within the social and behavioural segment of risk analysis there seems to be agreement that the perceptual biases of scientific experts do, at least partly, arise from social and cultural factors. As Jasanoff[138] concludes: "Cultural variation appears to influence (..) the way (..) scientists select among competing interpretations of data (..)

129 (Douglas and Wildavsky 1982)
130 (Cotgrove 1981)
131 See also Chapter 3A
132 compare (Slovic 1987; Slovic et al. 1985; Douglas and Wildavsky 1982)
133 (Douglas and Wildavsky 1982) In this first Cultural Theory book a simple dichotomy of 'center' and 'border' was used, which in subsequent work evolved into the two-dimensional grouop-grid classification.
134 (Fischhoff et al. 1984)
135 (Douglas and Wildavsky 1982)
136 Ibid.
137 (Tarr and Jacobson 1987; Jasanoff 1987; 1991)
138 (Jasanoff 1991)

and the techniques for coping with uncertainty". Coping with that reality requires seeing the information from many perspectives[139].

In sum, risk is thus multi-dimensional and variably defined among individuals[140]. Social research on risk indicates that both science and the public exhibit different legitimate perspectives towards risks. Conflicts are therefore inherent to risk issues. In this context, the role of risk analysis should be to provide evaluation of the major consequences arising in risky decisions that reflects plural risk perceptions, incl. conflicting expert opinions, interdisciplinary variety and public value systems[141]. By illuminating the variety of judgements, we may in principle be able to understand which policy differences with regard to risk can be reconciled and which not. Instead of favouring one risk perception, the challenge is to make the case for different views on risk[142]. Risk should thus be estimated from multiple perspectives with the idea that such a multiple perspective-approach "results in a balanced understanding of risk"[143].

2.2. THE NEED FOR PARTICIPATION

In order to organise risk analysis in such a way that it assures real involvement of stakeholders, it is argued that decision-makers, citizens, opinion leaders and representatives of interest groups should actively participate in the process. Especially in the constructivists risk community, we can find ideas on risk analysis as a participatory process. Participatory processes, also referred to as the 'multiple-stakeholder approach'[144], provide a way to design a workable environment in which all parties can co-operate in addressing risk issues. Participation in risk analysis is not a new issue. Nelkin and Pollak[145] reviewed various types of participation in evaluating the risks of technology as have been practised already in the 1970s, such as public inquiries (e.g. the Berger Inquiry in Canada[146] and the Windscale Inquiry in Britain[147]), complaint investigations (e.g. in France[148] and in Germany), citizen advisory groups (e.g. in the USA), referenda (e.g. in Switzerland) and citizens' dialogues (e.g. in Sweden and in Germany). However, at that time no systematic attention was paid to participatory procedures, methods and the actual benefits of participatory involvement.

139 (Fischhoff 1995)
140 (Earle and Cvetovich 1985)
141 Compare Beck's publications: see footnote 77, (Whipple 1985) (Fischhoff et al. 1984)
142 (Douglas and Wildavsky 1982)
143 (Jungermann and Femers 1995)
144 See, for example, (von Winterfeldt 1992)
145 Nelkin and Pollak (1980)
146 (Gamble 1978)
147 (Wynne 1978; 1982)
148 (Colson 1977)

The first thorough analyses of the effectiveness of participation in risk issues are of a recent date[149]. So far, the need for participatory processes has generally been underpinned with theoretical arguments and with reference to anticipated benefits. Among the pleas for participatory risk analysis we have found:

- Risk analysis should be an iterative process[150]. Participatory methods in theory assure ***iterative analysis***[151].
- Experts are too far removed from an appreciation of public attitudes and understanding. Participatory methods enable to ***integrate public knowledge and understanding*** in risk analysis.[152]
- Risk communication is more effective if it is structured as a ***two-way process*** than as a one-way transfer of facts from experts to the public is. Participatory processes involve such a two-way process.[153]
- Participatory methods are defended by the nature of ***democracy***[154]. Risk decisions imply that citizens must accept the undesired consequences[155], they must agree to do without some things and accept substitutes for others, they must obey specific rules, such as safety rules and environmental laws, etc[156]. People and communities have a right to participate in decisions that affect their lives, property and things they value. For this reason, all parties that have a stake in the risk issues concerned are legitimate partners in the risk analysis process[157]. Participatory methods are a way to involve stakeholders more directly in the formulation of policy[158].
- Risk analysis involves a ***normative judgement*** about what is desirable. Participatory risk analysis is considered to be one way to forge a societal dialogue addressing the question: How do we want to live?
- Participatory methods are considered to be the logical imperative for a ***pluralistic*** society. Due to legitimate pluralism, risk issues "must be necessarily resolved through negotiation and debate among many competing interests"[159].

149 (Geurts and Mayer 1996; Renn et al. 1995) (Geurts et al. 1987)
150 (Rayner and Cantor 1987)
151 Ibid.
152 (Somers 1995)
153 See, for example, (Covello et al. 1991; Jasanoff 1993; Renn et al. 1995; Slovic 1991)
154 See for example, (Kunreuther and Linnerooth 1983)
155 (Nelkin and Pollak 1980)
156 (Slovic et al. 1985)
157 (Covello et al. 1991)
158 This argument in favour of participatory methods is quite controversial, because in political theory and in the practise of representative democracy this type of direct participation is avoided (Hoppe, personal communication).
159 (Jasanoff 1991); The counter-argument is that there are other ways to organise negotiation and debate among many competing interests than participatory methods, such as a type of corporatism or elite-pluralism (Hoppe, personal communication).

In sum, proponents of participatory risk analysis see the following benefits of involving stakeholders and/or the general public: more creativity, improved production and diffusion of knowledge, integration of different sources of information and knowledge, mutual understanding between opposing groups, early co-ordination, improved legitimacy or enhancement of democracy, improved decision-quality, commitment of participants, and more effective communication between analysts and users of the analysis[160].

Participation does not necessarily imply to turn over "research labs to untrained persons"[161]. The aim of participation is "to bring the relevant parts of science into the public debate along with all the other issues affecting our society"[162]. In our point of view, scientific involvement is needed in participatory processes, in order to enable effective management of risks[163]. Only a societal debate 'armed"[164] with scientific arguments is able to separate the sheep from the goats. It could be argued that scientific information could be fed into the participatory process, without the scientists participating, however experienced risk communicators[165] argue that the following conditions have to be satisfied before non-academics feel able to judge and trust scientific information, i.e.:

CONDITIONS CONCERNING CONTENT

- familiarity with underlying science
- familiarity with assumptions, inputs and models
- familiarity with analytical perspectives
- ability to double-check

SOCIAL CONDITIONS

- familiarity with scientists/scientific community
- recognition of societal concerns
- respectful treatment

These conditions can only be satisfied if scientists are actively involved in the iterative and interactive process. Our conclusion is that both scientists and stakeholders are needed in participatory risk analysis in order to overcome a serious dilemma in complex risk analysis[166]: "The experts should not control society's (..) choices, but

160 (Geurts and Mayer 1996)
161 (Funtowicz and Ravetz 1992b)
162 Ibid.
163 Compare the type of participatory processes, which in Chapter 2 are described as mutual learning.
164 (Beck 1992)
165 E.g. (Fischhoff 1996)
166 Quote from (von Winterfeldt 1992), see also (Vlek 1996)

the public and their political representatives are not sufficiently informed to assume complete control themselves".

The challenge of participatory processes is to join different sorts of expertise and various perspectives, into a mutual learning process. Building upon Beck[167] and Fischhoff et al.[168], the following steps towards participatory risk analysis can be distinguished:

- risks should be revealed and be made subject of societal discussion.
- all participants, whether scientists, decision-makers, citizens, business people or interest groups, need to understand the limits to their own knowledge and expertise.
- politics should accept its limitations; it is not the only place where societal decisions are made.
- scientists should be self-critical; i.e. enough attention should be paid to (suppressed) scepticism.
- citizens, business people, scientists and other actors should admit that they make politics.
- non-academics need to understand the limits of advise provided by various experts.
- organisations and institutions should be organised in an open and pluralistic manner.

The ideal of the participatory risk society is a society in which the public is informed, involved, interested, reasonable, thoughtful, solution-oriented, co-operative[169], non-academics are co-producers of knowledge and heterogeneous coalitions are formed, composed of a 'strange' variety of participants. Participatory risk analysis would then imply a dialogue between such incidental and thematic 'coalitions of differences'[170].

Participatory risk analysis is like a many-sided conversation in which being ultimately right or wrong is not the issue. What matters, is that the dialogue continues with new questions. New kinds of questions will inspire new insights, which in turn will result in risk strategies that could not have been thought of before. Participatory risk analysis ideally is thus an iterative and continuous process, which can inform decision-making on risk issues by providing insights and suggesting risk strategies.

167 (Beck 1986) and his succeeding work (see footnote 77)
168 (Fischhoff et al. 1997)
169 (Covello et al. 1991)
170 (Beck 1996)

2.3. THE CHALLENGE

From the above assessment on concept of risk and literature on risk analysis, it can be concluded that integrated risk analysis has to satisfy the following requirements:

- Risk analysis should be organised as a participatory process.
- Risk analysis should reflect the variety of value judgements and perspectives.
- Risk analysis, being an iterative and continuous process, should nevertheless enlighten particular decision-making choices. The key task of risk analysis is to provide needed and appropriate information to decision-makers and the public[171]. Risk analysis should provide reliable and understandable information addressing the dimensions relevant to the public and decision-makers in a transparent manner.

From the above we can conclude that integrated risk analysis should be a process-oriented approach. Integrated risk analysis is seen as a mutual learning process and is defined as:

> *A dynamic and participatory process in which inevitably incomplete, conflicting, uncertain and situated knowledge is evaluated and structured into alternative risk judgements in such a way that robust strategies can be explored with the best possible understanding of current knowledge, its limitations and implications*[172].

Integrated risk analysis is not meant to be a panacea for all risk issues. Not all risk issues need to be settled in an integrated, participatory manner. Some risks are not so controversial and can be reasonably calculated by available methods. For that reason, it is necessary to explore and classify the different types of risk.

In order to develop a framework for integrated risk analysis the following issues have to be settled:

- defining and classifying risk
- set-up for participatory risk analysis, incl. guidelines, tasks and tools.
- developing methodologies that enable multiple risk assessments
- designing formats for risk statements

Our ambition is to seek in the impressive body of risk analysis literature seeds that may blossom in an integrated framework. From the scholarly literature on risk discussed in the previous sections, we conclude that scientific assessment and participa-

171 Compare (Stern and Fineberg 1996)
172 Phrasing is inspired by (Clark 1980; Morgan 1978)
173 (Rotmans 1998). See also Chapter 2.

tory processes have to be organised in an iterative and cyclical manner. There are two possibilities to structure such an iterative risk analysis effort, i.e. a demand-driven and a supply-driven approach[173]. The central issue underlying this difference is how much influence the participants have on the framing and structuring of the risk issue. In the supply-driven approach, scientists are framing the risk issue. The risk analysis effort in this mode starts with a scientific assessment of the risk issue at stake, which involves an assessment of the state-of-the-art knowledge and an overview of recognised risk perceptions. This scientific assessment is then evaluated in into a participatory process.

Risk analysis in a demand-driven mood reasons from the concerns expressed by stakeholders in a first participatory round. The stakeholders thus define the risk issue in this type of risk analysis. These concerns and the accompanying information needs are then, if possible, addressed in the scientific assessment of the risk issue at stake[174]. A demand-driven risk analysis differs from the supply-driven approach in the sense that stakeholders determine in the first round what risk issues are most pressing in societal terms and what developments and consequences should be taken into account in a risk analysis. In this way, the non-scientific participants frame the scientific assessment.

The framework for integrated risk analysis is presented in Figure 2, where the various components of such an integrated risk analysis are specified in the remaining of the present Chapter.

We would like to illustrate the various steps by means of an example, which builds upon the exemplary case of alternative technologies for electricity generation, provided by Fischhoff and colleagues[175] in their seminal paper on defining risk. The strength of the work of Fischhoff and colleagues is that it illustrates some ideas of multi-dimensional definition of risk and of pluralistic risk assessments, although it did not involve participation. Furthermore, the case allows to discuss those ideas that were not already implicitly or explicitly proposed by Fischhoff and colleagues.

CASE

> Six energy technologies were selected to consider, i.e. coal, hydropower, large-scale wind power, small-scale wind power, nuclear power, and energy conservation. The latter can reduce the demand for electricity, where the others can increase the supply of electricity.

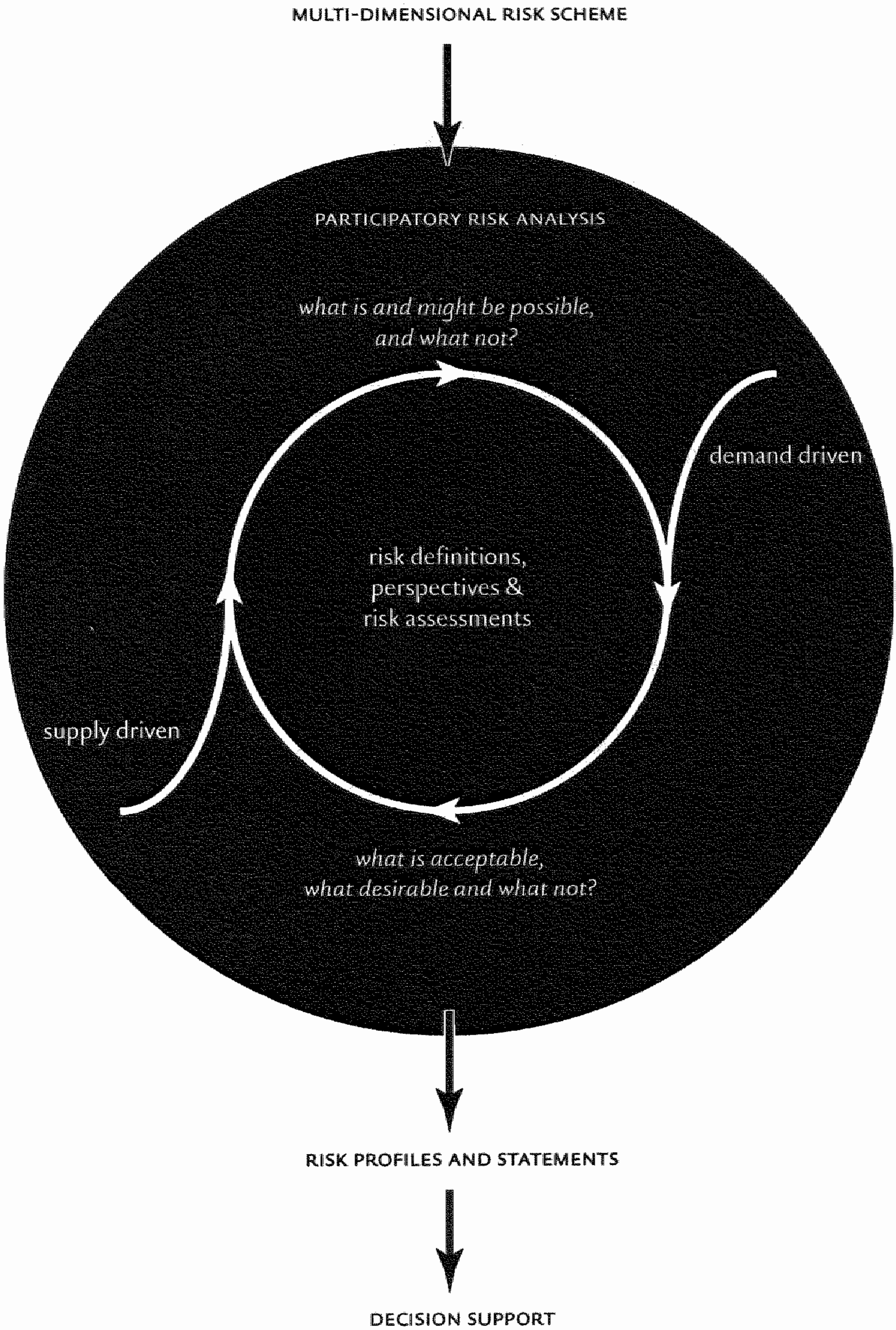


FIGURE 2 Framework for integrated risk assessment

3. Defining and classifying 'risk'

Risks are so diverse, how do we decide which ones need to be addressed in an integrated manner? Risk issues fundamentally differ with regard to[176]:

- the *level of control*: personal control *versus* collective affair
- the *time-horizon*: momentary, short-term, medium-term and long-term (i.e. inter-generational)
- the *spatial scope*: individual, indoor, local, regional, national, continental, and global
- the *level of uncertainty*[177]

These aspects are usually linked together[178], in the sense that collective risk issues that are long-term in character are usually inherently uncertain and quite often involve large scales. Conversely, personal risks are usually momentary or short-term, are small-scale and can be quite well estimated. The above risk aspects determine the level of public interest and societal importance[179], and thereby indicate whether the risk issue is policy-relevant. Building upon these aspects, risk issues can be classified as operational, tactical and strategic risks[180] (see Figure 3).

Individuals cannot control strategic risks and the time horizon usually transcends the short-term. Usually, this sort of risks cannot be exactly located and the level of uncertainty associated with this type of risks is high. Such strategic risks are complex issues[181]; they generally comprise social-economic, environmental and institutional dimensions, that they involve multiple scales, and that pertain to a web of problems. In case of strategic risks, a variety of risk factors usually accumulate and interact. While in case of operational risks risk perceptions may converge, in case of such complex issues divergent and fundamentally different risk definitions and risk perceptions usually dominate the societal debate. Especially in the case of strategic risks, a participatory process is needed that enables to recognise different perspectives, to consider these perspectives in a systematic manner and to arrive at robust

174 Compare (Fischhoff 1996) arguing that if public values direct the risk research this will change the topics being studied.
175 (Fischhoff et al. 1984)
176 Building upon (Funtowicz and Ravetz 1992a; 1992b; Fischhoff 1995; Gezondheidsraad 1996; Vlek 1996)
177 See Chapter 3A for a comprehensive discussion of the levels of uncertainty. See Chapter 4 for an extended discussion on risk and uncertainty.
178 (Gezondheidsraad 1995)
179 We hereby deviate from the classification of the (Fischhoff 1995; Gezondheidsraad 1996; Vlek 1996), in which the level of public interest is considered to be one of the constituting aspects.
180 This three-category classification resembles the distinction made by (Funtowicz and Ravetz 1990) and subsequent publications, in applied science, professional consultancy and post-normal science. Applied science deals with operational risks, professional consultancy with tactical risks and post-normal science with strategic risks.
181 See Chapter 2 for the definition of complex as adopted in this thesis.

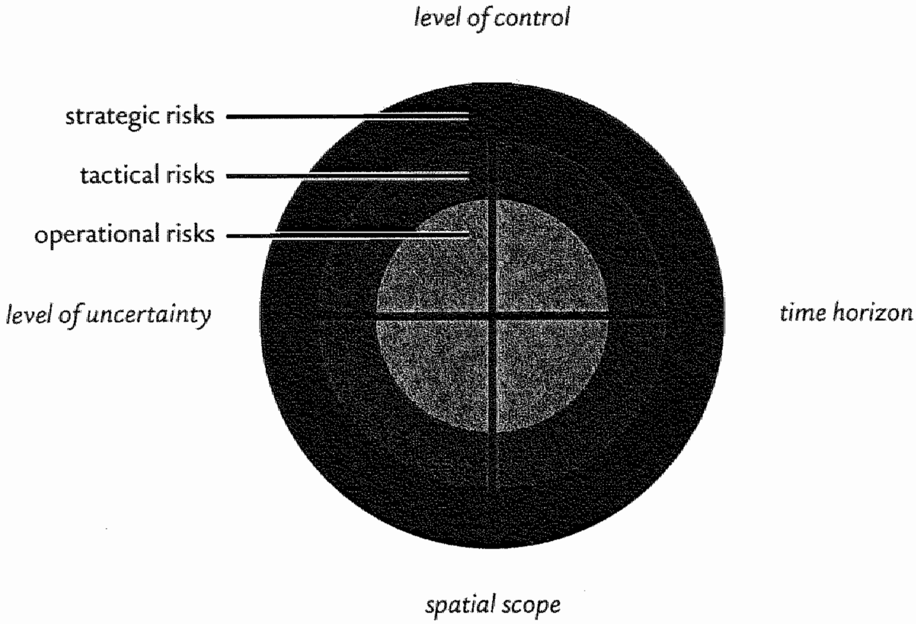


FIGURE 3 Classification of types of risk

risk statements that can inform decision-making. In sum, integrated risk analysis is especially relevant in case of strategic risks[182].

"Risky decisions" are choices among options, each of which has a variety of relevant features[183]. Although there is no unique definition of 'risk', from the above it can be concluded that risk in strategic risk cases is a multidimensional notion, of which some dimensions can be expressed quantitatively and others not[184]. For our purpose, we are interested in a notion of 'risk' that integrates scientific, psychological and socio-cultural dimensions. Integrated in this context means doing justice to the multiple dimensions in a balanced way so that it is more or less acceptable to experts, the public and decision-makers. An operational definition of risk thus should be[185] i) logically sound, ii) reflective of scientific expertise, iii) reflective of public values, iv) responsive to social concerns and v) acceptable to experts, the public and decision-makers. Building upon the above, the end product of the integrated risk analysis processes is:

> *Risk statements that are the joint product of knowledge (i.e. judgements of facts, values and uncertainties) about the future and evaluation of desired prospects about a complex, incompletely known issue.*

182 Compare Chapter 2, in which we argue that Integrated Assessment is especially relevant in the first phases of the policy life cycle.
183 (Fischhoff et al. 1984)
184 Compare (Gezondheidsraad 1995)
185 Compare the requirements as proposed by (Whipple 1985).

From the scholarly literature on risk it can be concluded that context-dependent risk-definitions are more appropriate. Reasoning from this premise, we would like to arrive at a generic multi-dimensional risk scheme that can be applied to different contexts. In this case, it suffices to indicate a general scheme that is as comprehensive as possible. Such a scheme can then serve as a starting point for defining risk in a compact way that is sufficiently comprehensive for the relevant risk issue[186].

Which characteristics or dimensions 'define' risk? Otway and his associates[187] characterise four clusters of risk attributes that could be useful, i.e.:

- economic and technical benefits factors
- environmental and physical risk factors
- psychological risk factors
- socio-political and cultural risk factors.

In order to be reflective of both public and expert knowledge, integrated risk estimates should indicate the relevant risk factors on these different attributes. In order to be relevant to decision-making processes, it is furthermore essential, although not sufficient, that risk analysis comprises options about "what to do", i.e. alternative policy options[188]. Furthermore, damages and benefits are distributed in time, space, as well as demographically distributed. This distribution may be inequitable and uneven. Decision-makers should be able to evaluate such trade-offs. It is therefore necessary that risk analysis addresses the question: risky to whom? How are the consequences distributed in terms of personal, collective, intergenerational, economic, sector-specific, societal, institutional and/or environmental impacts?

Risk statements should summarise insights with regard to the related questions[189]:

i) What might happen?

ii) What consequences are imaginable if it happens, and are these consequences acceptable/desirable?

in terms of both possible benefits (i.e. effects valued as positive by at least one party in the risk debate) [190] and possible damages (i.e. effects valued negatively by at least one party in the risk debate), further specified into:

   - social (e.g. in terms of health and quality of life), economic (e.g. economic losses/gains), environmental (e.g. in terms of ecological value,

186 Compare (Vlek 1996)

187 (Otway and Fischbein 1977 ; Otway et al. 1978)

188 See (Covello et al. 1991) for a synthesis that underpins this conclusion.

189 Compare Kaplan and Garrick (1981)

190 Risky activities or developments do generate some benefits for someone. If risk was just about negative consequences that are equally distributed, it would probably be much easier to get consent; see (Fischhoff et al. 1984; Gezondheidsraad 1995; 1996; Vlek 1990)

biodiversity and natural processes/functions) and institutional terms
- terms of distribution
- direct and indirect effects

iii) How plausible is the imagined event or series of events and how likely are the consequences?

iv) What can be done about it?

Answers to the above questions together in principle yield risk statements that comprise knowledge about the future and an evaluation of desired prospects. The first and third questions define what dimensions the assessment of knowledge about the future should address. The fourth question points to the evaluation of desired prospects. The second and fifth question involves both dimensions.

In addition to the above list of risk questions, the following list of key dimensions is compiled from social and behavioural research[191]:

- equity
- cause: e.g. in terms of *natural versus human-induced*
- catastrophic potential or 'maximum credible accident'[192]
- invisibility and dread[193]
- controllability
- voluntariness
- familiarity: *whether unfamiliar impacts are to be expected.*
- accident history: *whether activities have a history of major accidents.*[194]
- reversibility
- delay: *whether impacts will extend to future generations.*

Consistent findings in statistical analysis of perceived risks are the following two correlations[195]:

- a positive correlation between voluntariness and controllability
- a negative correlation between delay and familiarity[196]

These correlations enable us to condense the dimensions that can supplement or can enable to elaborate on the above questions.

191 This list is derived from (Jungermann and Slovic 1993; Nowotny 1976; Otway 1980; Otway and Fischbein 1977; Renn 1984; Slovic et al. 1980a; Vlek and Stallen 1981; Wynne 1980; Otway and von Winterfeldt 1982a; 1982b) (Covello 1985; Slovic 1987)

192 Both in objectivist and constructivist (for example, Beck) circles, the importance of the 'maximum credible accident' in thinking and deciding about complex issues is brought forward.

193 Social and behavioural research indicate that risk analysis involving dread and unknown risks need to be sensitive to higher order risks (Slovic 1991).

194 Accidents serve as signals of how risky an activity or development is (Jungermann and Slovic 1993)

195 E.g. (Vlek 1996; Vlek and Stallen 1980; 1981)

196 In other words in case impacts for future generations are expected, these impacts are considered to be unfamiliar.

From the above the following list of questions, further referred to as risk dimensions[197], can be deduced that may serve as heuristic in defining risk in specific contexts:

- what might happen?
- imaginable consequences?
- risky to whom?
- equity?
- cause?
- catastrophic potential?
- invisible dread?
- controllable? / voluntariness?
- familiarity? / delay?
- accident history?[198]
- reversibility?
- how plausible/likely?
- acceptable/desirable?
- what can be done about it?

This risk scheme expresses the multi-dimensionality of risks. We do not argue that all these questions have to be addressed in any risk case. Because of the wealth of risk dimensions, selection will be anyhow needed in practical risk cases[199,200]. The character and features of the specific risk issue should frame the selection of risk dimensions to be considered in the risk analysis[201]. Differences in the selection of risk dimensions will lead to different risk definitions. Currently, these selections are implicit and opaque, and thereby obscure the risk discussions. The aim of the above risk scheme is to allow systematic and transparent selection of risk dimensions with the aim that different risk definitions can be shared, in order to enhance the chances for a meaningful communication.

197 In the literature such questions that are meant to characterise risks are also referred to as risk attributes, see for example (Vlek 1996).
198 This dimension has to be treated with care in case of new technologies, because a too rigid interpretation may lead to unfair conclusions (Hoppe, personal communication).
199 Compare (Gezondheidsraad 1995)
200 Similar pleas for a comprehensive definition on the general level and derived specific simplifications can be found by (Vlek 1996).
201 Compare (Gezondheidsraad 1995)

CASE DEFINING AND CLASSIFYING RISK

The first step in integrated risk analysis is to consider which risk dimensions are crucial for the case. This can be done in a demand-driven or a supply-driven mode. Let us take the supply-driven approach, as Fischhoff *et al.* have adopted. They took into account the following 5 risk attributes:

- death risk for workers (*risk attribute 1*) and for the public (*risk attribute 2*) expressed in the expected number of deaths per Gigawatt year (Gwyr) of electricity generated or saved.
- morbidity risk expressed in expected person-days of incapacity per Gwyr of electricity (*risk attribute 3*).
- public concern in terms of the level of unknown (*risk attribute 4*) and dread (*risk attribute 5*). Psychometric methods are used to gauge these attributes.

How does this choice reflect the dimensions we have distinguished? The question 'what might happen?' is implicitly addressed by the choice of the 6 alternative technologies. The risk issue is thus brought down to the issue what are the risks associated with these particular technologies. The risk attributes chosen by Fischhoff *et al.* reflect the following risk dimensions either implicitly or explicitly:

IMAGINABLE CONSEQUENCES

- benefits: *electricity generation*
- damages: *i) dead workers, ii) dead citizens, iii) ill workers, and iv) unhappy public*

RISKY TO WHOM

- workers by electricity generation plants
- public

CAUSE

- *human-induced (technology)*

HOW LIKELY/PLAUSIBLE ARE THESE CONSEQUENCES

- *implicitly comprised in the measures used for death and morbidity risks*

WHAT CAN WE DO ABOUT IT

- *choice of technological option*

Risk attributes 4 and 5 are evaluated by means of psychometric methods. With a survey, respondents are asked to score the 6 technologies on the following properties (scale 0-100, score of 0 implies that technological option has this property according to respondent)[202]:

- observable
- known
- effect immediate
- old
- known to science
- controllable
- not global catastrophic
- consequences not fatal
- equitable
- individual
- low future risk
- can be easily reduced
- voluntary
- does not affect me

The scores of the sample on these properties are combined and aggregated[203] into values for risk attribute 4 and 5. In this way, the definition adopted by Fischhoff *et al.* addresses the dimensions of desired prospects by means of gauging public perceptions.

The general multi-dimensional risk definition is in this way translated into measurable items that are appropriate for the case under concern. Fischhoff *et al.* do not specify their case in terms of scale, so the size of the sample, the profile of the respondents, and on the basis of what data (local, national global) morbidity and death risks are calculated are not specified. In a real case, it is necessary to further concretise the items in spatial and temporal terms. Nevertheless, it illustrates how the generic risk scheme proposed in this Chapter, can serve as a heuristic in specific cases.

202 Although (Fischhoff et al. 1984) indicated that and how this data should be collected via a survey, they did not actually do such a survey. In their paper they used fake data.

203 (Fischhoff et al. 1984) did not explicitly discuss how the scores were combined and aggregated. In a real case, it is necessary to specify the aggregation procedure (see also Chapter 5).

4. Participatory risk analysis

How to design participatory risk analysis? Four principal groups have to be involved[204]:

- scientific experts, who generate required scientific and technical information.
- decision makers, who decide about risk issues.
- citizens and opinion leaders, who learn about risks through interactive communication and who, on that basis, formulate their risk judgements.
- interest group representatives, such as representatives of NGOs, who express interests associated with the risk issues.

The second step is to explore what tasks such a heterogeneous group comprising scientists and stakeholders should perform. What jobs are assigned to them? An answer to this question can be derived from a closer inspection of the risk dimensions. Reasoning from the characteristics of the different participants, we have attempted to indicate the likely expertise among scientists, decision-makers, citizens and interest group representatives (see Table 4).

The first responsibility of scientists is to indicate what is known and what not, and what seems to be possible and what not in the light of current knowledge. As a consequence scientists have a special role to play in highlighting facts, hypotheses and uncertainties with regard to the various dimensions. Taking account of the constructivist lessons, it is important that the scientists are aware of, and open about, their value judgements and perspectives. Building upon this profile of the scientists as participants in integrated risk analysis, it is possible to evaluate which dimensions in general require this kind of input (marked by ++), and for which dimensions this type of knowledge can be useful (marked by +). Some of the risk dimensions cannot be addressed by scientists. For example, scientists do not possess any particular competence or expertise with regard to the question whether the consequences sketched are acceptable.

The knowledge scientists contribute is usually of a general and abstract character. Decision-makers, citizens and interest group representatives can provide local knowledge, i.e. knowledge that is situated, context-dependent and site specific. This understanding and insight can supplement, complement and elaborate the input of scientists. Citizens and interest group representatives have a special role to play in sketching societal aspirations and constraints that are important in view of the stakeholders. Starting from this profile, it is possible to assess where the input of the non-

204 Compare (Earle and Cvetovich 1985), who also mention mass media representatives who communicate risk information to the general public.

academic stakeholders is essential (for example, with regard to the equity) (marked with ++), where it would be welcomed (marked with +), and in which cases decision-makers, citizens and representatives of interest groups do not seem to possess particular competence of expertise.

	INVOLVES EXPERTISE OR INVOLVEMENT OF		
RISK DIMENSION	scientists	decision-makers	citizens and interest group representatives
What might happen?	++	+	+
Imaginable consequences?	+	+	+
Risky to whom?	++	+	+
Equity?		++	++
Cause?	++	+	+
Catastrophic potential?	++		++
Invisible & dread?			++
Controllable/ voluntariness?	+		++
Familiarity/delay?	++		++
Accident history?	++		+
Irreversibility?	++		
How plausible/ likely?	+	+	+
Acceptable/ desirable?		++	++
What can be done about it?	+	++	++

TABLE 4 Participants' likely expertise and knowledge related to tasks in integrated risk analysis

LEGEND empty signifies no particular competence or expertise, + indicates relevant competence or expertise, ++ indicates outstanding competence or expertise

If we take the preliminary division of roles as sketched in Table 4 as starting point, the participatory process should be organised in such a way that scientists collect and communicate facts, hypotheses and uncertainties on the following dimensions: i) what can happen?, ii) imaginable consequences?, iii) distribution of risk?, iv) cause?, v) catastrophic potential?, vi) delay?, viii) accident history?, ix) irreversibility?, x) plausibility/likelihood?, and xi) what can be done about it?. In this assessment process, they have to be aware of subjectivity and multi-interpretability. Scientists can furthermore use psychometric methods to estimate lay perceptions of: i) catastrophic potential, ii) invisibility & dread, iii) controllability/voluntariness and iv) familiarity.

The set-up of participatory processes should stimulate decision-makers to consider especially equity issues, and options and strategies. The citizens and interest group representatives have a special role to play in expressing the perceived level of i) catastrophic potential, ii) invisibility and dread, iii) control and/or voluntariness, iv) familiarity and/or delay. Furthermore, these participants should be invited to express their local knowledge concerning the following dimensions: i) what can happen?, ii) imaginable consequences?, iii) distribution of risk?, iv) cause?, v) accident history?, vi) plausibility/likelihood?, and vii) what can be done about it?. Last but not least, the key role of these participants is to express which risks and imaginable consequences are acceptable and which are not. The participatory process should be organised in such a way that this role is appointed to the non-academic participants.

Inspection of Table 4 helps to articulate what we expect from participants in participatory risk analysis. Following this line, the tasks assigned to the participatory processes in a supply-driven risk analysis involve:

- to ***structure, enrich*** and ***evaluate*** the ***scientific assessments***[205]:
    - to articulate local, situated and case-specific *knowledge*.
    - to formulate *information needs* with regard to imaginable developments and consequences that were not taken into account.
    - to assess how *likely* the considered developments and consequences are from a societal point of view.
    - to propose and evaluate *policy and societal responses.*
- to ***evaluate*** the considered developments and plausible consequences in terms of:
    - equity
    - the catastrophic potential associated with the consequences
    - the level of dread and invisibility associated with the consequences
    - the level of familiarity
- to express and assess ***societal constraints and aspirations*** both in terms of desirability of benefits and unacceptability of impacts.
- to evaluate ***trade-offs*** between societal constraints and aspirations, economic benefits, and technical and physical possibilities.
- to produce ***informed risk judgements***.

In a demand-driven risk analysis, primary to the jobs described above, it is the responsibility of the participants to frame the risk analysis by determining what risk issues are most pressing in societal terms, what developments and consequences should be considered in the risk analysis, and how risk should be defined (i.e. so what risk dimensions should be considered).

205 Dependent on whether a demand-driven or supply-driven approach is adopted in the integrated risk analysis effort the emphasis attached to these tasks differ.

Risk communication literature suggests conditions for participatory processes[206]. The first and most important is mutual respect among all participants in the process. The advantage of the participatory approach is that people stereotype less when they are dealing with someone they know[207]. In that sense, participatory processes may enhance trust building within the group, which in turn will stimulate the process.

Social and behavioural studies indicate that there is little chance that the participatory group formulates definite risk statements without guidance[208]. The participants presumably disagree, because they are arguing from different perspectives. Real dialogue means adapting the strategies, institutions, procedures, etc. to *one another's* ideal[209]. To keep the dialogue going and to prevent deadlocks, the participatory processes should be structured in such a way that the participants are from time to time forced to put oneself in someone else's position[210]. Role games and/or explicit discussion guides for the facilitator may be suitable in this respect.

The above procedure for participatory risk analysis should not be regarded as a rigid blueprint. We just attempted to be clear about what kind of input can, and probably should, be expected from the various participants and in what way these expectations have implications for the structure of the participatory process, and for the roles and responsibilities ascribed to the participants. In doing so, we have tried to sketch some guidelines and heuristics that can be used in setting up participatory processes for integrated risk analysis.

CASE PARTICIPATORY PROCESS

With the first characterisation of the alternative technologies for electricity generation in terms of the five risk attributes, a participatory process could be set up. Taking into account the guidelines for participatory risk analysis as expressed earlier in this Chapter, four groups have to be involved:

- *scientific experts*: in this case we can think of *engineers*, who can explain the technical details of the diverse options, *health experts*, who can generate the required information with regard to the health risks associated with the various forms of electricity generation, *life-style specialists* as sociolo-

206 See (Covello et al. 1991) for a synthesis of the insights gained in risk communication during the last two decades.
207 It should be noted that this only holds for the spokespersons actually participating in the process, and not for those the are representing.
208 (Jungermann and Slovic 1993)
209 (Douglas and Wildavsky 1982)
210 See, for example, Chapter 2 for gaming approaches to participation.

gists and anthropologists, who can indicate the consumer patterns, *economists*, who can indicate the anticipated demand for electricity and the costs associated with electricity generation, and *jurists*, who can indicate the legal aspects. Furthermore, in order to be able to run the whole process, we need *experts on participation* and *facilitators*.

- *decision-makers*: in this case, representatives of local and national authorities, esp. for the department of Energy, Economy and Public Health and local and national members of parliament, and private decision makers in the energy sector.
- *citizens*: in this case, inhabitants of the area where electricity generation takes place (potential risk victims), and a random sample of residents of the country (both as electricity consumers and as indirectly involved).
- *representatives of interest groups*: in the case of electricity generation the following organisations seem to have both a stake in the issue and may provide relevant information: representatives of workers in energy utilities, the anti-nuclear movement, environmental movements which have experience in energy and resource issues, and labour unions.

Fischhoff *et al.* did not set up a participatory process. Nevertheless, taking into account what they did, the participatory process could have been helpful to evaluate the estimates of the various risk attributes. How would the participants estimate the risky properties of the different technologies for electricity generation? The participatory process could furthermore have helped to indicate whether all relevant technological options have been taken into account, or that, for example, representatives from the energy sector or members from the anti-nuclear movement consider that other alternatives are feasible. The group of participants could, for example, have reached the conclusion that electricity generation based on solar technology should be considered. Furthermore, a participatory conclusion could have been that also options for altering consumer behaviour should be included in the risk analysis. By changing life-styles the future demand of electricity may decrease, which affect the need for building electricity generation facilities.

Furthermore, the participatory process could have been used to assess societal constraints and aspirations. For example, the participants could have been asked to express whether nature area might be sacrificed for building new plants. And whether large-scale wind plants are acceptable from an aesthetic point of view. Or whether it is acceptable to rely on coal supply from countries that do not have legislation that guarantees that the coal-miners work under humane conditions. Such questions could have been addressed in the forms of role-plays or scenario-exercises, in which the participants are asked to 'paint' their desired future and the most undesirable future.

The above discussion illustrates how a participatory process in the case of electricity generation could have informed the risk analysis. It would have enabled to decide whether the adopted risk framework was able to address the issues that stakeholders consider relevant, so that the risk framework could have been adjusted in an earlier stage. Furthermore, insights into societal constraints and aspirations could have helped to put the multiple risk statements that the analysis delivers into a broader context. It may have helped Fischhoff *et al.* to build a bridge from integrated insights into concrete policy recommendations.

5. Multiple risk assessments

Using the risk scheme presented in the previous section in actual integrated risk analysis would involve the following steps (see also Figure 4)[211]:

- selection of the relevant risk dimensions
- identification and selection of measurable items (indicators) that adequately[212] represent the various risk dimensions for the specific case under concern
- gathering of information/data/estimates to gauge the selected items/indicators, both in qualitative and quantitative terms, as well as in terms of quality and uncertainty.
- scoring with respect to each dimension
- evaluation of trade-offs and weighing of the various dimensions (i.e. assignment of importance weights)
- formulation of a multi-dimensional risk profile

Each of these steps involves value judgements. It is a question of ethics to determine which risks are to be considered, how risk is to be characterised, how the different dimensions of risk should be weighted, etc. This means, as is argued earlier in this Chapter, that we have to accommodate for multiple perspectives in such a risk analy-

211 Compare (Fischhoff 1995; Gezondheidsraad 1996; Vlek 1996)

212 Crucial in the identification of risk items/indicators is to signify the appropriate spatial and scale.

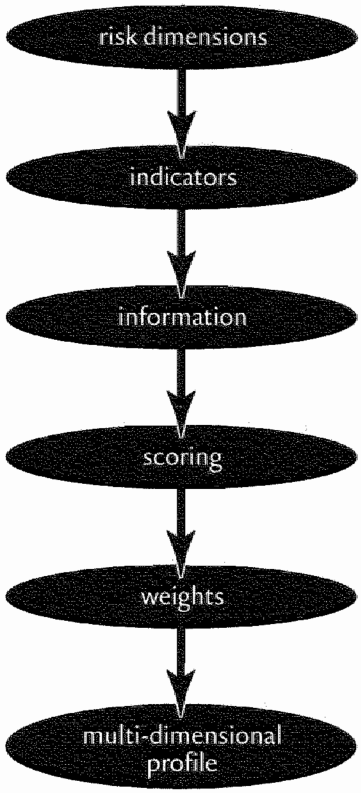


FIGURE 4 Steps in risk analysis

sis[213]. But how? Following social and cultural risk analysis, the various sets, scores and weights can be motivated by different risk perceptions. People interpret and estimate risk differently according to their perspective and their position with regard to the specific issue. With regard to the latter, the following classification of roles in the risk debates is of interest[214]:

- *the directly involved*: the risk-taker(s)[215], those gaining[216], and the risk victim(s); revolting risk victims become risk protestors.
- *the indirectly involved*: risk regulators (i.e. authorities and institutions), the media, and the general public; both the media and the general public can play an important role as risk protestors.

213 This question is mainly addressed within the paradigm of probability. However, while we further on suggest not using this notion in risk analysis, we will not explore the literature on subjective probability distributions.

214 (Gezondheidsraad 1996) Compare (Ravetz 2000)

215 Also referred to as risk imposer (Ravetz 2000)

216 This can be individuals, communities, companies, institutions, etc.

Questions about risk management are societal questions. Ideas about the vulnerability of nature, about the responsibility towards future generations, and individual freedom shape risk perceptions[217]. Cultural theory of risk[218], a constructivist theory, argues that it is not necessary to involve the endless number of individual perceptions to account for social and cultural variety[219]. Anthropology, which investigates meaning and actions against the background of implicit cultural biases, provides some structuring of the variety in risk attitudes. For example, a dichotomy indicating two paradigmatic world views, i.e. industrialists and environmentalists, provided by Cotgrove[220] (see Table 2), the traditional dichotomies of political sciences (i.e. left-wing versus right wing, and materialistic versus post-materialistic) and the four risk cultures of Cultural Theory (see Table 3). The distinction by Cotgrove features two very specific categories, and is thus rather limited.

Features of world views	**Industrialists**	**Environmentalists**
core values	• material, economic growth • natural environment is resource • anthropocentric	• spiritual growth • ecocentric • harmony with nature
economy	• market forces • rewards for achievement • differentials • individual assurance	• public system • incomes related to needs • egalitarian • social security
governance	• authoritative structures, technocratic	• participatory structures
society	• centralised • large-scale • ordered • institutionalised	• decentralised • small-scale • flexible • community-based
nature	• ample reserves • environment is controllable	• resources limited • nature in delicate balance
knowledge	• confidence in science and technology • rationality of means	• limits to science • rationality of ends

TABLE 2 Features of pragmatic worldviews proposed by Cotgrove

The typology derived from grid-group analysis, the so-called 'Cultural Theory', so far received most attention in risk analysis[221]. Cultural theory distinguishes four risk

217 (Gezondheidsraad 1996)
218 e.g. (Thompson et al. 1990; Rayner and Cantor 1987; Rayner 1987; Funtowicz and Ravetz 1985). A crucial publication in this context is (Krimsky and Golding 1992).
219 (Rayner and Cantor 1987; Rayner 1987)
220 (Cotgrove 1981)
221 See footnote 218 for references.

cultures, i.e. hierarchy, individualism, egalitarianism and fatalism, which allows a richer analysis than a dichotomy does. These positions are 'extremes'[222] which means that together they seem to expand the space of viable risk perceptions.

central features of risk cultures	**hierarchist**	**egalitarian**	**individualist**	**fatalist**
myth of nature	robust within limits (nature perverse/ tolerant)	fragile (nature ephemeral)	robust (nature benign)	lottery (nature capricious)
concept of human nature	sinful	born good, malleable	self-seeking	some are more lucky than others
needs & resources	can manage resources but not needs	can manage needs but not resources	can manage both needs and resources, with emphasis on manag-ing resources upwards	can manage neither needs nor resources
management style	control	preventive	adaptive	-
learning style	anticipation	trial without error	trial and error	luck
salient risks	loss of control (i.e. of public trust)	catastrophic, irreversible and inequitable developments	threats to functioning of markets	-
risk attitude	risk-accepting	risk-aversive	risk-seeking	risk-absorptive

TABLE 3 Features of four risk cultures associated with Cultural Theory[223]

The idea is to use a set of perspectives to develop:

- multiple sets of context-dependent risk items
- multiple syntheses of the information on risk items
- multiple sets of scores
- multiple sets of weights
- multiple risk profiles

in a consistent and transparent manner. It seems promising to explore whether and under which conditions the Cultural Theory typology is an appropriate scheme to be used[224]. The typology of perspectives provided by Cultural Theory is deductive, in the sense that general social scientific insights and arguments are used to arrive at an aggregated typology. In case such a simplification is not desirable or not acceptable for the risk issue under concern, an inductive, bottom-up approach is advocated. An

222 (Douglas and Wildavsky 1982)
223 Main sources underlying this Table: (Thompson et al. 1990; Schwarz and Thompson 1990)
224 See also Chapter 3A and Chapter 5.

inductive approach implies reasoning from empirical research in which the perspective and interests of individuals or groups involved in the particular risk issue are articulated. These responses can then be clustered to a limited set of perspectives.

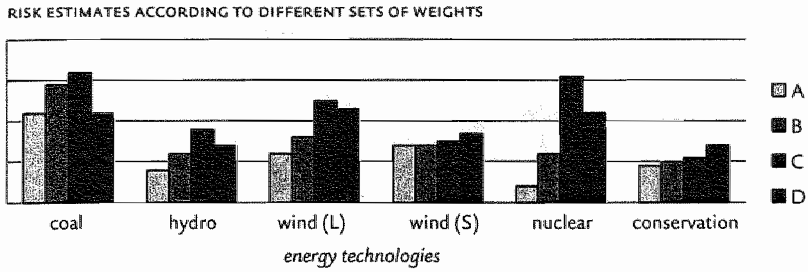
CASE MULTIPLE RISK ASSESSMENTS

Fischhoff *et al.* did not propose a way to arrive at alternative syntheses of the available information, which would have led to different estimates for the five risk attributes. Their way of dealing with inherent uncertainty in knowledge on such a complex issue is to consider solely the worst case. In other words, the scientific data is interpreted from one very specific point of view. An alternative would have been to interpret the data, which forms the basis for estimates on death risks and morbidity risks, also from other perspectives. For example, a more 'middle-ground' perspective that prefers to use the most-likely case as basis for the risk analysis. Or a more technocratic perspective, that interprets the historical accident data from the point of view that the *present* technology underlying the various options for electricity generation is much safer.

Psychometric data could also have been used to construct alternative estimates for the two risk attributes dealing with public support (i.e. the level of unknown and the level of dread). Fischhoff *et al.* have averaged the individual scores to arrive at a single value for these risk attributes. However, a more in-depth analysis of the psychometric data could have yielded groups of opinions reflecting different risk-attitudes. The risk-cultures proposed by Cultural Theory could have been used as heuristic device to guide such an analysis[226]. In that case, the survey questions on properties of the various technologies could have been complemented with questions that enable to characterise roughly the basic risk-attitude of groups of respondents. Such a clustered analysis of the data could then yield different valid estimates for the public support risk attributes.

Notwithstanding the lack of pluralism with regard to the synthesis of available, incomplete and uncertain, knowledge, Fischhoff *et al.* propose a pluralistic approach with regard to weighing the various risk attributes. They formulated four sets of weights that can be considered as reflections of four perspectives on the value of life. Let us assume that these particular sets of weights (A, B, C, and D) resulted out of the hypothetical participatory process, as described above. Together with the scores of the six technologies on the five risk attributes, these sets of weights are used to compute risk estimates. The resulting risk estimates are shown in Figure 5 below.

FIGURE 5 Multiple risk estimates



These estimates are used to indicate the relative riskiness of the six technologies according to the four sets of weights. The resulting characterisations of the alternative technologies for electricity generation in terms of riskiness are indicated in Table 5.

riskiness	Set of weights (perspective) A	B	C	D
low risk	nuclear	conservation	conservation	conservation
	hydro	hydro	small-scale wind	hydro
	Conservation	nuclear	hydro	small-scale wind
	large-scale wind	small-scale wind	large-scale wind	coal
	small-scale wind	large-scale wind	coal	nuclear
high risk	Coal	coal	nuclear	large-scale wind

TABLE 5 Multiple judgements of alternative technologies in terms of riskiness

The same information can be visualised with use of a multi-star representation[227], as is done in Figure 6.

225 Hoppe (personal communication)

226 Concrete suggestion on survey questions on Cultural Theory can be found in (Dake 1991; 1992; Dake and Thompson 1993) and (Jaeger et al. 1999). Suggestions for how psychometric analyses and the risk cultures associated with Cultural Theory can be used in a complementary manner can be found in (Marris et al. 1997). The author learned that just this idea on using Cultural Theory was proposed by Steve Rayner to Paul Slovic in the mid 80s, but it was never performed (Steve Rayner, personal communication).

227 See (Rotmans and de Vries 1997) for use of the multi-star representation as way to visualise multi-dimensional and multi-perspective information into one figure.

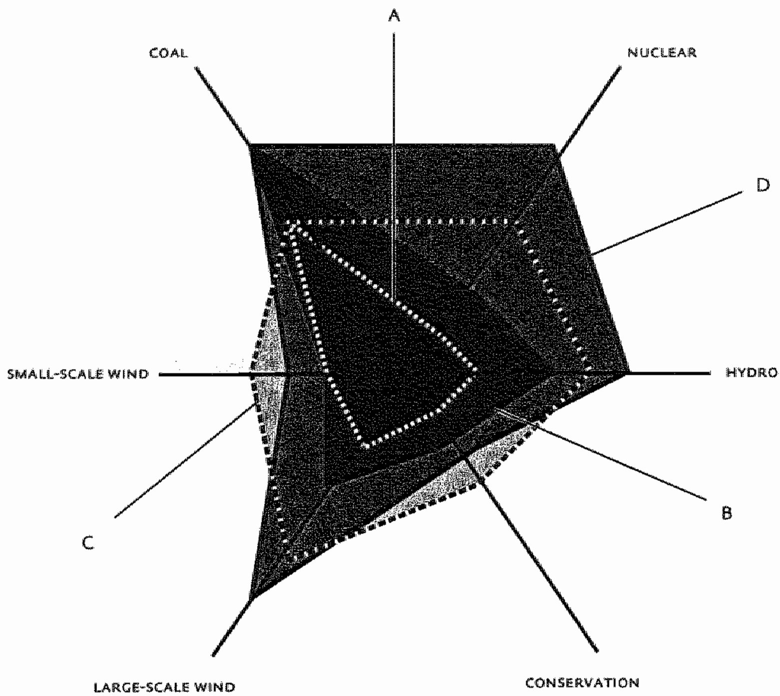


FIGURE 6 Multiple star-representation of risk estimates

In case, multiple syntheses of the information on the risk attributes would have been used, the analysis would have increased with one dimension. Let us assume that the four risk-cultures associated with Cultural Theory are used to arrive at different sets of estimates for the five risk attributes. Such a risk assessment could have been performed using a matrix set-up (see Table 6). As a result of such a structure, the ultimate risk estimates would not only differ because different weights are used (as in Figure 5), but also because different estimates for the underlying risk attributes are used. Furthermore, it would have yielded more estimates due to the increased number of combinations.

	Perspective			
Risk attribute	**hierarchist**	**egalitarian**	**individualist**	**fatalist**
death risk workers				
death risk public				
morbidity risk				
public concern: unknown				
public concern: dread				

TABLE 6 Set-up for pluralistic risk assessment

This scoring and weighting could also have been done in a participatory effort. An example of more participatory risk assessment is the citizen panel approach adopted by the Environmental Protection Agency (EPA) in the US[228]. In these panels citizens develop rankings of risk over a period of time with considerable scientific support. Such citizen panels can in principle also be used to suggest alternative perspectives. This example shows that participatory risk assessment in the systematic way as proposed in this Chapter seems to be a possible avenue.

6. Risk statements

The ultimate goal of participatory risk analysis is to produce informed judgements and robust recommendations. In this context the following issues are crucial in the participatory risk analysis: i) how to communicate risk statements?, and ii) how to integrate the pluralistic risk estimates informed by participatory processes into robust risk statements that reflect insights relevant to societal decision-making on risk?

6.1. HOW TO COMMUNICATE RISK STATEMENTS?

It is generally observed that citizens do not know how to interpret probability[229], especially not in case of extreme values like 1 in a million. Furthermore, also the "political decision-making processes do not take the probabilistic perspective of the risk analyst"[230]. If, as is suggested by many risk communication experts[231], we **drop the use of probability**, what is the alternative? We then need to find ways that are compatible with the essentially non-probabilistic orientation of decision-makers, stakeholders and the general public.

Does the scholarly literature on risk suggest alternatives to probabilistic statements? Both objectivist and constructivist scholars stress the importance of the 'maximum credible accident' in thinking and deciding about complex issues. To this

228 (EPA 1993)
229 among others (Covello 1984; Slovic et al. 1980b; Starr and Whipple 1980)
230 (Lathrop 1980)
231 For example, (Covello 1985). See for a recent and comprehensive discussion on communication problems concerning probability (Kaplan 1997).

end scenario approaches[232] may provide useful suggestions how such maximum credible accidents could be assessed.

Among the few principles that have come down to us from early risk analysis there is one that states that **comparisons** are more meaningful than absolute numbers or probabilities[233]. It should be noted that risks are difficult to compare, because risks are so diverse. So we do not plea for a comparison in the traditional sense, but we advocate comparative analysis in which participants arrange risk issues in mutual consultations. In this context risk-comparisons are only used in relative terms and in an illustrative manner. Comparisons that indicate the "relative riskiness"[234] can help to put risk estimates into perspective[235]. It should be noted that risk comparison does not necessarily imply a quantitative exercise. Qualitative comparison is equally valid.

Some comments have to be made: risk comparisons should in principle not be presented as argument to settle the question, such as[236]:

> *The risk of **a** (e.g. emissions from a plant or flooding) is lower than the risk of **b** (e.g. driving a car or smoking cigarettes). Because you find **b** acceptable you should also find **a** acceptable.*

This argument has a basic flaw in its logic for the following reasons:

i) comparisons in terms of concentrations of hazardous substances seem to minimise and trivialise the problem, and they can be misleading because the potency of the various substances varies widely,
ii) because the risks fundamentally differ in character: risks of type a are not controllable and are usually not voluntarily taken, while the risks of type b are controllable and voluntarily taken,
iii) people do not want to be forced in this way,
iv) because of accumulation of risks: "because I already accept b, which is risky, I do not want to take more risks".

Psychological research on risk communication indicates that risk comparisons that present unrelated risks (such as the risks associated with motorcycling versus the risk of flooding) do not influence risk perceptions[237]. The use of this type of risk comparisons can undermine the trust and credibility necessary to estimate risks. Not-

232 See Chapter 2 and Chapter 3A for discussions on scenario approaches.
233 E.g. (Rothschild 1979; Sowby 1965)
234 (Fischhoff et al. 1984)
235 See for example (Covello et al. 1991)
236 (Covello et al. 1991; Rothschild 1979)
237 (Slovic 1991)

withstanding these reservations, it may sometimes be useful to contrast risks in the above manner, to indicate the different ways in which they are treated in society[238].

The challenge is to use risk comparisons that address related issues and that are not perceived as an effort to pre-empt judgements about acceptability. Covello *et al.*[239] provide a ranking of risk comparisons. Relevant, appropriate and helpful risk comparisons are those that compare:

- ***the same risk at two different times***: "The risk associated with *x* is around *y*% less than *z* years ago".
- ***with a standard:*** "Exposure to *x* is well below the level that authority *y* considers safe"[240].
- ***different estimates of the same risk***: "Our best estimate of the risk is *x*, whereas the worst case risk estimate we have calculated is *y*, on the basis of methodology 2 we arrive at estimate *z*, whereas that of organisation ABC is *v*".
- ***the risk of doing something versus not doing it***: "If measure *a* is implemented the risk will be *x*, whereas if not, the risk will be *y*."
- ***alternative policy options:*** "The risks associated with option *a* is *x*, and the risk associated with option *b* is *y*".
- ***the same risk as experienced in other places:*** "The most serious problems associated with *x* have been encountered in place *A*, while here the risk is only about *y*% from that in *A*".
- ***risk from one source of a particular negative effect with the risk from all sources of that same adverse effect:*** "The risk on *a* posed by *x* is roughly *y*% of the total risk on *a* in this community".

In these comparisons it is important to be open about the uncertainties associated with the various risk estimates, so as to be able to evaluate the level of confidence that can be attached to these risk comparisons. They can be helpful in investigating the character and features of the different risks in order to be able to explore in the participatory process which risks seem to be the most risky.

Psychological research on risk reveals that in representing risk it is important to be aware of the possibility of so-called 'framing-effects': the views on risk can be easily manipulated by the presentation format[241]. Kaplan and Garrick[242] were among the first to argue that risk should be represented graphically. Furthermore, not all

238 (Crouch and Wilson 1982)
239 (Covello et al. 1991)
240 This type of risk estimates is not very helpful in risk contexts where authorities are not trusted.
241 Milestones in the academic literature on framing effects are (Tversky and Kahneman 1981) and (Slovic et al. 1982)
242 (Kaplan and Garrick 1981)

dimensions can be assessed in a quantitative way. The approach to risk as proposed here results in multi-dimensional, hybrid risk estimates, which by definition cannot be represented in a purely quantitative manner.

Risk estimates then cannot be expressed in one number. Notwithstanding the fact that the need for graphical representation was recognised so early, the risk literature does not provide an abundance of schemes that yield understandable risk figures[243]. The ultimate challenge for the future is to integrate quantitative and qualitative estimates into a risk profile of certain pathways into the future. In this effort, risk analysis may benefit from advances made with regard to indicators and indices[244] in other fields, such as Integrated Assessment.

6.2. HOW TO INTEGRATE PLURALISTIC RISK ASSESSMENTS INTO ROBUST RISK STATEMENTS?

The challenge we face is to integrate multiple risk estimates via comparisons in terms of relative riskiness, and ranking to robust risk statements that can inform societal decision-making processes. The above process yields for each strategy or activity plural perspective-based multi-dimensional risk profiles. One way to create robust conclusions is to evaluate which strategy seems to have the best risk profiles, taking into account the various risk comparisons. It does not imply that the so-called 'best alternatives' are the safest, or that it leads to an acceptable or desirable future. In terms of nature of the decision, robust risk statements involve exploring which strategies or activities seem to be acceptable or even desirable taking into account a wide variety of perspectives, and which are not. It is important that the risk statements reflect the process and the considerations to be of use in the decision-making process[245]. The argumentation is as important as the output[246].

243 The representation provided by (Fischhoff et al. 1984) that is thoroughly discussed in the following section is one of the rare examples in which risks are visualised in a qualitative, understandable manner.

244 see, for example, (Rotmans 1997)

245 Compare (Fischhoff 1996)

246 (Gezondheidsraad 1995)

CASE ROBUST RISK STATEMENTS

Mathematically speaking, there are 720 rankings[247] of the six alternative technologies, so it is rather likely that the rankings that result of the above process will differ. These rankings can also be represented using the multi-star representation; however, due to the number of 'stars' it will be rather 'crowded'. For that reason in this case an alternative representation may be more practical, such as the risk area[248] presented in Figure 7. In this figure a dot in a row of one of the technologies represent that that option for electricity generation scores the associated level of riskiness in one of the rankings. In the Figure below we have just indicated dots corresponding with the four rankings provided by Fischhoff *et al.*

technology	*relative riskiness*					
	low risk					*high risk*
nuclear	•		•		•	•
hydro		•••	•			
conservation	•••		•			
large-scale wind				••	•	•
small-scale winds		•	•	•	•	
coal				•	•	••

TABLE 7 Risk area representation of multiple rankings

The example on alternative technologies for electricity generation reasons from the beginning from a comparison between alternative options. In that sense, all the statements discussed above are, implicitly or explicitly, phrased as "The risk associated with option a is x, and the risk associated with option b is y". As discussed in section 6.1, this is an appropriate and relevant way of communicating risks.

The multiple perspective-based risk estimates furthermore enable to compare different estimates of the same risk. Especially if also the assessment of risk attributes is pluralistic (as we recommended), risks can be compared in terms of: "Our best estimate of the risk is x, whereas the worst case risk esti-

247 I.e. 6!

248 This representation is inspired by the representation (Hilderink and van Asselt 1997) used to synthesis a large number of multiple perspective results of a simulation exercise into one figure.

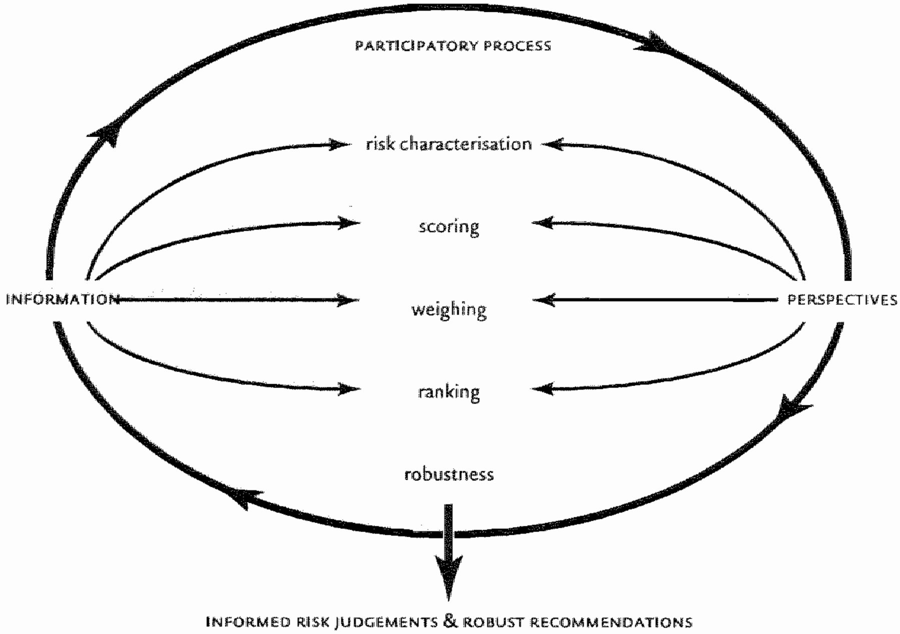


FIGURE 7 Framework for participatory, intergated risk analysis

mate we have calculated is y. On the basis of another methodology, we arrive at estimate z, while that of organisation ABC is v."

Nevertheless, it may be that participants in the risk analysis process are served with some other appropriate risk comparisons that complement the one used so far. In this particular case, the scientific experts may be asked to generate information that allows comparison of the risk of one technology over time. For example, what were the death risks associated with electricity generation based on coal 25 years ago? Last but not least, it may be helpful to allow comparison of the risks associated with the various technologies in the (nameless) country under concern with the risks as experienced in other countries. To that end, the scientific experts should try to collect available, reliable data on mortality and morbidity associated with electricity generations in other countries, as well as assess survey results on risks in other countries.

Fischhoff *et al.* explicitly state that they do not provide a definitive statement. They underpin this lack of integration in the following way: "Even a definitive statement about risk would have no necessary implications for most policy-making". They are right in acknowledging the limits of every analytical endeavour that aims to support decision-making. However, with this argument they reduce any risk analysis to fighting a losing battle. We argue that it is possible to go beyond multiple risk estimates, and to search for ways to integrate pluralistic risk estimates into robust risk statements. To illustrate our argument, we extend the case of electricity generation beyond what Fischhoff *et al.* did.

Our assessment of the risk estimates was helped by the various representations of the multiple rankings on riskiness, as provided in the previous section. Such integrated visualisations of the multiple risk assessments inspire integrative thinking in terms of concrete, robust policy recommendations. So such graphical representations are much more than just nice figures. They are helpful, may be even indispensable, tools in the integration exercise.

The evaluation in terms of relative riskiness indicates that conservation is the most preferred option by three perspectives, while at the same time it is not considered to be a high-risk option by the remaining perspective. This observation may then result in the robust statement that energy conservation is the most acceptable technology in balancing societal benefits and negative impacts. In terms of recommendation for policy, this statement implies that it is worthwhile to assess how energy conservation technologies can be stimulated. By RD&D programs? Legislation? Financial incentives? This type of robust statements identifies how further analysis, and what kind of analysis, could shed light on the decision-making properties of the risk issue.

Another robust statement that results from the above risk analysis on electricity technology is that opting for nuclear power is likely to create societal tensions. This can be concluded from the observation that nuclear power is in one perspective considered to be the most risky and in another a low-risk technology. With regard to enlarging energy supply, hydropower seems to be the option for which societal support may be created most easily at the general level, although also in this case not-in-my-backyard tensions can be anticipated.

From the above hypothetical risk analysis, it is also clear that electricity generation is a controversial risk issue. A robust recommendation building upon this insight would be to explore which technological options for energy supply are most flexible, in the sense that they can be easily dismantled in case the energy demand did not increase in the way assumed in this scenario. Such a characterisation of the technological options would allow decision-makers to keep options open. This type of recommendations indicates how further analysis can clarify relevant aspects of the risk issue under concern.

The above hypothetical recommendations are presented to illustrate that notwithstanding the fundamental diversity in risk definitions and risk perceptions the outcome of pluralistic participatory risk analysis is not necessarily a deadlock situation of dissent. It furthermore illustrates that clearly characterised disagreements, such as on nuclear energy, can still inform decision-making. It is even argued that a well-managed, mutually respectful process of participatory risk analysis may reveal some significant areas of agreement, even among diverse individuals from a wide variety of backgrounds, and that the result of such a process may be fewer, and better focussed, conflicts about risk[249].

7. Conclusions

The present Chapter proposes a theoretical outline for integrated risk analysis that can be used for the analysis of strategic risks, i.e. risks that are inherently uncertain, that are beyond the reach of individual control, and that are far-reaching both in terms of temporal and geographical terms. According to the Dutch Health Council[250], strategic risk issues necessitate new forms of dealing with risk. Integrated participatory risk analysis aims to address this need. The proposed framework (see Figure 8 for a summary) synthesises shared premises and multi-disciplinary insights resulting from three decades of academic research on risk. In doing so, we aim to reconcile the strengths of scientific analysis with psychological, social and cultural values into one coherent paradigm. In this way, it may provide a bridge between the various groups within the risk community, as well as between risk analysts, decision-makers and stakeholders.

The framework for integrated risk analysis should not be considered as a rigid blue print for risk analysis. It has never been the aim to provide a potential standard. The risk of standardising in the context of complex risk analysis is that essential unique aspects of actual risk cases are neglected in the analysis. The aim has been to sketch a general interdisciplinary framework that synthesises the multi-disciplinary insights and that can be used in a flexible way to organise integrated risk analysis in a manner that is theoretically sound.

This Chapter furthermore explores how this framework could be used. The challenge is to test the soundness of this proposed approach in concrete risk studies, also in comparison to existing approaches to risk issues. The key question[251] is

249 (Fischhoff 1995)
250 (Gezondheidsraad 1996)
251 Phrasing inspired by Charles Vlek (personal communication).

whether the proposed integrative approach offers something that could improve the current practise at public bodies, like the Ministry of Public Health, Planning and Environment (VROM) in the Netherlands, which currently apply a rigid standard setting and testing approach to risk management[252], and the Environmental Planning Agency (EPA) in the US[253], which already adopts participatory risk ranking approaches. To that end, in particular the potential value and limitations of the following suggestions have to be empirically tested:

- the proposed method for ***multi-dimensional risk characterisation***
- the ***manageability*** and ***effectiveness*** of ***participatory processes*** structured around the proposed tasks.
- the proposed approach for ***multi-perspective risk analysis***, e.g. the ***typology of risk cultures*** as tool to consider plural interpretations in different phases of risk analysis.
- the practical value of the proposed type of ***robust risk statements***

The aim of the following Chapters is to use the proposed framework and insights on the concept of risk to develop a credible approach for risk analysis and uncertainty management in the context of Integrated Assessment of complex problems. From the current Chapter we can conclude that key notions for such an endeavour are[254]:

- PLURALISM
- PARTICIPATION
- ROBUSTNESS

252 See (VROM et al. 1989) for a description of the current approach. See (Gezondheidsraad 1995; 1996) for a critical review.

253 (EPA 1993) See also (Gezondheidsraad 1995) for a summary of EPA's experiences.

254 The same key notions materialise from addressing the above aim of this thesis from our overview of the state-of-the-art in Integrated Assessment (Chapter 2) and from our philosophical evaluation of the concept of 'uncertainty' combined with a critical review of the current practise in uncertainty analysis (Chapter 3A).

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CHAPTER 4

Uncertainy and risk in perspective

So far, we have discussed the concepts 'uncertainty' and 'risk' as independent instances. However, the two concepts are related. In this Chapter, we will argue that uncertainty and risk are two sides of the same coin, i.e. the limited predictability of complex issues. Furthermore, as can be concluded from the previous Chapters, the key challenges uncertainty management and risk analysis face are comparable. Instead of considering uncertainty and risk as two separate concepts and viewing uncertainty management and risk analysis as two different branches, we think it is interesting to explore how the two concepts and the two methodologies can be used in a complementary manner in decision-support on complex issues. Our aim is thus to develop a framework for integrated uncertainty management and risk analysis.

This Chapter will first study in some more depth the interconnectedness between uncertainty and risk. Then we will move forward with the key challenges that resulted from the theoretical analyses as provided in the previous chapters. The first key notion is pluralism. Using the concept pluralism in developing an integrated framework for decision-support requires a better understanding of the notion of pluralism. To that end, this Chapter will study pluralism in some more depth in order to provide a basis for crystallising the ideas on pluralistic uncertainty management and risk analysis. We then discuss the role of participation and robustness in relation to our ambition to develop an integrated framework for uncertainty management and risk analysis. The Chapter will then conclude with a definition of integrated uncertainty management and risk analysis that synthesises the theoretical ingredients.

1. Uncertain risks and risky uncertainties

The concept of 'risk' is closely connected with the prevalence of uncertainty. Risk deals with *uncertain* situations in which a number of possible undesirable outcomes might occur, of which at least one, but possibly more, is undesirable[1]. Personal, collective, societal and environmental risks and their evaluation as 'good' or 'bad' thus arise from the uncertainty surrounding the occurrence of particular events or series of events. We do only think and talk about risk in the face of uncertainty. Deciding about risk is deciding in uncertainty[2]. So risk analysts do not discuss situations with certain outcomes, although uncertainties can arise in many different ways[3]. Some risks can, notwithstanding uncertainty, reasonably be calculated. To give an example[4]: if a person crosses a crowded street blindfolded, there is obviously a high risk that the person will be killed or at least injured. In that sense, the outcome seems to be certain. Nevertheless, even in this clear case the risk analysis involves uncertainty. Part of the uncertainty is due to variability: the actual outcome will depend on where the individual precisely is when a car arrives, the actual speed of the car and to behavioural variability, such as whether the driver stop if he or she notices the person. Part of the uncertainty is due to lack of knowledge: the actual outcome will depend on the nature of the fenders and other features of the specific car.

The multitude of factors, dimensions and scales that trigger strategic risks cause inherent uncertainty[5]. So risk analysis concerned with strategic risks that involve inherent uncertainty and which are much more difficult to assess. Examples of cases in risk analysis for which no historical data or no analogies are available to determine risks are the release of a new chemical to the environment, the introduction of a new technology, and unprecedented human disturbance of natural processes. In these cases, the risks are difficult to estimate, primarily due to uncertainty associated with lack of knowledge. Uncertainties with regard to the complex relationships between causes and effects make it very difficult to assess what is likely to happen if a particular event or a concurrence of circumstances comes about. Furthermore, social and behavioural research on risk perceptions indicates that if the underlying mechanisms and processes are not well understood, lay estimates, especially concerning

1 (Merkhofer 1987)
2 This is not to say that deciding about risk is only deciding about uncertainty. As follows from Chapter 3B risk analysis also involves different judgements of facts and certain outcomes associated with the risk issue under concern.
3 (Crouch and Wilson 1982 ; Gezondheidsraad 1995)
4 This illustration reasons from the example given by (Crouch and Wilson 1982)
5 (Gezondheidsraad 1995)

involuntary risks, tend to be higher[6]. The level of uncertainty is thus a risk dimension. So there is not only the problem that uncertainty violates the exactness of risk estimates, but also that the level of uncertainty co-determines the risk estimate itself. Uncertainty is thus central to risk analysis, but the paradox is that risk analysis is also complicated by the omnipresence of uncertainty.

Apart from the issues discussed above, there is another aspect that makes the relationship between risk and uncertainty intricate. As argued in Chapter 3B, risk perceptions differ, which yields a wide variety of risk definitions and risk estimates, especially in the case of strategic risk. This increases the uncertainty for those involved in the risk debate. On the other hand, the fact that risk estimates are thus uncertain, is on its turn revealed by the disagreement among experts[7].

The above thus reveals that uncertainty[8] and risk are interrelated on the following levels:

- the uncertain reality of what may occur
- the uncertain analysis of assessing the uncertain risks
- the variable evaluations of the uncertain risk analysis

There are two major reasons that the risk concept is relevant to our endeavour. First, risk is a concept that is deployed in every day life, and thereby familiar to decision-makers and the broad public. As argued by Luhmann[9], risk is the general form in which society describes and assesses its future. Ravetz[10] argues that the political way of dealing with uncertainty appears to be to create a story about risks. In other words, communication of future outlooks in terms of risk is therefore likely to enhance understanding between science and society. Second, attempts to estimate risks also reveal where the greatest uncertainties lie[11], and thereby provide valuable insights for uncertainty analysis. And vice versa: knowledge of uncertainty helps to indicate where risks are expected by exploring what-if situations.

Due to the nature of complexity, i.e. multidimensional, multi-scales and multi-problem[12], complex issues are inherently uncertain and involve strategic risks. Or to phrase it differently, complex problems are about radical uncertainty and strategic risk. In the face of complexity, we are facing both uncertain strategic risks and risky

6 (Covello 1984)
7 (Jungermann and Slovic 1993; Beck 1986)
8 We are not talking here about uncertainty in the sense of quantified ranges as is usually done in scholarly risk literature. We are referring to uncertainty as a much more fundamental issue (see Chapter 3A). Our uncertainty concept (see Chapter 3A) goes beyond merely measurable uncertainty, and includes ignorance and indeterminacy.
9 (Luhmann 1993)
10 (Ravetz 2000)
11 (Whipple 1985)
12 See Chapter 1.

radical uncertainties. Complexity is complicated, because of inherent uncertainty. Complexity is important, because of the strategic risks involved. If we would restrict ourselves to uncertainty, we will not understand the importance of complexity. On the other hand, if we just focus on risk, we will never understand the features of complexity.

It is important to recognise that risk and uncertainty are interlinked concepts. Uncertainty and risk can be considered as the two sides of the same coin, i.e. the limited predictability as a result of complexity. 'Uncertainty' is generally associated with the rationality of science, while 'risk' is a notion that seems to correspond most with the rationality of decision-making. Figure 1 indicates how the degree of uncertainty and the level of risk are related. From an integrated perspective, this means that the one cannot be adequately studied without considering the other, and vice versa. In case of operational risks and measurable uncertainties an adequate toolkit for decision-support is available in the form of quantitative risk assessment and methods for uncertainty analysis. As follows from Chapters 3A and 3B, those current decision support methods fail to address esp. radical uncertainties and strategic risks. This implies that applying current decision-support tools to complex issues can be compared to hammering a nail with a mixer. In current decision-support on complex issues we apply methods that are not geared to the essential features of complexity, which implies that scientific decision-support fails in addressing decision-makers' need. So probably not so much is left to them than muddling along.

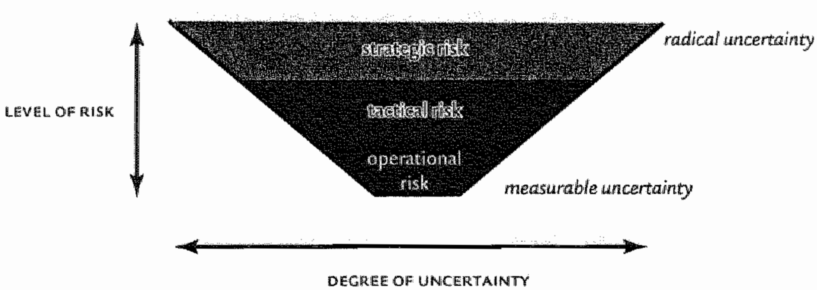

FIGURE 1 Level of uncertainty and type of risk

From a decision-support perspective, the challenge seems to be to use both concepts in a synergetic way in the analysis of what might be possible and seems to be plausible. Uncertainty management should yield insight in strategic risks, while risk analysis should involve a thorough analysis of the salient uncertainties. To that end, we would like to explore a framework for integrated uncertainty management and risk analysis that is theoretically sound. Such an integrated framework for uncertainty management and risk analysis would in principle be able to be used in decision-support on complex issues. Our line of reasoning is summarised in Figure 2.

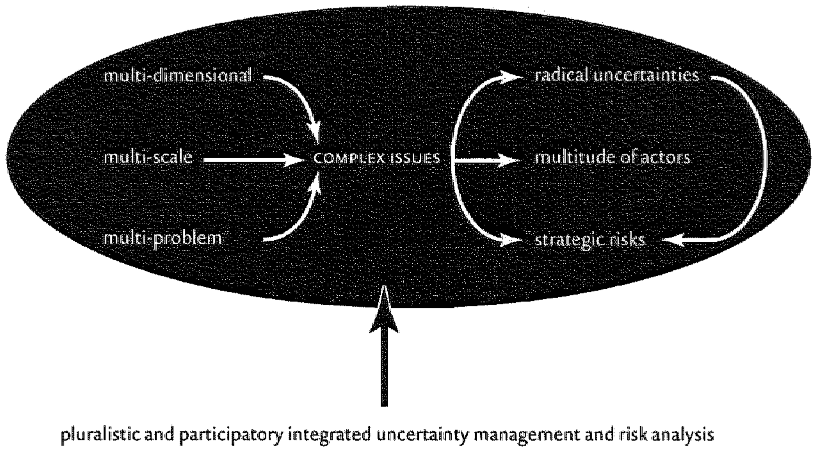

FIGURE 2 Principle of complexity and pluralism

2. Pluralism[13]

Complexity stimulates pluralism[14]. Due to inherent uncertainty there are plural legitimate interpretations. In case of strategic risk, there is divergence of risk perceptions. Furthermore, by the nature of complexity, complex issues involve a multitude of actors.

Pluralism thus means that different perspectives are legitimate and viable, also within science. Pluralism fundamentally conflicts with the positivist, singular, paradigm[15], because in this latter paradigm different explanations are accepted in the sense of necessarily provisional: in the long run 'pluralism' will disappear. Schools of thought that reason from inherent pluralism share that they all renounce the positivist principles. But they differ with regard to the question how far the significance of pluralism reaches. We will investigate the essence of the differences between pluralistic schools of thought by sketching a transition from positivist singularity to constructivist pluralism, in order to explore the consequences of the adoption of a certain perspective in pluralistic assessment endeavours. Based on these assumptions,

13 This section substantially benefits from discussions with Bastien Clement (student in Cultural Sciences, University of Maastricht) and the essays he produced during his internship at ICIS (November 1998 - March 1999).

14 While pluralism on its turn increases uncertainty, as is discussed in Chapter 3A.

we would like to assess questions which and how many perspectives are to be considered in the assessment and which uncertainties are included in the perspective-based analysis and evaluation, and which are not.

To see something from a certain perspective implies having a view on reality, and thereby presupposes that humans, as knowing subjects, visualise the 'outside world'. This notion of a perspective presupposes objectifying the world and subjectifying the knowing individual: a distinction is made between object and subject. This can be illustrated by means of the turn in the art of painting in the 14th and 15th century. During the Renaissance, the perspective projection method came into use. This is a geometric method to draw objects so that it matches the way in which a spectator sees those objects from a certain position.

The first deviation from positivism can be compared to the perspective art of painting. In this school of thought, it is recognised that scientists observe the world from a certain perspective, which is determined by tradition, school of thought or culture. Different perspectives provide a kaleidoscopic view on the world. Observation is thus put into perspective. This line of reasoning can be traced back to Kant[16]. In his inquiry on the limits to reason, Kant asserted that we could not discern 'das Ding an sich'. Hume[17] also argued that knowledge does not simply result out of empiricism. A sequence of events is observed and scientists put into a causal order. In doing so, science projects its own framework onto the world, as the painters portray the panorama from their standpoint. Similar thoughts can be found by Popper[18], who held that every statement about the world is 'theoretically mediated', which means that an observation is always an interpretation of findings in the light of a theory. Recognition of the perspective character of observation does not necessarily lead to relativism. The various partial perspectives on the 'world out there' can in principle complement as well as contradict each other. If the various perspectives complement each other, they allow drawing a richer image of reality. In case of contradiction, the partial perspectives highlight controversy.

The analogy between the concept 'perspective' in art and science goes further. With the projection method, the painters dissociate themselves from the world, which they attempt to reproduce in all dimensions. This can be compared by the above view on pluralism in science. One step further is to realise that a perspective

15 See Chapter 3A for a basic discussion on positivism.
16 (Kant edition 1997; Scruton 1982)
17 See (Ayer 1980)
18 (Popper 1959; 1973; Corvi 1997)

is dependent from the painter's position in the landscape, he or she is painting. In other words, a perspective is a relative and not an absolute notion. A perspective is not simply a representation of the landscape, but a perspective is also 'created' along with the landscape. Perspective and object thus interact. In the context of science this means that a perspective about the world is inseparable from the relation to that world.

Such an interpretation of perspective implies that the dualism between object and subject is questioned. Kuhn's thinking[19] corresponds to this line of reasoning. According to Kuhn, a perspective is obtained in interaction with the world. The distinction between observation and interpretation is no longer drawn. Observations are considered to be interpretations about which agreement is reached within the scientific community. Facts exist, but only within what Kuhn refers to as a paradigm. A paradigm involves values and research styles shared by the researchers 'socialised' within that paradigm. In that process of socialising, the exemplary archetypes of problem-solving, so-called 'exemplars' are crucial. Anomalies are problems that cannot be solved according to the archetypal exemplars, and thus observations that fall beyond the paradigm. Anomalies play a critical role in paradigm shifts: if the number of anomalies continues to increase, at a certain point of time the reigning paradigm will be questioned. Such a change of scientific perspective can be compared to what in psychology is called 'Gestalt-switch'. This can be illustrated by means of the example of the duck-rabbit-figure (see Figure 3). A paradigm shift implies that

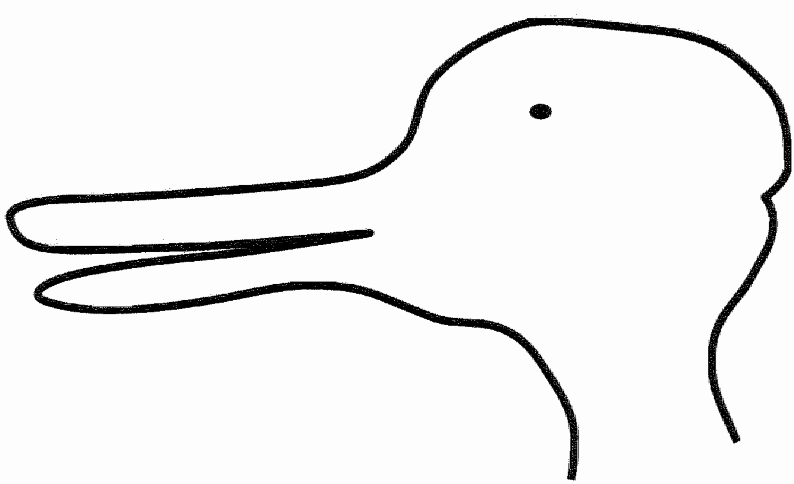

FIGURE 3 Duck or rabbit?

19 e.g. (Kuhn 1970)

what was seen as a duck is now considered to be a rabbit. Such a change of perspective cannot be analysed in terms of a transformation of observations, because the drawing itself remains the same. So perception seems to take place within a socio-cultural context. With the concept of 'paradigm', Kuhn related cognitive changes to the culture of science and social interactions within science.

The above perspective can be considered as an internal explanation for pluralism in science, because it is focused on socio-cultural factors *within* science. Mannheim[20] introduced another view on pluralism. He argued that cognitive knowledge is essentially connected to societal circumstances. The 'Edinburgh school'[21] goes further in assuming a causal relationship between social and cultural structures and science. This school of thought argues that the intellectual stand and scientific interpretation root in social and cultural structures *outside* science. This external explanation of pluralism is related to Durkheim's social theory[22]. This theory has it that there are collective perspectives, so-called 'representation collectives', that do not follow from interactions between actors, but which are social givens. An individual comes across such collective perspectives and will internalise such a perspective, consciously or, more often, unconsciously. In this 'external' explanation, pluralism in science thus arises from pluralism in society.

The above perspectives on perspective share that they distinguish between the world of science and the social world. Different movements within philosophy and social studies of science[23] break out of this dichotomy between internal and external. This view stresses that science is interwoven with institutional, political and social interests, intentions and preferences. Intellectual conflicts are thus social conflicts, and pluralism within science is societal pluralism. This perspective on pluralism has it that knowledge is embedded in societal interaction patterns and the rules of the interwoven community, also referred to as 'societal field'[24] or 'network'[25]. This perspective on pluralism has it that knowledge is not a statement about reality, but that reality is shaped by science. In this perspective, developing a scientific theory means painting a new version of the world.

We consider the above perspectives on pluralism as different viewpoints that constitute a spectrum between positivism and constructivist pluralism (see Figure 4).

20 e.g. (Mannheim 1936)
21 (Barnes 1977; Barnes and MacKenzie 1979; Barnes and Bloor 1996)
22 see (Lukes 1975)
23 E.g. post-modernism and radical social-constructivism; see for an overview (Hess 1999)
24 (Bourdieu 1975)
25 (Latour and Woolgar 1979)

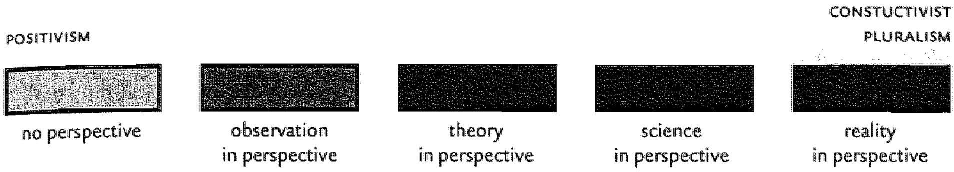

FIGURE 4 Spectrum of perspectives on perspectives.

Changing point of view implies a paradigm shift in which fundamental assumptions change, so it cannot be considered as a continuous spectrum. The first deviation from positivism is associated with putting observation into perspective. This school of thought remains reasoning from one of the essential principles in positivism, i.e. the dichotomy between object and subject. The major difference between the school of thought characterised as "observation in perspective" (e.g. Kant, Hume, Nietzsche, and Popper) versus "theory in perspective" (e.g. Kuhn) is that the latter transcends the dichotomy between object and subject. But the "theory in perspective"-perspective still contains another principle of positivism, i.e. the dichotomy between the cognitive and the social, and thus between science and societal structures. This dichotomy begins to disappear in the next viewpoint characterised as "science in perspective". This school of thought has it that science is part of society. The most extreme point of view does not even consider science to be something special. It is considered just to be another network or field. This "reality in perspective"-perspective goes hand in hand with methodological relativism, implying that 'facts' result out of social processes. This school of thought can thus be considered as the most fundamental form of constructivist pluralism[26].

3. Pluralism as a fact[27]

Within physical science, there is still a large group of scientists adhering to the positivist paradigm, while the majority of contemporary philosophers of science seem to be at the other end of the spectrum. The presented views on pluralism are irreconcilable, but on the other hand they seem to co-exist. Furthermore, it would even be in conflict with the whole notion of pluralism, if we would argue that one of the above

26 It is interesting to note that early research in this perspective on pluralism wonders why there is relatively little pluralism in science, see e.g. (Collins 1985)

27 This section substantially benefits from discussions with Bastien Clement (student in Cultural Sciences, University of Maastricht) and the essays he produced during his internship at ICIS (November 1998 - March 1999).

viewpoints is the one and only 'best'. In other words, there are different perspectives on perspectives, as a consequence of which there is pluralism about pluralism.

So notwithstanding our modesty about truth claims as expressed in the previous chapters, we arrive at a strong truth-claim about pluralism. This may seem an inconsistency, but it is a paradox: it is truth claim about discourse. In other words, we put pluralism forward as a fact on discourse that can easily be verified.

The distinction between reality and discourse touches upon another fierce debate between scientific practitioners and those practising social studies of science and philosophy. The first group generally has it that reality exists and can be studied. In this point of view reality is the *starting point* of scientific investigation. The latter argue that reality as such does not exist. Reality is the result of social processes and discourse. So the essence of something 'real' is not its physical existence, but the way it is interpreted. This point of view is beyond the head of scientific practitioners, and generally means that they turn their back on social scientists and philosophers. We would like to escape this deadlock, by arguing that to date both recognise that scientific discourse exists. This means that they in principle could agree on claims on this level, where agreement with regard to 'reality' is principally unattainable.

Above, we have attempted to prove that pluralism exists in the discourse, in order to provide some common ground for a collective endeavour in which we explore pluralistic ways of performing science. The existence of the different schools of thoughts about pluralism is only one example. Within all social sciences fundamentally different schools of thought can be observed. For example, within psychology we find behaviourism, which reasons from human behaviour and which ignores human thinking, versus cognitive psychology that aims to understand behaviour out of mental processes. Within sociology a gap can be observed between explanatory and interpretative sociology. Different schools of thought can also be observed within economics, i.e. neo-classical economics, Keynesian economics, ecological economics and evolutionary economics, but also within the natural sciences. In physics, we can discriminate between Newtonian physics and quantum physics. These schools of thought can in a certain way be considered to be complementary, because the one explains phenomena that cannot be explained by the other, but the two explanatory schemes are also incompatible. Within the Earth sciences, schools of thought can be discerned that ranges from viewing the world as one of order to that of chaos and complexity.

Although the enumeration is not exhaustive, it seems legitimate to conclude that fundamentally different schools of thought coexist within science. In view of inherent uncertainty, no objective criteria enable to decide which one is definitively the 'right' one. As a result of debates and new insights, some schools of thought may disappear and others will see the light. The scientific discourse is and will continue to be disunited. On the level of discourse, we conclude that pluralism can be proved.

4. Pluralism in perspective

Pluralism implies cultivating a diversity of perspectives, without necessarily slipping into an indifferent relativistic tolerance of all view points. Which and how many perspectives are accepted depends on the viewpoint taken with regard to pluralism (see also Table 1). In the "observation-in-perspective"-perspective only scientific frameworks are accepted as legitimate perspectives, while the "theory-in-perspective"-perspective acknowledges different scientific paradigms. In the "science-in-perspective"-perspective a typology of socio-cultural perspectives is welcomed. The "reality-in-perspective"-perspective recognises those perspectives that are observed in actual networks or societal fields. The latter viewpoint would never accept an a-priori classification of perspectives, because it holds that knowledge and interpretation are embedded in social interaction patterns.

perspective on pluralism	observation-in-perspective	theory-in-perspective	science-in-perspective	reality-in-perspective
type of perspectives	scientific hypotheses	scientific paradigms	socio-cultural perspectives	observed in actual networks

TABLE 1 Perspectives on pluralism in relation to type of perspectives considered

The consequence of pluralism is that we have to realise that in exploring a pluralistic approach we, either explicitly or implicitly, take up a certain perspective on pluralism. As argued above, adopting a perspective on pluralism has serious implications for choosing a typology of perspectives and for dealing with different perspectives in decision-support endeavours. If we take pluralism and our own effort to render pluralism explicit, serious, this implies that we have to be transparent about the adopted perspective.

In this thesis, we obviously go beyond the positivist paradigm that fundamentally debars pluralism. In our earlier work[28], we were not explicit about our perspec-

28 E.g. (van Asselt et al. 1996; van Asselt and Rotmans 1995; 1996; 1997; 1999)

tive on pluralism. With the above characterisation of the different viewpoints on pluralism, it is worthwhile to reflect in retrospect on our implicit principles. We reasoned that pluralism in science is inherent in view of uncertainty. The framework of science puts forward cognitive and rational standards. In a situation without uncertainty, it would in principle be possible to detect the most appropriate perspective for science. This also implies that, measured by its own yardsticks, pluralism in science in situations free of uncertainty would be unmasked as 'bad science'. However, in situations with inherent uncertainty, different perspectives are legitimate, also within science. This is a modest view point on pluralism that conflicts with the extreme constructivist pluralism that argues that in situations in which there is pluralism in society, this will always be mirrored in science.

The perspective on pluralism that underlies the methodology of perspective-based model routes[29] comes close to both the "theory-in-perspective"-perspective and the "science in perspective" -perspective. Both views have it that observation and interpretation are intertwined and that the knowledge derived from observation and interpretation is perspective-dependent. In Rotmans *et al.*[30], the earliest record of our pluralistic ambitions, a clear distinction was made between scientific perspectives (i.e. based on scientific hypotheses or theories) on the one hand, and cultural perspectives (i.e. characterising human attitudes) on the other. The initial idea was to use scientific perspectives (like the Gaia-perspective and the 'Expectation-of-the-unexpected'-perspective) to address the scientific uncertainties, i.e. "uncertainties occurring in the environmental system which arise from the degree of unpredictability of global environmental change processes and which may be narrowed as a result of further scientific research or more detailed/appropriate modelling"[31]. Second, the cultural perspectives (i.e. hierarchist, egalitarian and individualist[32]) were thought to be related to social and economic uncertainties, i.e. "uncertainties occurring in the human system which arise from the degree of unpredictability of future geopolitical, socio-economic and demographic developments, and which are inherently 'unknowable' or in practise unpredictable"[33]. In this view on perspectives, a clear distinction is made between science and non-science. The two are considered to be separate, independent domains. The starting point of our pluralistic approach to Integrated Assessment modelling thus closely corresponded with the "theory-in-perspective"-perspective.

29 (van Asselt et al. 1996; van Asselt and Rotmans 1995; 1996; 1997; 1999)
30 (Rotmans et al. 1994)
31 Citation (Rotmans et al. 1994)
32 See Chapter 3A and 3B for short descriptions of these perspectives associated with Cultural Theory and a bibliography of Cultural Theory.
33 Citation (Rotmans et al. 1994)

However in the course of the research, a mental change can be observed. We first argued[34], in line with Morgan and Henrion[35], that different sources of uncertainty in modelling can be distinguished (i.e. statistical variation, variability, linguistic imprecision, approximation, subjectivity and disagreement among experts) and that these sources produce both the so-called scientific and the so-called socio-economic uncertainties. In this way, the distinction between scientific and socio-economic uncertainties faded into the background. Second, we put forward that a new approach to uncertainty analysis in IA models was necessary[36], because standard uncertainty analysis does not address uncertainty due to subjectivity and disagreement. Our main argument became that subjective judgement and disagreement occur due to the adoption of different (cultural) perspectives by scientists. It became our aim to develop a methodology "to analyse and clarify perspective-related uncertainties in Integrated Assessment models"[37].

The above mental change implied that scientific judgement was at least partly related to cultural perspectives. The sharp division between science and culture prevalent in the first phase has thus been transcended. In the practice of building and using perspective-based model routes in the TARGETS-model, the change became even more fundamental. Perspective-based model routes were used to address all selected uncertainties in the TARGETS model, while the starting point has been that perspective-based model routes should be used for a subset of uncertainties and that the method should be used in combination with other methods (such as probability-based methods).

An explanation for this extended use of perspective-based uncertainty analysis is that this new method also promised to solve two recognised shortcomings of standard uncertainty analysis, i.e.[38]:

- the uncertainty estimates associated with standard methods for uncertainty analysis are difficult to understand by non-modellers
- standard uncertainty analysis neglects uncertainty in model structure[39]

With these promised advantages the multiple model route methodology turned out not to be just attractive for addressing uncertainties that were neglected so far. In

34 (van Asselt and Rotmans 1995)
35 (Morgan and Henrion 1990)
36 (van Asselt et al. 1996; van Asselt and Rotmans 1995; 1996; 1997)
37 (van Asselt and Rotmans 1995)
38 (van Asselt et al. 1996; van Asselt and Rotmans 1995; 1996; 1997)
39 This innovative feature of the concept of perspective-based model routes was in the TARGETS model not used to the full extent: the model structure changes are confined to changes in the equations, it did not involve separate modules. An example of an attempt to arrive at different modules can be found in (Geels et al. 1995), in which fundamentally different conceptualisations of the biogeochemical cycles were proposed.

practice, it began to serve as a full alternative for standard uncertainty analysis. The other methods for uncertainty analysis were used in a supportive mode, instead of a more complementary manner; sensitivity analysis was used to select the most important uncertainties in the submodels[40] and also to further analyse the model outcomes[41], and probability-based methods (i.e. Monte Carlo) have been used to generate uncertainty ranges for each perspective-based projection[42]. Available techniques such as Monte Carlo and sensitivity analysis were thus primarily used to enrich perspective-based uncertainty analysis.

Within the TARGETS project, the perspective-based model routes were thus used as *the* methodology for uncertainty analysis. Furthermore, using *cultural* perspectives[43] to address the model uncertainties, marked the transformation from the original starting point "science and culture" into the standpoint "science as culture". It was not a cognitive mental change, but an implicit and probably unconscious shift in the course of the project. The final design of the (cultural) perspective-based model route methodology and its implementation clearly suffuse the "science-in-perspective"-perspective, which has it that scientific judgement is culturally determined.

It is probably no surprise that this fundamental change with regard to the underlying epistemological principles resulted in a tension, or even an inconsistency, between the theoretical classification of uncertainty and the methodological framework. The current thesis dissolves this tension, by underpinning the methodology with a more fundamental typology of uncertainty. The typology of uncertainty used in earlier work did not really address uncertainty at the deepest level. The sources of uncertainty in models as provided by Morgan and Henrion[44] are of a different kind. The classification is a mixture of ontological uncertainty (esp. variability), epistemological uncertainty (esp. approximation) and manifestations of uncertainty (esp. disagreement, subjectivity and linguistic imprecision). These unlike sources were in our earlier publications treated as if they were homogeneous. Thus arguing that disagreement and subjectivity are related to perspectives necessarily implied that

40 This use of sensitivity analysis is not documented for all submodels of TARGETS. Some exceptions are van (van Vianen et al. 1994) and (den Elzen et al. 1995)

41 See esp. (Hoekstra et al. 1997)

42 See (van Asselt et al. 1996), (Hilderink and van Asselt 1997; de Vries et al. 1997; Strengers et al. 1997; den Elzen et al. 1997; Rotmans et al. 1997)

43 We left it in between whether this perspective is personal, or whether it is a collective given that is adopted by the individual. However, we followed the argument of, for example, (Rayner 1991), who has it that in order to understand the staggering of perspectives (as opposed to the actual variety) in science, it is legitimate to restrict oneself to, what (Durkheim 1986) calls 'representations collectives', i.e. those perspectives that describe ways of thinking, understanding and interpretation that manifest themselves at a collective level (meso or macro). Cultural Theory corresponds to these assumptions.

44 (Morgan and Henrion 1990)

the other uncertainties were "perspective-free". Notwithstanding this "perspective-free" qualification, uncertainties in the model that arose out of either epistemological uncertainty (uncertainty due to lack of knowledge) and ontological uncertainty (uncertainty due to variability) were included in the perspective-based uncertainty analysis.

The typology of uncertainty as proposed in this thesis[45] does not consider disagreement and subjectivity as sources of uncertainty. It *explains* why disagreement and subjectivity are likely to occur in science. In the context of our exploration which uncertainties are correctly included in perspective-based endeavours, the distinction between measurable and radical uncertainties is relevant[46]. Measurable uncertainties can be calculated. This implies that either margins (in case of unreliability) or seasonalities (in case of variability) can be established, so that the uncertainty can be described quantitatively (either in terms of a domain or as stochastic equation). The "theory-in-perspective"-perspective implies that these measurable uncertainties can be considered to be perspective-free. The interpretation of radical uncertainties, i.e. uncertainties that can at best just be roughly estimated, are perspective-dependent in both the "theory-in-perspective" and the "science-in-perspective"-perspective. This is an example of what fundamental implications the adoption of a certain perspective on pluralism carries with it for actual pluralistic assessment. Not only which and how many perspectives are considered in the assessment is dependent on the adopted stand on pluralism, but also which uncertainties are included in the perspective-based analysis and evaluation, and which are not.

We have learned from our experiences with pluralistic Integrated Assessment so far, that it is necessary to be explicit about the viewpoint on pluralism that guides the endeavour. In choosing one of the perspectives on pluralism we will lose those audiences that adhere to another. The stand implicitly adopted in our research so far[47] has been in between the "theory-in-perspective"- perspective and the "science in perspective"-perspective. In doing so, we were criticised by the scientific practitioners who thought that we went much too far, as well as by the social scientists and philosophers who thought that we went not far enough. This criticism was not directed towards our pluralistic approach, but it was targeted to the specific pluralistic stand. This problem cannot be solved due to the variety in perspectives on pluralism. Applying the notion of pluralism in the practise of decision-support neces-

45 See Chapter 3A.

46 See Chapter 3A for a discussion on this distinction.

47 See also Chapter 3A for a detailed description of our work on pluralistic methods so far.

sitates choosing a position in the spectre ranging from 'observation-in-perspective' to 'reality-in-perspective'. In some cases, there may be clear arguments to choose one of the perspectives. Best practice in this context at least implies being aware of which view on pluralism is adopted and why, in order to facilitate communication and understanding.

It is not the aim of this thesis to defend a specific perspective on pluralism. Our major ambition is to allow scientific practitioners in decision-support to go beyond positivist 'monism', without neglecting the pluralism about pluralism. To that end, we have attempted to make the pluralism on pluralism explicit, in order to help practitioners to be conscious about their starting point. In order to facilitate scientific decision-support to go beyond positivism in a *consistent* way, our aim is furthermore:

- to explore the general features of a pluralistic approach
- to sketch the specific methodological choices associated with a certain perspective on pluralism.

5. Towards pluralistic methods

Pluralism means that different interpretations of uncertainty and different risk perceptions are legitimate. In the above, we have convincingly argued that our key hypothesis[48]:

> *It is necessary to consider multiple perspectives in decision-support on complex societal issues*

is scientifically sound. We thus want to make a virtue out of need. Our conclusion is that a pluralistic approach is both promising and necessary in the analysis of complex issues, and in particular in decision-support addressing complex issues. A pluralistic approach means that the uncertainties and risks associated with the issue are interpreted according to different perspectives and that these different interpretations and risk judgements are compared and confronted in order to draw a richer image of the issue under concern.

In the previous chapters and in the current one, we have provided a thorough motivation and underpinning for our pluralistic starting point. And secondly, we have explained that uncertainty and risk are actually two sides of the same coin, and that synergy is welcomed between uncertainty management and risk analysis. Such

48 See Chapter 1.

an integrated, pluralistic approach seems in principle adequate to allow decision support on complex issues. We have furthermore argued that due to pluralism about pluralism we cannot end up with *the* pluralistic method. Our aim will be to develop an approach for pluralistic integrated uncertainty management and risk analysis that embraces different specific methods that share the basic pluralistic principles and the major procedural steps.

To that end, we will first briefly explore the two other key notions that resulted from Chapters 3A and 3B, i.e. participation and robustness. Participation is related to pluralism. Participation is necessary if the required variety of perspectives extends beyond scientific points of view. As argued in Chapter 2, there are different levels of participation. Whether participation is necessary and to what extent it is practised, depends on the following:

- the character of the controversy/dilemma
- the sources and nature of the salient uncertainties
- the perspective on pluralism
- the aspired scope and nature of the insights

and it is furthermore important whether the decision-support activity as such is considered to be:

- a tool for social learning (i.e. a two way learning process between scientists, decision-makers, stakeholders and the general public)
- a method for improving the democratic character of policy formulation

In the latter two cases, which can be considered as forms of action research, participation seems to be a prerequisite[49]. With regard to the first four issues raised, participation is required to a greater or lesser extent in case one of the following descriptions apply:

- *the controversy/dilemma involves complex issues*[50]*;*
- *the salient uncertainties are due to value diversity, behavioural variability and societal randomness*[51]*;*
- *the salient uncertainties are related to psychological, socio-political and cultural risk factors*[52]*;*

49 See Chapter 3B for some reservations.
50 (Funtowicz and Ravetz 1990)
51 See Chapter 3A for a discussion on sources of uncertainty.
52 See Chapter 3B for a discussion on risk factors.

- *the adopted perspective on pluralism transcends the distinction between the world of science and the social world (i.e. the "science in perspective"-perspective and esp. the "reality in perspective"-perspective);*
- *the aim of the decision support endeavour is to deliver normative judgements;*
- *the decision support endeavour intends to provide recommendations that bear on public support.*

Because of the features of the complex issues considered and the ambitions associated with Integrated Assessment, it is inconceivable that none of the above reasons for participation would apply. The process of integrated uncertainty management and risk analysis is thus not by definition participatory, although it can be expected that in the majority of the applications participation is highly recommended or even indispensable. This means that integrated uncertainty management and risk analysis in the context of IA will have to be a participatory endeavour.

The third key issue, i.e. robustness, is also closely related to pluralism. Due to inherent pluralism, the positivist ambitions of true and objective, and the modest version hereof, i.e. the most probable and the most plausible, are replaced by the ambition of robustness. Because it is impossible to arrive at a unique interpretation of uncertainty and one perception of risk, the challenge of decision support is twofold: to arrive at insights that hold irrespective of the adopted perspective,
to suggest strategies that i) appear to trigger a future that is acceptable, or even favourable, to different perspectives, ii) that seems to avoid those that one or more perspectives consider to be highly undesirable, and iii) that are flexible enough to be changed or reversed if new insights emerge.

This definition of the challenge for decision-support acknowledges that it is impossible to arrive at consensus with regard to worldviews[53]. The idea of a 'shared perspective' composed of bits and pieces of the various perspectives assumes that a kind of meta-perspective exists, which assumption is fundamentally inconsistent with pluralism. Searching for robustness involves assessing which strategies are acceptable to different perspectives, without consensus on the underlying arguments. Such robust recommendations can inform decision-making on complex, and thus radically uncertain and strategically risky issues.

It thus follows from the above that integrated uncertainty management and risk analysis has to be pluralistic, at least partly participatory, and that it aims to deliver

53 For the distinction between worldview and management style see Chapter 3A.

robust recommendations. Building upon our elaboration so far, our challenge can be summarised as:

> *Integrated uncertainty management and risk analysis is an assessment process in which the salient uncertainties are interpreted according to different perspectives and structured into multiple risk judgements in such a way that robust insights can be deduced.*

How to integrate uncertainty management and risk analysis? Uncertainty and risk are two sides of the same coin, but they have different features. As argued in Chapter 3B, risk statements are the joint product of informed estimates about the future and the evaluation of desired and undesired prospects. Uncertainty management means an assessment of the knowledge base. In line herewith, we conclude that uncertainty management forms one of the bases for risk analysis. On the other hand, uncertainty management results in a wide variety of possible futures. As argued earlier, the output of uncertainty management is difficult to understand by decision-makers. Evaluation and translation is necessary in order to enable decision-makers to use this knowledge. Risk analysis can thus be considered as a logical next step after uncertainty management. The consequence is that uncertainty management can be used to improve the assessment of the knowledge about the future in risk analysis, while risk analysis is used to transform and communicate the outcomes of uncertainty management into decision-relevant information.

Integrated uncertainty management and risk analysis can thus be considered as a two-step approach, with uncertainty management as the first step and risk analysis as the second. If this were it, it would be more appropriate to talk about *coupled* uncertainty management and risk analysis. In our point of view there are more opportunities to benefit from a synthesis of the two approaches. One of the crucial and most difficult steps in uncertainty management is the selection of salient uncertainties. Any selection implies weighing and evaluation. In Chapter 3A, we have argued how checklists and sensitivity analysis can be useful in this selection process. The NUSAP approach can also be of help to identify the degree of uncertainty. In the context of decision-support, the salience of uncertainty depends on whether the uncertainties are relevant in view of the decisions to be taken or the strategies to be developed. This is a typical chicken or egg problem: it is necessary to know the most important uncertainties before exploring decisions and strategies, while the importance of uncertainty can only be determined in view of the proposed decisions and strategies.

How to deal with this mutual dependency? Pluralistic theories that consider perspectives as a-priori givens argue that a priori value patterns determine which uncertainties are relevant and which are not. In this case, the perspective framework can be used to filter which uncertainties are important. Other pluralistic theories do not reason from such a-priori perspectives. It both cases it seems important that integrated uncertainty management and risk analysis is an iterative effort. After a first cycle, it is necessary to evaluate the conclusions by checking whether the uncertainties that may have a crucial impact on the conclusions have all been considered. Second, the selection process can be informed by risk analysis. As argued in Chapter 3B, risk is multidimensional. This multi-dimensional risk scheme can be used as another checklist to determine whether the uncertainty is salient in view of decision-support. The first step in risk analysis is to select the risk dimensions that are crucial in view of the dilemma or controversy under concern. The next step then would be to explore to what extent the identified uncertainties are related to the selected risk factors. This means that the uncertainties are characterised in terms of both scientific importance and policy relevance. This systematic approach and crosscheck increase the probability that the salient risky uncertainties and uncertain risks are captured in the assessment process from the early beginning on.

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CHAPTER 5

Pluralistic framework for integrated uncertainy management and risk analysis (PRIMA)

In line with the theoretical criteria and conditions discussed in the previous part of this thesis, a general framework for pluralistic integrated uncertainty management and risk analysis is proposed in this Chapter. The various steps will be discussed as concrete as possible. In the next part of the thesis, it will be explored in practice by means of the case of an example of an actual assessment process (Chapters 6-8). The aim is that by means of this testing, the theoretical outline can be developed into a more practically feasible framework (Chapter 9).

The aim is to provide a generic framework that is theoretically sound and that provides hints how these steps can be performed in practise. It should always be tailored to the specific case, adopted to the needs of those involved (both analysts and clients) and it should be possible to use it in a flexible manner in order to accommodate for the state of affairs and the actual running of things. The aim is that the general framework for pluralistic integrated uncertainty management and risk analysis, can be used as a kind of 'ideal plan', that inspires and challenges practitioners. The PRIMA framework is designed to help setting up pluralistic trajectories that enable practitioners to deal with uncertainty and risk in a way that acknowledges state-of-the-art theorising on complexity, uncertainty and risk. Such a change of practice would in principle increase the analytical and methodological quality of the assessment and the decision-support[1].

1 See Chapter 2.

1. General framework

How to come from a scattered complex problem to robust recommendations? In the previous Chapter, we concluded that:

> *Integrated uncertainty management and risk analysis is a participatory assessment process in which the salient uncertainties are interpreted according to different perspectives and structured into multiple risk judgements in such a way that robust insights can be deduced.*

How can such an assessment process be set up? What steps have to be performed in any pluralistic approach to integrated uncertainty management and risk analysis? The major steps are visualised in Figure 1. In view of the aim of the framework to serve as a kind of guide, this scheme of steps should not be interpreted as a rigid procedure, but as an attempt to structure the desired ingredients of pluralistic integrated uncertainty management and risk analysis.

The above scheme represents a very ambitious programme. In order to be able to see the connection between the various steps, the framework can also be described in terms of various stages. The first stage can be described as defining the overall perspective, both in terms of which perspective on pluralism is adopted and in terms of the controversy or dilemma being assessed. The next phase can be characterised as "uncertainties in perspective". In this stage the scan, selection and perspective-based interpretation of uncertainties is the central task. In the following phase, it is assessed what scenarios seem to be possible and plausible. This involves scanning the future from a wide variety of perspectives. This stage can therefore be typified as "scenarios in perspective". The next challenge is to assess risks, taking into account the variety of perspective-based assessments gathered in the previous phases. Putting risk in perspective can yield robust insights. This stage is therefore characterised as "risks in perspective". It is very important to test the quality of the robust insights by reflecting on the previous steps, that means evaluating whether the uncertainties and risk factors relevant for these particular conclusions have be considered in an adequate manner. This stage of quality assessment can be considered as closing the assessment cycle (see Figure 2). This process then yields outputs that can be used as qualified recommendations in the decision-making community and as priorities for the research agenda in the scientific community. Building upon these new insights the process can be iterated with an adopted or new definition of the controversy or dilemma, or with another perspective on pluralism.

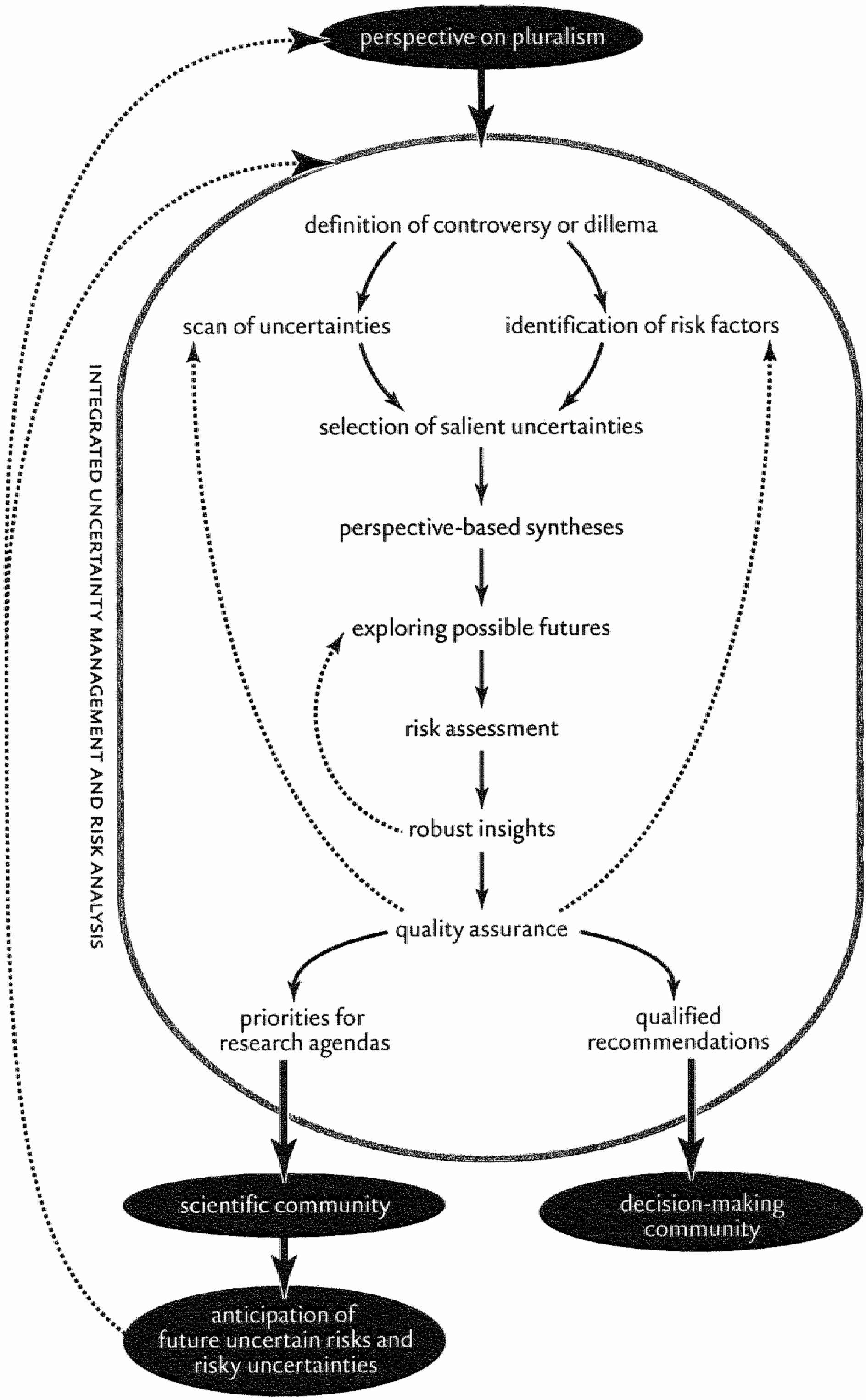

figure 1 General framework for pluralistic integrated uncertainty management and risk analysis (prima)

In sum the following phases can be distinguished (see also Figure 2):

- definition of 'starting perspective'
- uncertainties in perspective
- scenarios in perspective
- risks in perspective
- quality assessment
- use of outputs

The various steps, including concepts, tools and methods that enable to perform these steps, are described stage-wise in the following sections.

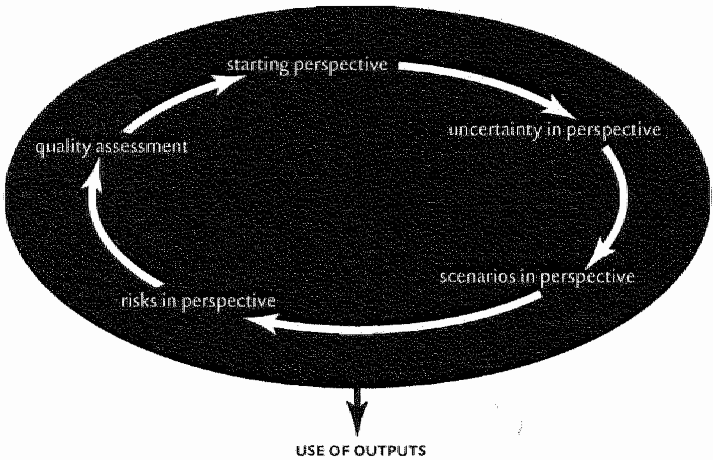

FIGURE 2 Multi-stage approach to pluralistic integrated uncertainty management and risk analysis (PRIMA)

2. Starting perspective

As can be concluded from the previous Chapter, applying pluralism means taking up a certain stand with regard to pluralism. On the highest level of abstraction, we could argue that diverse types of pluralistic analyses have to be carried out. This would tally with the theoretical considerations, but it is clear that in being too far beyond current practise and in being too time-consuming, this would turn integrated uncertainty management and risk analysis into a mission impossible. We would advise that the first step is to choose that perspective on pluralism that corresponds most with the attitude of both the analysts and the clientele, and then to be consistent with this perspective during the assessment process.

PERSPECTIVE ON PLURALISM

There are three crucial choices that are dependent on the choice for the pluralistic stand, i.e.:

- the type of uncertainties included in the pluralistic analysis
- whether a demand- or a supply-driven approach is advocated
- portfolio of methods for uncertainty analysis
- the perspective framework used

In the following we would like to address these issues from the various perspectives on pluralism. The aim is to help practitioners to decide in choosing which perspective on pluralism is most appropriate in their situation and to facilitate them in being consistent throughout the analysis. The features associated with the various perspectives on pluralism are summarised in Table 1 and are further explained and explored in the remaining of this section[2].

perspective design choice	*"observation in perspective"*	*"theory in perspective"*	*"science in perspective"*	*"reality in perspective"*
uncertainties included	radical uncertainties	radical uncertainties	radical and measurable uncertainties	everything is uncertain
type of assessment	supply-driven	supply-driven & participatory	participatory	demand-driven
methods for uncertainty analysis	standard methods with perspective-based as supportive	perspective-based and standard methods in a complementary manner	perspective-based with standard methods as supportive	fully perspective-based
perspective-framework	hypotheses	scientific paradigms	socio-cultural perspectives	perspectives result out of participation / observed in actual networks

TABLE 1 Practical differences between perspectives on pluralism

The "observation-in-perspective"-perspective holds that observation is shaped by what the researcher wants to falsify or verify. This means that competing hypotheses are the basis for pluralism in this specific stand. A perspective in this context thus means a coherent set of hypotheses. The practical implication is that if this view on pluralism is accepted in the study on complex issues, the scientists have to infer competing sets of hypotheses, which are then used to interpret the salient uncer-

2 See also Chapter 4.

tainties. This realist perspective implies an essentially supply-driven assessment, in which the perspective-based analysis is restricted to radical uncertainties.

The "theory-in-perspective"-perspective includes radical uncertainties in the perspective-based analysis, while measurable uncertainties are treated with standard methods. This perspective on pluralism advocates the supply-driven approach, although this does not exclude the possibility that some of the activities are participatory.

In case of the "theory-in-perspective"-perspective it would be appropriate to use different scientific paradigms to compose a set of perspectives. Even in disciplines in which the reigning paradigm is very dominant, it will be possible to discern at least one alternative, either by an analysis of the history of this discipline or by retrieving the line of thought of contemporary dissidents. As far as our knowledge extends, such a systematic analysis of paradigms in different disciplines and integration of disciplinary paradigms into interdisciplinary perspectives have never been performed. As a consequence developing a set of perspectives in this way seems to be a research programme in its own right.

A more pragmatic approach within the "theory-in-perspective"-perspective would be to reason from major dichotomies within science. Table 2 is a first attempt to highlight major constituting dichotomies. In this way, a perspective-framework can be developed that on an abstract level roughly describes major diverging viewpoints present within science. These scientific perspectives can then be used to interpret the salient uncertainties.

scientific clusters	some major dichotomies		
economic sciences	market-oriented	↔	government-oriented
	rational actor & equilibrium	↔	adaptive learning agents & non-equilibrium
	need-oriented (demand)	↔	resource-oriented (supply)
social-cultural sciences	individual	↔	collective/social phenomena
	determinism	↔	voluntarism
	cognition	↔	behaviour
environmental sciences	anthropocentric	↔	ecocentric
	scarcity	↔	abundance
	adaptive capacity	↔	fragility
institutional sciences	institutionalised politics	↔	subpolitics
	hierarchy/power structures	↔	egalitarian/democracy

TABLE 2 Exploration of major dichotomies within science

A more bottom-up way to arrive at a set of perspectives that could be used in the "theory-in-perspective" mode would be to deduce perspectives from elicitation processes with scientific experts. That means that a representative set of scientists is asked to interpret the salient uncertainties. The various interpretations are compared in order to discern patterns of interpretation. These patterns can then be considered as empirically revealed scientific perspectives[3].

As said before in the "science-in-perspective"-perspective a typology of socio-cultural perspectives is welcomed, because pluralism in science results out of pluralism in society. Such a typology can be found in Cultural Theory[4]. It is clear that Cultural Theory organises some dichotomies that are important in social and cultural science conceptualisations, such as hierarchy versus egalitarianism, market versus government, centralised versus decentralised, and individualism versus social solidarity[5]. We advocate to adopt the three active perspectives inferred from Cultural Theory[6], while bringing them a little more down to Earth through renaming and summarising them in terms of heuristic rules[7]. This pragmatic approach was inspired by our analysis of European scenarios, in which four different patterns of thinking about the future were clearly recognisable (i.e. the money-maker, the doom monger, think green, and wait and see[8]). Our experience was that this clustering was acceptable to experts that resist to Cultural Theory, while it to our opinion at the same time reflects the basic characteristics shaping the cultural theory perspectives. The complicated naming of the perspectives is one of the recognised obstacles, also for them neutral or positive to Cultural Theory. The first adjustment thus involves a renaming[9], i.e.:

- the market optimist (instead of individualist)
- the environmental worrywart (instead of egalitarian)
- the controllist[10] (instead of hierarchist)

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3 In such an exercise the following references can serve as source of inspiration: (Nordhaus 1994), (Morgan and Keith 1995)

4 See Chapter 3A and 3B for short descriptions of these perspectives associated with Cultural Theory and a bibliography of Cultural Theory. See Chapter 3A for a discussion of our experiences in using the perspectives proposed by Cultural Theory. See also Chapter 4.

5 As argued in (van Asselt and Rotmans 1996; 1997)

6 We realise that we are not doing justice to Cultural Theory by just presenting their perspective scheme. Cultural Theory is in fact a theory of social organisation; the perspectives recognised in Cultural Theory are emergent properties of social organisation. Although in using Cultural Theory we have been aware of the dependence of perspectives on the relevant social organisation, this feature of the Cultural Theory perspectives is not explicitly used in this context, but it could be explicitly used in that way in case the whole PRIMA process involves stakeholders from different social contexts. In the current thesis, the perspectives are used as stereotypes.

7 This exercise substantially benefits from the discussions within the 'perspective' working group at ICIS (autumn 1998 till spring 1999), in which apart from the author, Nicole Rijkens, Frank van Asten, Bastien Clement and Josine Spierenburgh were involved, and the discussions within the broader ICIS team resulting out of topical lectures on perspectives and Integrated Assessment. Furthermore, the adjustments were informed by the experiences of using Cultural Theory as perspective frame in various contexts.

8 (van Asselt et al. 1998)

9 This adjustment was inspired by the discussions within the 'perspective' working group (autumn 1998 till spring 1999). The renaming was explicitly advised by prof. Kees Schuyt in a vivid discussion about the pros and cons of Cultural Theory.

10 Wording inspired by Hella Haase's novel "Huurders en onderhuurders" (1971).

Furthermore, the practical experiences inspired us to propose summaries (see Table 3) comprising the heuristic rules that turned out to be critical in interpreting uncertainties according to the Cultural Theory perspectives. We have furthermore tried to prioritise these critical features. In doing so, the summarised characterisations can be used as heuristic schemes in quickly applying the above perspectives with assessment practitioners and stakeholders not familiar with Cultural Theory.

	market-optimist	*environmental worrywart*	*controllist*
heuristic rule 1	Free market and anti-regulation; Economic growth and technological development are progress;	Nature is vulnerable, and thus in need of protection from excessive exploitation; Aversive to environmental risks; Prevention is better than cure.	Societal stability through regulation, norms and hierarchy; Acceptation of inequalities
heuristic rule 2	Individual development and material self-interest are the motives for action. Success is a personal responsibility.	Equity.	Risk-aversive; Anti abrupt change; Easy doing otherwise the line will break.
heuristic rule 3	Nature is not fragile; it can stand rough handling.	The economy is a means and not an aim. Conscious consumption.	Authority through expertise and experience.
heuristic rule 4	Problems are solvable; . Risks are challenges and opportunities	Human beings are essentially solidary and act accordingly; Collective interest.	Power and status are the motives for action.

TABLE 3 Features of socio-cultural perspectives

The above typology of perspectives can be used in the “science-in-perspective”-mode. This typology may also be useful as source of inspiration in the “theory-in-perspective”- perspective, because, although this typology transcends scientific disputes, it inhibits particular combinations of stands taken with regard to the major dichotomies prevailing in science (compare Table 2). Within the “science-in-perspective”-perspective a deductive strategy of deriving perspectives from the participatory process can also be considered.

The "reality-in-perspective"-perspective only recognises those perspectives that are observed empirically in actual interactions. This viewpoint denies the possibility of any a priori classification of perspectives, because it holds that perspectives are embedded in social interaction patterns. Because science is granted no special role, adoption of the "reality-in-perspective"-perspective implies that the whole assessment process should be participatory. Interpretations of uncertainty arise out of the interactions in the participatory process. In its extreme form, this perspective has it that social interactions are unique, which implies that the assessment is not reproducible and that the results cannot be generalised. In a less post-modern variant, it is possible to infer patterns out of the empirical study of the interaction processes. So far, the constructivist literature does not provide a scheme that can be applied in pluralistic efforts. This implies that at the moment a pluralistic integrated uncertainty management and risk analysis in a "reality-in-perspective" mode involves that the assessment process is demand-driven and necessarily participatory.

DEFINITION OF CONTROVERSY OR DILEMMA

After having adopted a certain perspective on pluralism, the next step is to define the complex issue under concern in terms of a controversy or dilemma. This enables to define the problem, and to demarcate what is the focus of the assessment, what will be studied, and what not. The controversy or dilemma should be phrased broad enough to comprise various perspectives, while it should be concrete enough to serve as starting point for analysis. In view of the aim of integrated uncertainty management and risk analysis, the formulation has to be sensible, understandable and legitimate both from a scientific and a decision-makers' point of view.

This starting perspective stage results in decisions with regard to uncertainties included, the type of assessment, the portfolio of methods, the perspective-framework, and the problem formulation, which choices structure the further process.

3. Uncertainty in perspective

This phase involves scanning the uncertainties and identifying the relevant risk factors. The taxonomy of sources and types of uncertainty provided in Chapter 3A can be used to systematically assess and characterise the uncertainties involved (see Figure 3).

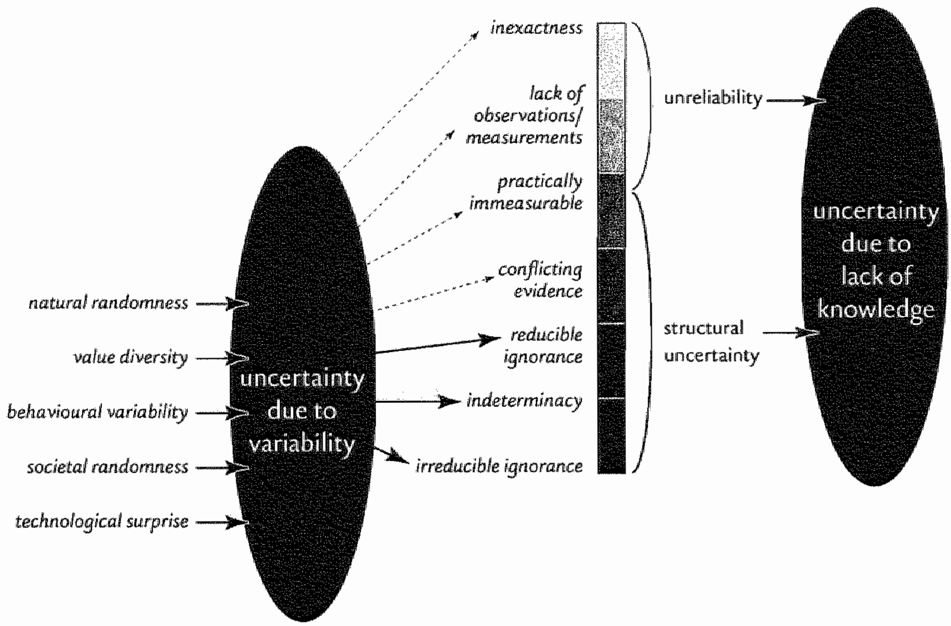


FIGURE 3 Typology of uncertainty (see Chapter 3A)

The multidimensional risk scheme (see below) that is given in Chapter 3B can serve as a starting point for exploring risk factors in a structured manner:

- what might happen?
- imaginable consequences?
- risky to whom?
- equity?
- cause?
- catastrophic potential?
- invisible dread?
- controllable? / voluntariness?
- familiarity? / delay?

- accident history?
- irreversibility?
- how plausible/likely?
- acceptable/desirable?
- what can be done about it

The characterisation and features of types of consequences can also be useful in this context, i.e. benefits (desired effects) and damages (undesired effects), further specified into:

- social (e.g. in terms of health and quality of life), economic (e.g. economic losses/gains), environmental (e.g. in terms of ecological value, biodiversity and natural processes/functions) and institutional terms
- terms of distribution
- direct and indirect effects

Both activities will be an iterative effort, i.e. going back and forth between the theoretical aspects of the two notions and the specifics of the issue under concern. Building upon these parallel steps, the salient uncertainties have to be selected. Salience in the context of decision support and Integrated Assessment implies that the degree of uncertainty is significant and that the policy relevance is high[12]. How to determine which uncertainties are salient? Taking into account that salience in this context has both a scientific and a decision-making dimension, the conclusion is that this step can best be done by means of a participatory process. Whether the degree of uncertainty is high and whether the uncertainties are highly policy relevant can then be determined in an intersubjective manner. It can also be decided that different sets of salient uncertainties are composed in relation to the various perspectives that are used in the specific assessment. Figure 4 sketches a participatory selection process. The taxonomy of uncertainty is useful to identify and characterise the uncertainties. Heuristics as checklists, sensitivity analysis and NUSAP may help to estimate the degree of uncertainty. By means of the identified risk factors, the uncertainties can also be characterised in terms of policy relevance. These two features of uncertainty, i.e. degree and policy relevance, in principle enable to select those uncertainties that are salient in view of the complex issue.

12 Compare (Funtowicz and Ravetz 1990)

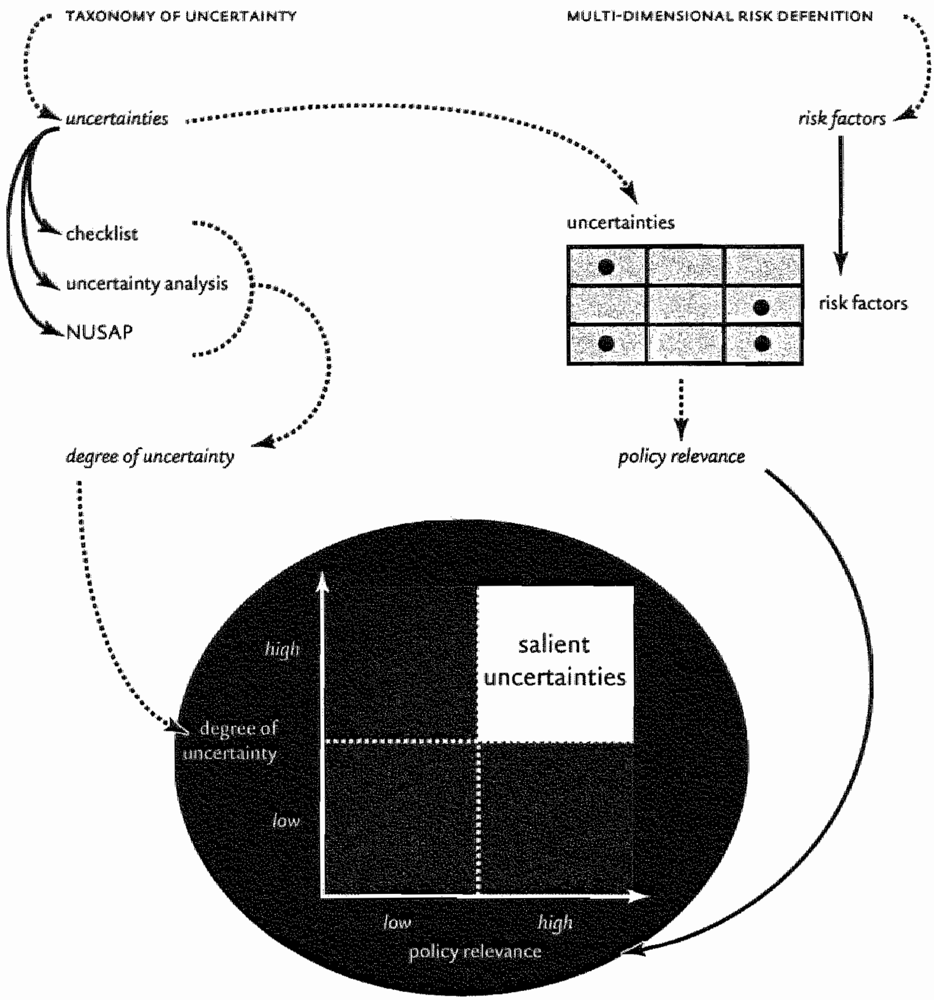


FIGURE 4 Routing for selection of salient uncertainties

Salient uncertainties can be clustered in terms of world view and management style[13]. Uncertainties associated with worldview involve uncertainties pertaining to economic, environmental and socio-cultural processes. Uncertainties associated with management style deal with policy preferences in terms of strategies and options, and with institutional processes. The distinction between world view and management style is relevant in this interpretation phase. The salient uncertainties have to be interpreted according to different perspectives. The fleshing out of worldviews

13 This distinction reflects the common dichotomies between perceiving and acting, between autonomous and policy-driven, and between how it is and what we should do. In using perspectives in decision-support this distinction is crucial, see (van Asselt and Rotmans 1995; 1996; 1997).

(see Table 4) can be done qualitatively, semi-quantitatively or quantitatively. The syntheses of the interpretation of 'world view' uncertainties with factual information yield different conceptualisations of the dynamics underlying the relevant complex issue.

perspective **uncertainty**	*perspective A*	*perspective B*	*perspective N*
uncertainty 1			
uncertainty 2			
uncertainty x			

TABLE 4 Interpretation format for world view according to perspective

Interpreting the salient uncertainties associated with management style involves a scan of the strategies and options[14] that have to be considered in the analysis. This can be done in different ways, for example i) by means of a participatory exercise in which the decision-makers and/or stakeholders participate, ii) by a review of strategic documents checked with the policy sciences literature, or iii) by using the perspectives for a structured and systematic brainstorm. Ideally the different approaches are combined to guarantee an adequate coverage both of options and strategies viable in the decision-making community and of innovative responses. This stage should result in fleshing out plural management styles (see Table 5).

perspective A	**perspective B**	**perspective N**
policy option 1	*policy option 3*	*policy option x*
strategy 2	*strategy 1*	*strategy y*
...	...	....

TABLE 5 Interpretation format for management style per perspective

The major outcome of this phase is a consistent perspective-based set of salient uncertainties, in which worldview and management style are distinguished. Table 6 illustrates the outcome of such a process with reference to the TARGETS project, in which endeavour the original Cultural Theory labels were used[15]. These worldviews and management styles form the building blocks for assessing the future. Furthermore, the intermediary product, i.e. the list of salient uncertainties that is deter-

14 Policy analysis literature provides techniques for option generation, see for example (van Heffen et al. 1999) and (Hoppe 1998).
15 For more details, see Chapter 3A.

mined in a systematic and participatory manner, as such can already proven to be a valuable input to the decision-making process and can be used to set the scientific agenda.

	Hierarchist	**Egalitarian**	**Individualist**
economy	moderate desired economic growth	low desired economic growth	high desired economic growth
population & health	• physical limits • family planning programs as driving force • health as human capital • health services	• environmental and social limits • societal developments as driving force • health as human asset • social-economic and environmental health determinants	• no limits • individual possibilities as driving force • health as consumption good • ageing
energy	moderate technology development	environmental technology	energy-efficient technology
climate	• amplifying effect of geophysical feedbacks • moderate cooling of aerosols	• strong amplifying effects of geophysical feedbacks	• radiative effects are strongly dampening effects
water	• supply oriented • stable runoff as potential water supply • medium response to climate change	• demand oriented • clean fresh water stock as potential supply • high response to climate change	• market oriented • no limits • low response to climate change
land & food	• present diet • 3.3 Gha arable land • middle recuperative power of degraded land	• vegetarian diet • 2.8 Gha arable land • low recuperative power of degraded land • negative effect of temperature increase	• American diet • 3.8 Gha arable land • high recuperative power of degraded land • positive CO_2 fertilisation effect

TABLE 6A Example of perspective-descriptions in terms of worldview

	Hierarchist	Egalitarian	Individualist
population & health policy	• family planning • anti-abortion • selective health care policy (cure)	• human development (esp. education for women) • legislation of abortion • comprehensive health care policy (prevention)	• legalisation of abortion • market-oriented health policy
energy policy	• no carbon tax • moderate R&D programs for new energy supply and • efficiency options	• carbon tax towards 500$/tC in 2020, constant afterwards • R&D programs on renewable resources	• no carbon tax
water management	• increasing charges on water	• water-taxing • active policy on public water supply and coverage • R&D programs on small-scale technology	• market pricing of water • high-tech R&D programs if water gets scarce (e.g. desalination)
land management	• reforestation policy • agricultural planning (incl. irrigation, fertilisers, deforestation, reforestation)	• eco-forestry (e.g. reforestation) • eco-agriculture (less clearing, no fertilisers)	• protection of wood sector • intensive agriculture (incl. genetic engineering)

Table 6b Example of perspective-descriptions in terms of management style

It should be noted that the above approach to flesh out plural perspectives is stylised, in the sense that it does not take into account the policy system and the associated balance of power. Each political system will tolerate and select particular management styles[16] or will prefer certain compromises[17]. However, our aim is not to mirror nor to replace the political process, but to indicate legitimate interpretations of uncertainties, both in terms of worldview and in terms of management style, as a decision-support endeavour. The actual evaluation of perspectives has to take place in the policy arena.

16 See, for example, (Molenaers and Thompson 1999).
17 In the next step 'scenarios in perspectives' combinations of management styles can be included in order to assess potential compromises.

4. Scenarios in perspective

In this thesis, a scenario is defined as an alternative image of the future, created from mental maps or models that reflect a specific perspective on past, present and future developments[18]. A scenario is thus an assessment of the future reasoning from a particular interpretation of the salient uncertainties. In our approach, the perspective-based interpretations that result from the previous step serve as starting point for scenario-analysis. In this way, scenarios are thus used as a tool to address uncertainty by systematically "thinking through" the consequences of different interpretations of the salient uncertainties. In view of the decision-support ambition, it is important that the scenarios involve the selected risk factors. In other words, the risk factors form a kind of content list for the images of the future.

The perspectives can be embodied into quantitative models (i.e. perspective-based model routes) or in qualitative descriptions (i.e. perspective-based knowledge patterns). It is important here to distinguish between autonomous and policy-driven developments. To that end the various worldviews and management styles are systematically combined (see Figure 5) in order to explore different utopian and dystopian outlooks. In doing so, each scenario thus involves a particular management style (composed of policy options) and a particular interpretation of how the world functions.

In the context of the complex issue under concern, it might be interesting to go beyond the rigid management style and worldview scheme. Some extensions of this basic scheme are:

test a particular policy option or strategy against all world views

i) divide the worldviews into economic, socio-cultural, ecological and institutional clusters[19], ii) design interesting combinations and iii) test policy options and management styles against these combinations.

- introduce surprises and assess how the various perspective-based assessments of the future would change[20]
- explore the consequences of a future change of management style[21]
- combine these approaches

18 See Chapter 2 for a summary of scholarly ideas and discussions on scenarios and scenario development. Here we limit ourselves to using the notions and concepts introduced in Chapter 2.

19 This clustering is inspired by the distinction into economic capital, socio-cultural capital, ecological capitcal and institutional capital that is guiding the ICIS research programme (see for example (Rotmans 1997a; 1998; ICIS 1999)).

20 The introduction of surprises into scenario development is a key innovation of the VISIONS project (see Rotmans 1997b; Rotmans et al. 1999;van Asselt et al. 1998)

21 See (van Asselt and Rotmans 1996) and (Janssen and de Vries 1998) for this kind of experiments with perspective-based model routes.

This systematic exploration of the future either yields quantitative forecasts or narratives dependent on the scenario method used. This phase thus results in a broad range of scenarios that covers the wide variety in legitimate interpretations of the underlying salient uncertainties and that comprises those risk dimensions relevant for the strategic debates. In doing so, this approach to scenario analysis puts uncertainty at the heart of the assessment. These scenarios show the range of possible futures constrained by current state-of-the-art knowledge. With integrated uncertainty management and risk analysis we scan what is possible. For complex issue, it is by definition impossible to come up with the most plausible or the most probable scenario. Scanning what is possible, and what not, is the relevant information integrated uncertainty management and risk analysis yield.

MANAGEMENT STYLE	WORLD VIEW perspective A	perspective B	perspective N
perspective A	utopia	dystopia	dystopia
perspective B	dystopia	utopia	dystopia
perspective N	dystopia	dystopia	utopia

FIGURE 5 Scheme for utopian and dystopian experiments

5. Risks in perspective

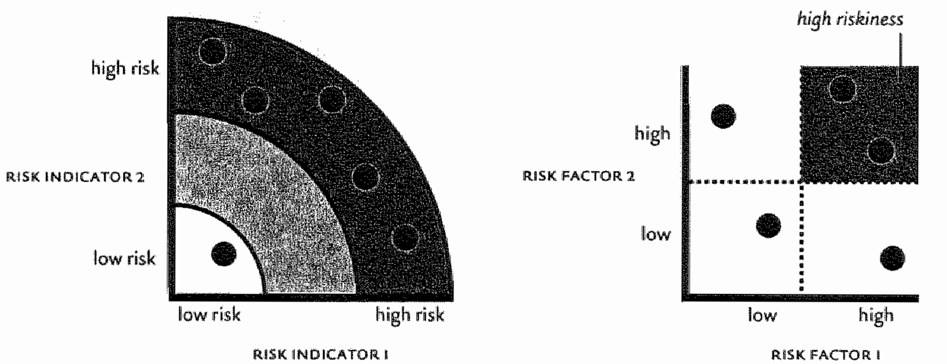
The previous stage can be considered as a phase in which divergence was a key principle. In the present phase, convergence is the ambition. The challenge is to go beyond the multiple perspective-based 'sprinkler' of "would-be-worlds"[22]. Assessment involves providing general insights relevant for decision-makers that are valid regardless of the preference for a certain perspective. The challenge is to analyse the scenarios in such a way that it enables to draw robust conclusions. In this process the notion of risk turns out to be useful, because it allows evaluating the scenarios.

In case of quantitative forecasts, we can assess how these outlooks score if we take two of the selected risk factors as indicators. These two indicators enable to define low-risk, moderate-risk and high-risk areas for the resulting two-dimensional

22 (Casti 1997)

space. The next step is to plot the outcomes of the set of scenarios in this two-dimensional space. The resulting picture indicates which policy options seem to be interesting to consider. On the other hand, thorough analysis of the scenarios that landed in the high-risk area may provide insights in which policy strategies may cause an undesirable future.

In this way, the scenarios can be compared and confronted. This step implies that the various scenarios (and thus images of the future) are assessed in terms of riskiness[23]. In Figure 6 it is illustrated how this can be done for a particular set of scenarios (e.g. scenarios associated with the same strategy) in the light of two unambiguous risk factors. Such an analysis of the scenarios in terms of risk areas can be done either qualitatively or quantitatively. The conclusion from the risk figures as shown in Figure 6 would be that the first strategy seems to be highly risky, while about the second one it is difficult to draw a similar robust conclusion. In this case, the conclusion would be that controversy about this strategy is to be expected.



LEGEND Each bullet represents a scenario associated with a particular strategy/policy option. The bullets altogether represent different scenarios that perspective-based assessment of the particular strategy/policy option yields.

FIGURE 6 Two ways to create risk areas signifying a set of scenarios characterised in terms of two risk indicators

In case of more risk indicators similar exercises can be done by means of multi-dimensional visualisations such as the multi-star representation[24] (see Figure 7) or by means of an aggregation procedure that enables to compose risk estimates pair-wise (see Figure 8).

23 Compare Chapter 3B.
24 See also Chapter 3B.

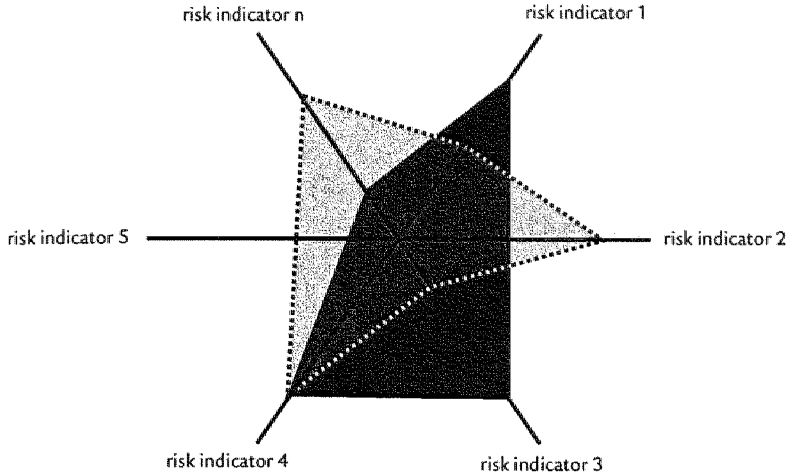


figure 7 Multi-star representation in which two scenarios are scored on various risk indicators

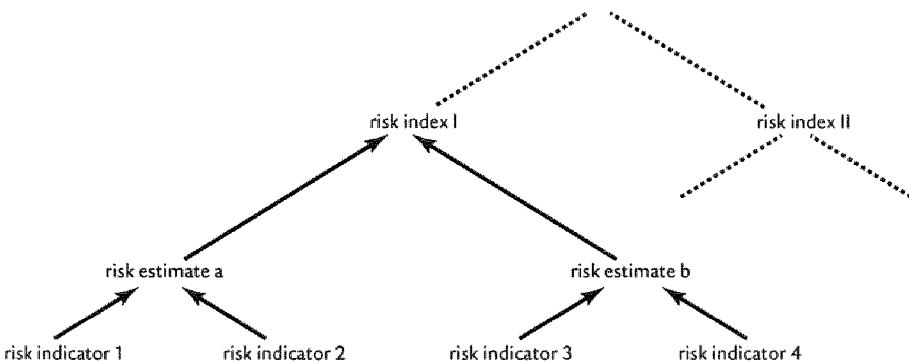


figure 8 Aggregation procedure for composite risk estimates

By performing the assessment of risks in the above manner, it is possible to assess insights that are robust, i.e. insights that transcend the biased interpretations of uncertainty. Box 1 illustrates this type of insights that were derived from the integrated assessment of global change and sustainable development using the TARGETS model. This box provides examples both on the level of specific issues (i.e. population development and climate change) and on the integrated level.

BOX 1 Examples of robust insights derived from pluralistic integrated assessment

POPULATION[25]

Population numbers and health status, expressed in life expectancy, are selected as the key indicators to assess population and health risks. Risk intervals are determined for both indicators, i.e.:

for population[26]*:*

low-risk:	population number below 7.7 billion people,
moderate-risk:	population numbers between 7.7 billion and 12 billion people
high-risk:	population numbers above 12 billion people.

for human health[27]*:*

low risk:	health levels above a life-expectancy of 77 years
moderate risk:	health levels with a life-expectancy between 66 and 77 years
high risk:	health levels below a life expectancy of 66 years.

By implication, a future characterised by a population number below 7.7 billion with an average life-expectancy exceeding 77 years is considered a safe situation in demographic and epidemiological terms.

Analysis of Figure 10 shows that none of the utopian and dystopian futures is considered to be highly risky, although some of them are likely to enter the high-risk area in the course of the 22nd century. On the other hand, none of the management styles yields a future that would be safe in every case. The egalitarian utopia is the future closest to the desired state of the world. The analysis of dystopia and utopian experiments furthermore suggests that moderate population sizes and fairly good health are most likely where society is to a certain extent collectively 'makable', so that governing incentives might create favourable conditions. However, high population numbers are also reconcilable with an extremely good health in a market-oriented society. Figure 9 shows that the majority of countries in the future are not found in the area with deterioration of life expectancy (i.e. high-risk area with regard to health). In other words, referring to the question of whether a healthy life and popu-

see over »

25 This description builds upon (Hilderink and van Asselt 1997)

26 Building upon (Cohen 1995)

27 Building upon current observed life-expectancy levels as reported by (UNFPA 1996)

BOX I

lation growth is irreconcilable, our experiments suggest that an improvement of the global life expectancy to a level comparable to the present situation in developed countries is most likely. Worth noting is that a healthy life seems reconcilable with significantly differing future population trajectories.

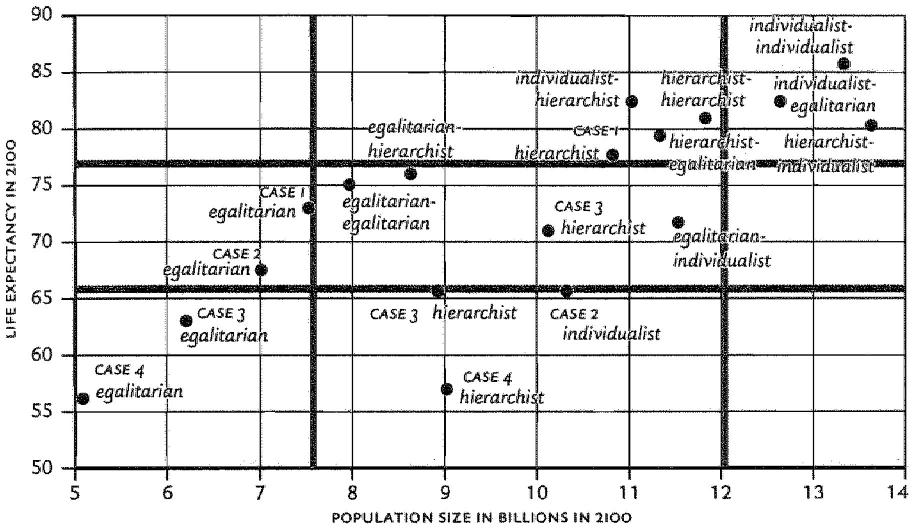


FIGURE 9 Example of scenario assessment presented by means of risk areas

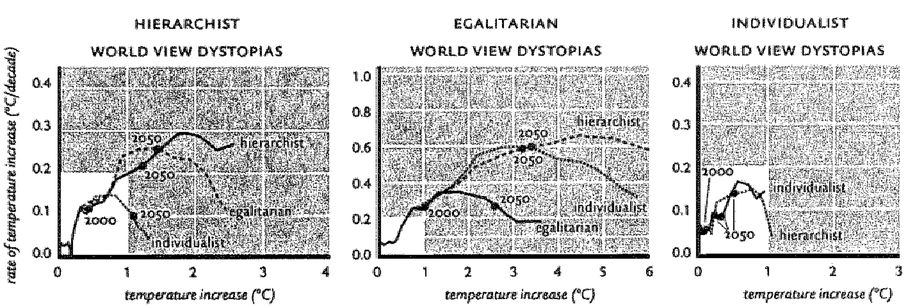


FIGURE 10 Simulation results presented by means of risk areas

What, in sum, do the utopian and dystopian experiments tell us with regard to the population and health controversy? A doomsday scenario featuring excessive population numbers in miserable health conditions is not very plausible.

see over »

BOX 1

Climate change[28]

The outputs of the utopian experiments in terms of atmospheric CO_2-concentration and temperature increase are presented in Figure 10. Inspection of these graphs leads to the interesting conclusion that a high temperature increase (to about 3.5°C by the end of the next century) can be explained by a relatively low CO_2-concentration (i.e. the egalitarian utopia). On the other hand, a concentration of CO_2 in the atmosphere to about twice the present level (i.e. the individualistic projection) does not necessarily yield high temperature increases. The individualistic utopia features a temperature increase of about 1°C in the course of the 21st century. Standard climate scenarios always show the concentration-temperature combinations low-low, middle-middle and high-high. How to explain the counter-intuitive results produced with multiple perspective-based model routes? Such an analysis of the climate controversy indicates by way of narratives how large the uncertainties are and how to understand outcomes in terms of interpretations of the underlying uncertainties. Comparing the egalitarian and individualistic utopia teaches us how crucial the uncertainties concerning amplifying and dampening feedbacks are in forecasting the future. The outcomes yield that if amplifying feedbacks dominate the biosphere-atmosphere response to initial warming signals, the absolute temperature increase will be significant, even if the CO_2-emissions do not increase dramatically. On the other hand, if dampening feedbacks dominate, the future average climate will not be affected much, even by high CO_2-emissions.

Another interesting observation is that it is not appropriate to consider the hierarchist as a middle-ground perspective. The utopian results with the CYCLES model show that the hierarchist is not always in the middle. The hierarchist utopia shows the highest atmospheric concentration of CO_2. An explanation for this is that the hierarchist perspective is more pessimistic than the individualist concerning the development and penetration of energy-efficient technology and the market-mechanism with regard to alternative energy sources. On the other hand, the hierarchist does not expect severe life-style changes as the egalitarian perspective does. As a result the CO_2 emissions, and thus the atmospheric CO_2 concentration, in the hierarchist utopia are higher than in the two other utopian images of the future.

see over »

28 This assessment builds upon van (Rotmans and van Asselt 2000 (in press)), which is a further assessment of experiments reported in (den Elzen et al. 1997).

BOX 1

Global change and sustainable development[29]

Some of the more illustrative dystopias are presented in Figure 11. The most catastrophic future is the one in which an egalitarian worldview is combined with an individualist management style. In this case, the world would be confronted with significant changes in the global climate and, partly as a consequence, with serious food and water shortages. Life expectancy only increases slightly compared to the present world average, and the resource base is squandered. The main conclusion is here that if policy-makers want to reduce the risks of such a catastrophic future, they should pursue an egalitarian policy that aims at a high quality of human life (in particular health care and education for women), carbon tax, R&D programs on renewable resources and small-scale technology, water taxing, public water supply policy, and eco-forestry and eco-agriculture policies. However, analysing the egalitarian management styles in general, it is obvious that they contain the potential risk of reducing socio-economic benefits in terms of a lesser improvement of quality of life and human health. An interesting observation is further that detrimental climate impacts are absent in a future where the world functions according to the individualistic world view and egalitarian policy measures are carried out. The counter-intuitive result means that an egalitarian government in combination with an adversative world view (that of the individualist), turns out to be more effective in terms of socio-economic and environmental prosperity than in case of the egalitarian utopia.

What kind of policy-relevant insights do the simulated utopian and dystopian futures teach us? At recent UN summits on sustainable development issues (e.g. UNCED in Rio, 1992; the population and development summit in Cairo, 1994; the Earth Summit in New York, 1997), developed countries argued that developing countries should curb their population growth in order to reduce the world-wide environmental pressure. Expressing this pressure in the form of an anticipated climate change, our scenarios show that this dogmatic reproach is rather simplistic. Figure 7 shows five futures where the population number exceeds 10 billion (about a doubling of the present number), while the rise of global-mean temperature is less than 2 degrees Celsius. On the other hand, however, the developing countries' argument that west-

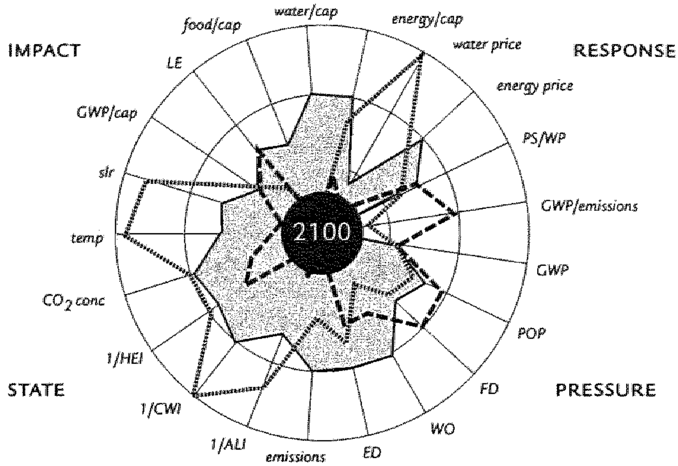
see over »

29 This assessment is derived from (Rotmans and van Asselt 1999; 2000 (in press)), which is an assessment of the experiments reported in (Rotmans and de Vries 1997).

BOX I

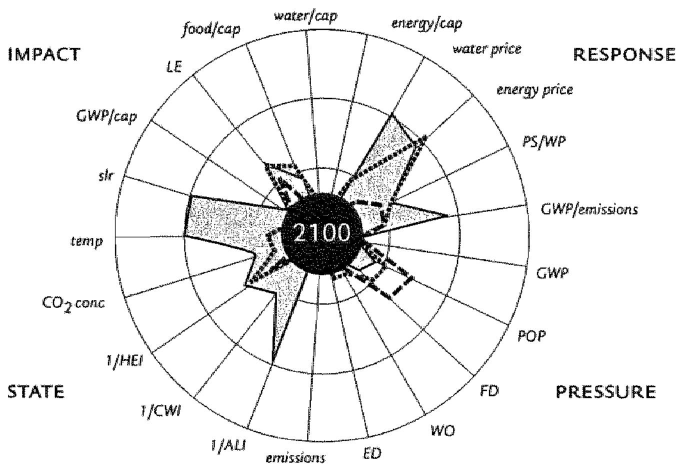
MANAGEMENT STYLE
hierarchist

WORLDVIEW
hierarchist
egalitarian
individualist



MANAGEMENT STYLE
egalitarian

WORLDVIEW
egalitarian
hierachist
individualist



MANAGEMENT STYLE
individualist

WORLDVIEW
individualist
hierachist
egalitarian

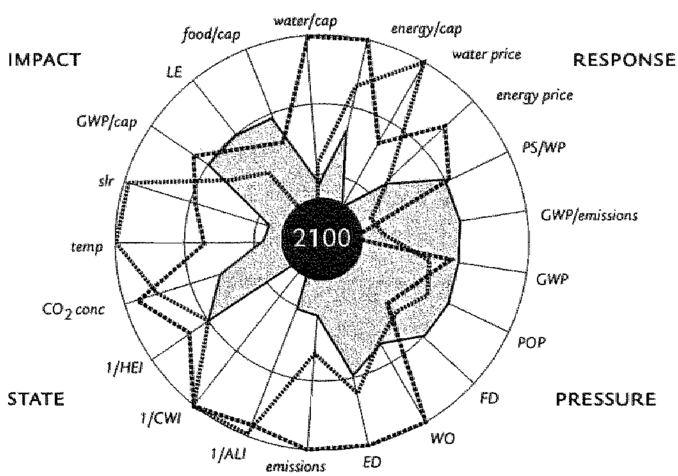


FIGURE 11 Dystopian experiments represented by means of multi-star

see over »

BOX 1

ern lifestyle of overconsumption, indulgence and dissipation will inevitably plunge the world into a climate catastrophe is also oversimplified. Analysing the whole range of scenarios, shows that a future in which high GWP levels and luxury diets are combined with small climate changes (i.e. the individualistic utopia) is as plausible as a future world that faces both an environmental and socio-economic catastrophe (i.e. the dystopia with an individualistic management style and an egalitarian world view). In sum, the way to sustainability is not simply a choice between population and consumption as it is quite often phrased in the policy makers' realm. Our assessment reveals further that:

- the individualistic management style (i.e. market-oriented health policy, market pricing of water, high-tech R&D programs, protection of industrial sectors, and intensive agriculture, incl. genetic engineering) is the most risky in terms of climate risks as global-mean temperature and sea level rises.
- the hierarchist management style (i.e. family planning, selective health care policy (e.g. cure), moderate R&D programs for energy efficiency and new energy supply options, reforestation policy and agricultural planning) is least effective when evaluated in terms of improvements in resource efficiency.
- the observation that a transition to a less energy-intensive society is foreseen in the egalitarian and individualist utopia reveals that both a market-driven energy policy and a strict carbon-tax policy are potentially promising strategies to support such a shift. This result again underlines the importance of developing less energy-intensive technologies.
- the egalitarian management style (i.e. investments in human quality, taxing systems, R&D programmes on new technologies, and eco-friendly policies) is the most effective in curbing population growth, although it should be noted that this is at the expense of a significant improvement in life expectancy.

The major conclusion is that a global catastrophe does not appear to be imminent. But the projections generated with the TARGETS model clearly indicate that pursuit of current trends is most unlikely to result in a sustainable future whatever the perspective is. Our major insight referring to the fundamental controversy on global change is that it seems possible to provide a future world population with more food per capita than the current level and that there are several potentials for a transition to a less energy-intensive, but healthy economy. It is most likely that the global popu-

see over »

BOX 1

lation on average will live longer and healthier than today, which, however, does not mean an equitable distribution of health. The resource base is at risk, but there are many promising ways to safeguard the environment for future generations. However, there is a serious risk that water may become scarce[30], even at the global level.
In sum, this assessment indicates huge potentials for rather robust policies, characterised by a balance in safeguarding natural resources, a transition towards clean and less resource-intensive technologies, while providing the world population with enough food and clean water, fulfilling the conditions for a healthy world population.

A more qualitative way to evaluate the riskiness of strategies, is to evaluate outlooks of the future in terms of the following risk questions:

- what might happen?
- how plausible?
- imaginable consequences?
- how likely?
- what can we do about it?

These risk questions can also be used to deepen the analysis in case the previous approach to risk analysis has been followed.

In the above, we have pretended as if in all cases the risk indicator can be unambiguously be determined. This may be the case in some cases, however in the majority of the cases the risk definitions differ. That means that the evaluation of desired/undesired prospects is perspective-dependent: which scenarios seem to be most desirable and which are considered to be nightmarish is in many cases perspective-

perspective **image of the future**	*Perspective A*	*Perspective B*	*Perspective N*
scenario I	++	+	++
scenario II	+	++	--
scenario III	-	--	-
scenario z	--	-	+

LEGEND (++ most desirable, + desirable, - not preferred, -- unacceptable)

TABLE 7 Evaluation of prospects according to perspective

30 See (Hoekstra 1998; Hoekstra et al. 1997) for a more extensive discussion of the water dimension of the utopian and dystopian futures.

dependent. So pluralism may be also explicitly prevalent in this step: evaluation and weighing of the scenarios is done for different perspectives (see Table 7). The above approaches to risk analysis can then be used for each perspective to arrive at perspective-based estimates of prospects.

Using this perspective-based evaluation of the scenarios, we can assess whether there are scenarios, and thus strategies, that are to a more or less extent promising to all perspectives (in Table 7 scenario I), and which are considered to be unacceptable by the majority of them (in Table 7 scenario III). In assessing and comparing the various risk judgements, risk comparisons in terms of relative riskiness can be useful in this assessment phase (see Box 2 for appropriate risk comparisons[31]).

BOX 2 Risk comparison schemes

- THE SAME RISK AT TWO DIFFERENT TIMES

  "The risk associated with x is around y% less than *z* years ago"
- WITH A STANDARD

  "Exposure to x is well below the level that authoritative organisation *y* considers safe".
- DIFFERENT ESTIMATES OF THE SAME RISK

  "Our best estimate of the risk is x, whereas the worst case risk estimate we have calculated is y, on the basis of methodology 2 we arrive at estimate z, whereas that of organisation ABC is *v*".
- THE RISK OF DOING SOMETHING VERSUS NOT DOING IT

  "If measure *a* is implemented the risk will be x, whereas if not, the risk will be *y*."
- ALTERNATIVE POLICY OPTIONS

  "The risks associated with option *a* is x, and the risk associated with option *b* is *y*".
- THE SAME RISK AS EXPERIENCED IN OTHER PLACES

  "The most serious problems associated with x have been encountered in place *A*, while here the risk is only about *y*% from that in *A*".
- RISK FROM ONE SOURCE OF A PARTICULAR NEGATIVE EFFECT WITH THE RISK FROM ALL SOURCES OF THAT SAME ADVERSE EFFECT

  "The risk on a posed by x is roughly *y*% of the total risk on a in this community".

31 See Chapter 3B for source and motivation.

A comparison and confrontation of the various perspective-based scenarios, hence assessments of the future, enable to estimate what is possible or impossible, and what is desirable and what is not. Such an evaluation provides the basis for exploring whether insights about the complex issue can be discerned that hold in view of the different perspectives. In doing so, we can conclude whether the controversy or dilemma under concern involves significant risks, without adopting a specific risk definition. Risk in this case means that one or more perspectives, i.e. participants in the societal debate, are convinced that this controversy or dilemma may inhibit undesirable and unacceptable futures, and that the state-of-the-art knowledge does not allow excluding these futures.

This classification of the future outlooks in terms of risk allows us to evaluate which options and strategies seem to be most robust in terms of appearing to trigger a future that is acceptable, or even favourable, to different perspectives and in terms of avoiding those that one or more perspectives consider to be highly undesirable (see Figure 12). In this way, robust recommendations can be deduced. In the hypothetical outcome illustrated in Figure 12, decision 3 would be considered to be the most robust decision in view of the uncertainties and risks considered, while decision 1 is the most controversial considering the spread of riskiness estimates. In the latter case, controversy and disagreement is to be expected.

	policy option/ strategy					
	low risk					*high risk*
decision 1	•		•		•	•
decision 2		•••	•			
decision 3	•••		•			
decision 4				••	•	•
decision 5		•	•	•	•	

LEGEND Each bullet represents a scenario involving the particular decision

FIGURE 12 Assessment heuristic for robustness analysis

Another feature of robustness is that the recommended strategies and options are flexible enough to be changed or reversed if new insights emerge. For this reason it is important which uncertain, but imaginable, developments potentially could undermine the effectiveness and adequacy of the proposed strategies and options. In other words, which signals will in the future make evident that we have to adapt the chosen strategy? This analysis will yield the salient uncertainties from a decision-makers viewpoint. It will indicate which uncertainties constitute policy risks. In this way, the value of uncertainty is made tangible to decision-makers. Some uncertainties will be resolved through time. An assessment in the way as sketched in this Chapter enables to indicate by which actual development it is necessary to adapt the chosen strategy. In doing so, the integrated uncertainty management and risk assessment can yield signals for sequential decision-making.

Central in this step is to explore how easy or how difficult it will be to change the proposed strategies. Robustness thus implies an evaluation of the flexible character of the recommended options and strategies. The consequence of this analysis will be that notwithstanding the recognised promises, some strategies are rejected, while others are transformed. Furthermore, the assessment of options and strategies may result in the creation of innovative strategies and options not considered so far. In order to test the robustness of these transformed and newly broad up strategies, it is necessary to test these against the possible futures. This implies a focused iteration of the previous steps.

The idea is that by means of putting uncertainties, scenarios and risks in perspective, robust insights pertaining to the formulated dilemma or controversy can be deduced. The outcomes associated with this last stage are different types of robust recommendations that are sensible and understandable to decision-makers. The following types of recommendations are imagined:

- strategy *x* is more robust than strategy *y*, in the sense that it scores lower on more risk indicators
- strategy *x* seems to be a robust way to reach policy target *a*
- the most risky future (i.e. the most undesired scenario) associated with strategy *x* is a future in which ..., while the least risky future (i.e. the most acceptable scenario) is...
- a future in which ... is highly impossible (i.e. outlooks beyond the variety of scenarios)
- compared to doing nothing strategy *x* *decreases/increases* the risk of ...
- policy option *1* seems to be most effective (i.e. least risky) if accompanied by the following policy options.../embedded in the following strategy ...
- combining policy option *1* with policy option *2* *increases/decreases* the risk of ...
- the following uncertain issues are crucial in addressing the controversy/dilemma: ...

As the above list indicates, there are different ways to robustness. In case of agreement, i.e. the various valuations of the strategy result in a rather unequivocal opinion about the riskiness of the strategy, the robust conclusion involves a recommendation in terms of a recommendable strategy or a strategy that should be excluded from consideration. In case of disagreement, i.e. the riskiness estimates cover the whole range, the robust conclusion involves a kind of warning: this particular strategy is likely to involve a clash of opinions. The advantage of the integrated analysis is that it may enable to focus the debate by indicating what are the salient uncertainties and what are the key risk dimensions associated with this strategy. Analysis of the outlooks may also yield signals for decision-making. It should be noted that such an assessment is not a trick. The ideas presented in this Chapter enable to structure a creative process. The framework cannot guarantee the actual quality of the recommendations. The quality of the recommendations is heavily dependent on the quality of the people of involved (i.e. they should be able to use the framework for focussing and utilising their brainpower) and the actual process[32].

The major advantage of pluralistic integrated uncertainty management and risk analysis is that the level of robustness of the recommendations can be motivated, due to the comprehensiveness of the analysis, i.e. considering salient uncertainties and a wide variety of legitimate interpretations of the uncertainties which assessments are evaluated against different risk factors.

6. Quality assessment

Quality assurance[33] is central to integrated uncertainty management and risk analysis. To that end, it is necessary to re-analyse the recommendations. It is important to check again whether the crucial uncertainties and the critical risk factors pertaining to the recommendations have been adequately considered in the assessment process. It may be possible that uncertainties or risk factors that did not seem crucial in considering the broader complex issue are crucial now we have come down to particular conclusions. If such critical uncertainties or risk factors are discerned, it is important to test the recommendation against these uncertainties and risk factors. This can be done by a quick iteration of the assessment process. This procedure implies testing if uncertainty was treated adequately, or whether there are crucial uncertainties or risk factors, known or imaginable, which are undermining the robustness of the recommendations.

32 See also Chapter 2.
33 See also Chapter 2.

In view of quality assurance, it is furthermore important that the assessment does not stop with recommendations for decision-making. Transparency about the analytical and methodological quality of the assessment is needed in order to allow clients themselves to make an informed judgement about the quality of the assessment. Building upon Chapter 2, it would therefore be recommendable to accompany the conclusions with a summary containing a review of the credibility of the data sources, the disciplinary quality of the used knowledge elements, the degree of interdisciplinarity of the assessment process, incl. the level of collaboration with disciplinary experts, and the level of participation[34]. For the first two issues the pedigree-qualifications proposed by Funtowicz and Ravetz[35] can be used (see Table 8).

code	quality of model/ theoretical structure	quality of data	degree of peer acceptance
4	Established theory	Experimental data	Total
3	Theoretical model	Historical/field data	High
2	Computational model	Calculated data	Medium
1	Statistical processing	Educated guesses	Low
0	Definitions	Uneducated guesses	None

TABLE 8 Pedigree matrix

In summarising the other issues the following questions can be useful:

- who were involved and how were they selected?
- at what phases in the process and with what intensity?
- what has been done with the input of interdisciplinary experts and non-academic participants?
- do they recognise themselves in the assessment?

The responsible investigators can do such an assessment of the quality[36] of the process of integrated uncertainty management and risk analysis. However, it is advisable to involve peers or even an extended peer community in this effort. The output of this quality assessment involves *qualified* recommendations, i.e. recommendations of which the clients can also trace the robustness.

Apart from recommendations that aim to facilitate decision-support, it is advisable to explore what scientific insights can be deduced from the integrated uncer-

34 See (Rotmans and van Asselt 2000 (in press)) in which we report a first attempt to perform such a quality assessment as the final step in the assessment process.

35 (Funtowicz and Ravetz 1990). See also Chapter 3A for a summary of these pedigree qualifications.

36 Compare Chapter 2.

tainty management and risk analysis. Which salient risky uncertainties and uncertain risks would benefit from additional scientific research? In this way, the assessment can be used to set priorities for disciplinary and interdisciplinary research. This is also relevant in view of the robustness of decision-making, because it enables scientists to anticipate on uncertain risks and risky uncertainties that are crucial for *future* decision-making. Research always takes time. The consequence is that if research is initiated at the moment a controversy or dilemma is a topicality, it is to be expected that either time pressure corrupts the research results, or that the results arrive too late, which make them irrelevant to decision-making. Integrated uncertainty management and risk analysis can provide a basis for systematically anticipating future controversies and decision-makers' dilemmas. The proposed approach to decision-support can be considered as an attempt to escape the time-quality wringer that constitutes a serious threat to the viability of (supply-driven) decision-support. Integrated uncertainty management and risk analysis can therefore also be considered an investment both in the future analytical and methodological quality by creating a time-span for research, and in the usability and timeliness of future supply-driven decision-support. In this way, supply-driven Integrated Assessment would systematically build on lessons learned.

7. Conclusions

Compared with the analytical steps that are considered to be essential in Integrated Assessment (see Chapter 2), it can be concluded that the above framework for pluralistic integrated uncertainty management and risk analysis provides a methodology for performing the following activities:

- selection of salient uncertainties and policy risks
- trend analysis and evaluation
- assessment of options for decision-making

Integrated uncertainty management and risk analysis is thus not a full Integrated Assessment. On the other hand, the above comparison implies that in principle the generic framework as presented above can be added to the IA toolkit.

In the previous Chapter the requirements for an integrated approach to uncertainty management and risk analysis have been studied. Building upon this analysis, a generic pluralistic framework was proposed in this Chapter. In this framework new ideas were blended with steps associated with uncertainty management and those comprised in risk analysis. As this framework complies with the hypotheses that are theoretically tested in the first part of this thesis, the proposed framework for integrated uncertainty management and risk analysis is theoretically sound. It was attempted to be as concrete as possible in describing the various steps by indicating how concepts, tools and methods can be used to implement the framework into actual decision-support.

The observed pluralism about pluralism and the state of the art in social sciences prevent that pluralistic assessment is a straightforward exercise. Due to the essential differences between the different perspectives on pluralism, it is fundamentally impossible to arrive at one set of perspectives that can be used by all pluralistic endeavours. Furthermore, the state of the art does not offer an extensive overview of the various paradigms prevalent within the science. There is no accepted typology of social-cultural perspectives. Nor is a specific method available that enables to derive perspectives from a participatory process in a systematic manner, and there is neither a categorising of societal interaction patterns that is in accordance with empirical analysis of societal interaction patterns pertaining to uncertainty and risk[37]. So neither a particular set of perspectives for each of the pluralistic schools of

37 The latter kind of research is under way, see for example the PhD research on risk controversies carried out by Ruth Mourik, faculty of Cultural Sciences, University of Maastricht.

thought, nor general methods to yield them can be recommended. This implies that any pluralistic approach is vulnerable, because of the inevitable lacked credibility of any perspective scheme used. Hopefully, this problem will be resolved in the course of time due to advancements in social sciences in general and in social studies of science in particular.

On the other hand, in view of the shared disapproval of positivism, every pluralistic endeavour whatever the level of sophistication, deserves credit. The consequence of recognising that uncertainty and risk are inevitably pluralistic is that it became our duty to put the notion of pluralism into practice. The first steps have been designing a generic framework for pluralistic integrated uncertainty management and risk analysis, and proposing various legitimate and appropriate ways to apply this generic framework in a way internally consistent with the different perspectives on pluralism. The next step is to test and apply this theoretically sound methodology into actual decision-support.

From the description of the generic framework for integrated uncertainty management and risk analysis, it is clear that it is a demanding and time-consuming effort, even in case the most pragmatic route is chosen. We are convinced that it is worthwhile to invest intelligence, effort and time. First, because it is consistent to perform scientific decision-support in a way that is epistemologically right and thereby more valid. And second, because evaluated from a scientist perspective it in principal enables to improve the quality of decision-support. Radical uncertainty and strategic risk constitute the leitmotiv of the proposed framework. Due to this feature, the pluralistic framework for integrated uncertainty management and risk analysis in principle seems promising for decision-support on complex issues.

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Exploring the need for PRIMA

a case-study approach

The primary aim of this thesis is to propose a new approach to decision-support that is practically feasible as well as theoretically sound. We therefore want to explore in a real-life context whether the PRIMA framework, outlined and theoretically underpinned in the previous part of this thesis, has something to offer to the practise of Integrated Assessment. The aim of this practical test is twofold. First, we want to evaluate whether there is a potential need for a new or complementary approach to uncertainty management amongst practitioners. To that end, it is proposed to perform a retrospective case study involving previous decision-support on complex issues. Second, we want to explore the potential added value of the proposed approach compared to present assessment strategies for decision-support. Therefore, the retrospective analysis will be followed by a prospective study that enables to explore the practical feasibility of the PRIMA-approach in a real life context. To do so, it is necessary to set up a mutual learning process, in which we, together with the analysts, explore whether and how the PRIMA-approach is applicable in actual decision-support on complex issues.

1. Selection of the case

The ideal case is a decision-support practice that involves a series of comparable assessments produced on an ongoing, structural basis. Such a case would enable to carry out a retrospective analysis and explore the feasibility of the PRIMA-approach in the current assessment. An important pre-condition is that the analysts and the institute performing the assessments are interested in working with us. In the context of the present thesis, a decision-support endeavour that is explicitly meant to be an integrated assessment would be preferred as a case.

As argued in Chapter 2, Integrated Assessment is one of the more recent approaches to decision-support. That implies that it is not to be expected that an abundance of potential cases satisfies the above conditions. Taking the above into consideration, cases that can be thought of are, for example, the climate assessments of the Intergovernmental Panel of Climate Change (IPCC) and the Environmental Outlooks produced by the Dutch National Institute of Public Health and the Environment (RIVM). The IPCC process is very complex, involving many high-level scientists who are spread all around the globe. In principle it would have been possible to carry out a case study on the previous IPCC assessments. However, it would have been clearly beyond the scope and the ambitions of this thesis to set up a mutual learning process with the IPCC, or even with one of the IPCC working groups.

A case study on the Dutch Environmental Outlooks seems appropriate and more feasible. RIVM is considered to be one of the pioneering institutes in Integrated Assessment, and the institute characterises its work as being Integrated Assessment. The National Environmental Outlooks aim to be integrated assessments of the future with the explicit purpose to inform and support Dutch environmental policy-making. Approximately every four years, RIVM presents such a long-term assessment of the environment to the Dutch government. Since 1996, RIVM is by law appointed to serve as the Environmental Planning Agency, and the production of the Environmental Outlook is one of the official structural tasks RIVM has to fulfil. The first Environmental Outlook was published in 1988[1]. RIVM is currently preparing the fifth National Environmental Outlook that will be published in the course of 2000.

The Environmental Outlooks aim to provide an assessment of the environmental and health impacts in the Netherlands associated with the future state of the environment that results of a particular development of societal pressures in terms of economic growth, demographic developments, and consumption and production patterns. RIVM attempts to anticipate future developments in order to provide recommendations for environmental policy. The issue addressed in the Environmental Outlooks is complex[2], due to the fact that not one problem is addressed, but a tangled web of related issues, multiple dimensions are involved - both environmental, economic, socio-cultural and institutional factors and processes matter - and the underlying processes interact on various scale levels and on different temporal scales.

1 (RIVM 1988)

Taking this complex character into account, it is certain that uncertainty pertains to the assessment. This feature combined with the explicit policy support purpose of the Environmental Outlooks makes these RIVM assessments an interesting case in the light of our objectives.

RIVM is considered to be one of the cradles of Integrated Assessment. Jan Rotmans developed the pioneering Integrated Assessment model for climate change, IMAGE, at RIVM. The IMAGE model is still further developed and maintained by RIVM. 'Concern for Tomorrow', RIVM's 1st Environmental Outlook, was as one of the first integrated environmental assessments in Europe that actually informed decision-makers. The Environmental Outlooks served as an example for the Global Environmental Outlook (GEO), produced under auspices of the United Nations Environment Programme (UNEP)[3]. RIVM played an important supportive role in both GEO-1 and GEO-2. Also the European Environmental Assessments[4] produced by the European Environment Agency were inspired by RIVM's assessment template. RIVM's Environmental Outlooks fulfilled a model function in integrative decision-support. Because of this, the case study on the Environmental Outlooks is likely to yield insights relevant to other decision-support agencies as well.

The Environmental Outlooks constitute a series of integrated assessments that in principal allows for both a retrospective case study and a prospective analysis. The latter then would involve testing the PRIMA-approach interactively in the ongoing 5th Environmental Outlook process. Last, but certainly not least, RIVM's management had an expressed, but cautious interest in exploring alternative approaches for dealing with uncertainty in their assessment practise[5]. As said before, such an a priori interest in co-operation is a necessary pre-condition for testing the PRIMA-approach in the practise of decision support.

In line with the above considerations, we decided to carry out a multiple-case study on the Dutch Environmental Outlooks produced by RIVM. In this case study we want to analyse how uncertainty is managed in the previous environmental assessments (vertical analysis) and whether, and if so how, the approach to uncertainty has changed over time (horizontal analysis). In general, case studies are the preferred strategy if 'how' and/or 'why' questions are being asked about a contem-

2 Compare Chapter 1
3 (UNEP 1997)
4 (EEA 1995)
5 As is revealed by their interest in sponsoring the PhD research underlying this thesis and by the following remark in (RIVM 1999a): "See van Asselt and Rotmans (1995) who provides a promising approach for uncertainty analysis.

porary case over which the investigator has little or no control[6]. Building upon this retrospective, empirical analysis, we would like to explore whether there is a need for an alternative approach to uncertainty management.

The aim of the prospective phase is to apply the PRIMA-approach in the practise of the 5th Environmental Outlook. The aim of this phase is to explore together with the practitioners in an interactive manner whether the PRIMA approach can be of their use. RIVM did not commit itself beforehand to adopt the approach, but it was willing to experiment with it as part of their internal learning process. In this phase, we are not primarily observing and analysing. In a certain way, it acts as a kind of change agent[7]. The major questions that are to be addressed in this phase are whether the PRIMA-approach is practically feasible, and whether, and in what way, it is considered to be useful by the practitioners.

The ultimate aim of the Environmental Outlook case is to analytically generalise from the case-specific conclusions to general recommendations concerning the practical feasibility of the PRIMA-approach as a new methodology for Integrated Assessment.

In this Chapter we will concentrate on the retrospective research. To that end, we will first introduce both RIVM and the Environmental Outlooks in some more detail than has been done so far to provide a sound description of the research context and subject. In the second part of this Chapter, the research methodology is described. The actual case study is reported in Chapter 7.

2. RIVM[8]

RIVM, the National Institute for Public Health and the Environment, is both a researche institute and a governmental planning agency that has the task of supplying the Dutch government with the information it requires for its health and environmental policies. RIVM characterises its activities with the one-liner "research for human and the environment". Science and research lie at the heart of all RIVM's activities. RIVM aims to channel its expertise into different phases of environmental and health policy: alerting, controlling and consolidating. Eighty percent of its research concerns both structural and ad-hoc advise and reporting to the Dutch government.

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6 (Yin 1994).

7 See Chapter 1 on the adopted research perspective.

8 This section builds upon (van Asten 2000). Major documents on RIVM used in the following description are: (Van Zon 1990) and the most recent leaflets about RIVM and its division 5 (Environmental Research) (www.RIVM.nl)

Its alerting task implies that RIVM initiates research on topics that may become important in the future. The latter type of research involves twenty percent of its budget.

RIVM has a history that traces back to July 1909, when the Central Laboratory for Public Health was set up. This laboratory came under the Ministry of Internal Affairs. Its aim was to perform policy-relevant research on public health. In the early days, 13 people were working in this national lab. RIVM as it currently exists is the result of a history of mergers. In 1934 the Central Laboratory for Public Health merged with the Public Serological Institute into the National Institute for Public Health (RIV). This was not a big step in practice, because the two institutes were already located on the same area in Utrecht. The new institute counted about 75 employees. In the 50's, a new building was realised with help of the Marshallplan, in Bilthoven, where RIVM is still located. After 1950 the number of staff increased rapidly. In December 1950, RIV) employed 200 people, in 1957 this number was more then doubled to 500. In October 1965 the 1000th employee was welcomed. In 1984, RIV) merged with the Institute of Waste research (IVA) and the Public Institute for Water Supply (RID) into the National Institute for Public Health and the Environment (RIVM). At the time of the merger, the institute employed about 1100 people. The institute came under the Ministry of Welfare, Public Health and Culture (WVC), but it had the explicit duty to carry out research for the Ministry of Regional Planning and the Environment (VROM). At the moment, RIVM has about 1700 employees.

Because we focus on RIVM's environmental research and services, it is interesting to explore how RIVM became the governmental institute on the environment. The Central Laboratory for Public Health was a medical laboratory. However, apart from strict medical research, from the beginning on questions were addressed that nowadays would be characterised as environmental pollution issues, such as the health risks associated with water pollution due to industrial wastewater, and the quality of surface water in relation to swimming. The Serological Institute involved investigating samples of patients, control of food and medical drugs, and studies on the bacteriological pollution of water and air. In the Institute for Public Health that resulted out of the merger of these two institutes, the chemical-pharmaceutical department had the explicit task to estimate residues of insecticides and pesticides in relation to environmental pollution. In the late 30s, this research activity evolved into a research programme on the pollution of soil, air and surface water, although with emphasis on surface water.

Where RIVM's precursor in the pre-war period, during the Second World War and the early post-war period suffered from crisis, budget cuts and shortage of staff, after the 1950s ample resources were available. In addition the research attitude changed. The research activities became increasingly multidisciplinary and the attitude got increasingly society-oriented. In 1955, a separate laboratory within RIV for environmental research was established, i.e. the laboratory for research on soil, air and water. In the late sixties the political emphasis, both nationally and internationally, shifted to environmental pollution. As a response, RIV's board of directors argued that a coherent programme was needed to enable a systematic protection of the soil, water and air against microbiological, chemical and physical pollution. So far, research on the environment was carried out in the context of public health research. In the late sixties and the early seventies, environmental research got a more autonomous position within the institute. In this context, the institute formulated three decision-support instruments it aimed to develop: i) an overview of the type and degree of the pollution, ii) a continuous monitoring of pollution sources, and iii) an integrated approach to environmental pollution in the short and long term. To that end, measuring nets were issued, with an emphasis on the registration of water and air pollution. The establishment of the Public Institute for Public Health *and* the Environment by Royal Decree marked the evolution the institute has gone through.

Since 1984, it has been the explicit duty of RIVM to collect environmental data, to conduct research on the quality of the environment, and to inform the Dutch government. RIVM's task is to identify and assess the state of the environment, the underlying processes, and the expected development of the environment, both in the short and in the long term. The first Environmental Outlook, i.e. 'Concern for Tomorrow', is considered to be a milestone in the realisation of RIVM's environmental mission. This 1st Environmental Outlook served as the scientific basis for the first National Environmental Policy Plan (NMP), which appeared in 1989[9]. Since 'Concern for Tomorrow', the Environmental Outlooks play a key role in Dutch environmental policy-making.

Since the publication of 'Concern for Tomorrow', RIVM was in the political practise considered as the governmental environmental institute, the counterpart of the Central Economic Planning Agency (CPB) and the Social-cultural Planning

9 (VROM et al. 1989)

Agency (SCP). In 1996, RIVM got the legal status of environmental planning agency[10], i.e. being the official governmental decision-support institute on environmental policy. One task assigned to RIVM in this capacity is the production of the National Environmental Outlooks in a four years cycle. Under ordinary circumstances, this means that each government receives one Environmental Outlook during their reigning period. Besides, RIVM produces every year an Environmental Account (in Dutch: *Milieubalans*). The Environmental Outlook is a long-term environmental assessment, while the Environmental Account is a detailed description of the current state-of-the-environment. While the Environmental Outlook serves as input to strategic policy-making, the Environmental Account has an evaluative aim. A recent development is that RIVM is also responsible for the Nature Outlook (in Dutch: *Natuurverkenningen*)

At the moment 320 employees work in the environmental division, which comprises eight sectors. In Figure 1, the current organisation structure is provided. The department 'Environmental Assessment' (MNV) co-ordinates the environmental assessment activities, including the Environmental Outlooks, while the following laboratories are contributing to the analyses: the Laboratory for Waste Materials and Emissions (LAE), Soil and Groundwater Research Laboratory (LBG), Laboratory for Water and Drinking Water Research (LWD), Laboratory for Eco-toxicology (ECO), Department for Environmental Information Systems (CIM), Laboratory of Exposure Assessment and Environmental Epidemiology (LBM), Air Research Laboratory (LLO), Laboratory for Radiation Research (LSO), Centre for Substances and Risk Assessment (CSR), Laboratory for Health Effects Research (LEO), and Inspectorate Research and Environmental Incident Services (IEM).

In the beginning, the Central Laboratory conducted researches for both governmental organisations and non-governmental organisations, in that time especially medical organisations, hospitals or individual doctors. Nowadays, RIVM only serves the government, especially the ministries of VROM (Housing, Physical Planning and Environment) and of WVC (Welfare, Public Health and Culture) and it supports international organisations such as WHO (World Health Organisation), EU (European Union), UN (United Nations with special attention for the United Nations Environmental Programme (UNEP) and UNICEF) and the World Bank. RIVM's research activities have always extended beyond the national borders; people from RIVM actively participate in international research communities.

10 In Dutch: *Milieuplanbureau*

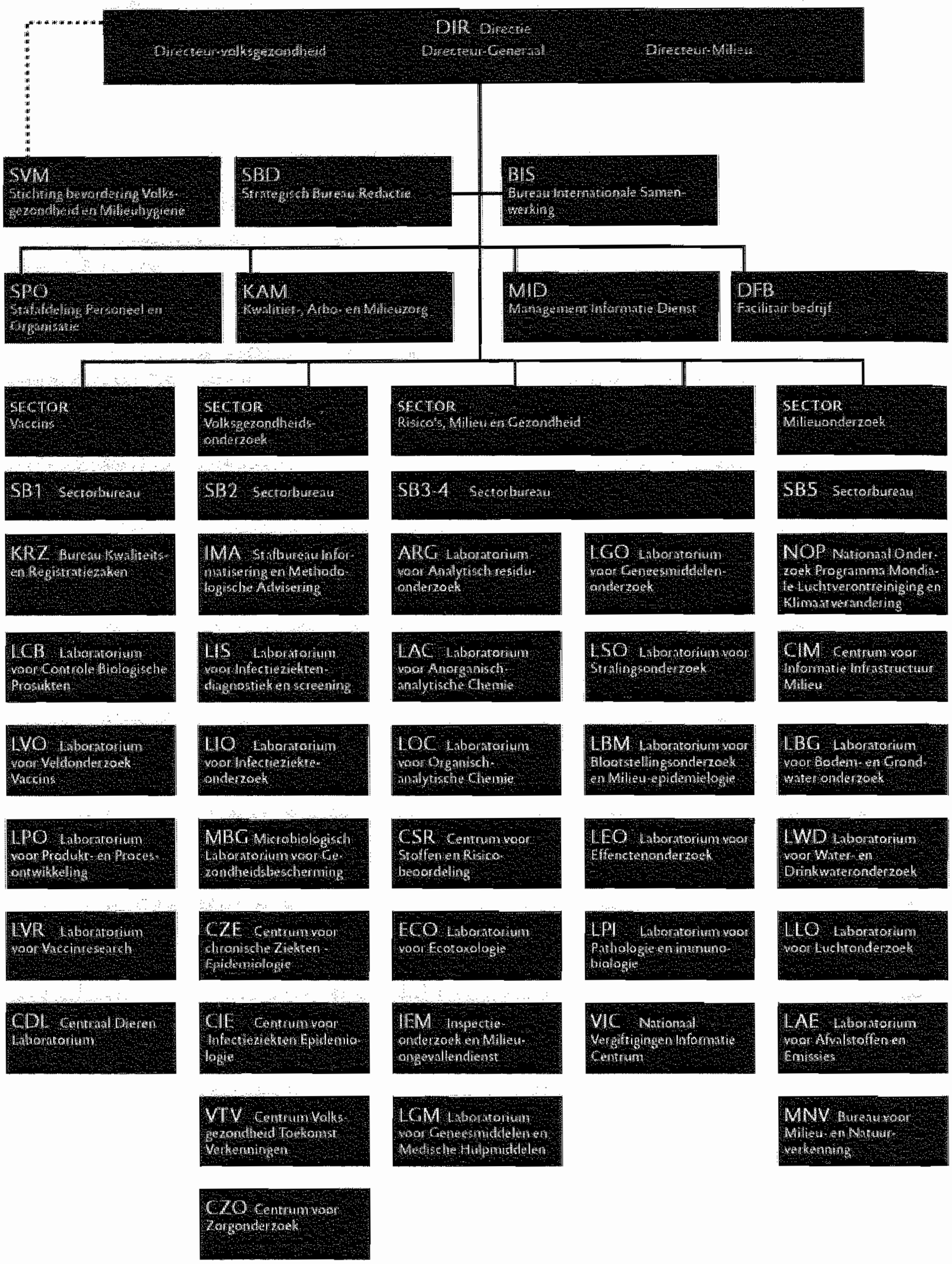

FIGURE 1 Organisation structure of RIVM

3. RIVM's Environmental Outlooks

The first Environmental Outlook was published in 1988 and was named 'Concern for Tomorrow'[11]. Its main message was: "the environment is getting worse at all scale levels despite all the efforts". This was a shock for the Dutch politicians, but also for society as a whole. In 1991, the second assessment, i.e. the 'Environmental Outlook 2 1990-2010'[12] was produced, which is primarily an update of the first one: prior to the second national environmental policy plan, the government asked RIVM to produce a new environmental outlook that assessed the proposed environmental policies. The third Environmental Outlook[13], published in 1994, indicated the effectiveness of policy plans in relation to the environmental quality objectives as formulated in the first Environmental Policy Plan. The most actual Environmental Outlook, i.e. the 'Environmental Outlook 4 1997-2020'[14], was produced in 1997. RIVM is currently preparing the fifth National Environmental Outlook, which will appear in the course of 2000.

The aim of a National Environmental Outlook (NEO) is to provide an assessment of the environmental and health impacts in the Netherlands associated with the future state of the environment that results of a particular evolving of societal pressures in terms of economic growth, demographic developments, and changes in consumption and production patterns. An Environmental Outlook thus describes the cause-effect chains relevant to environmental change. It furthermore involves evaluation of adopted and proposed Dutch environmental policies. With the Environmental Outlook, RIVM attempts to anticipate future developments in order to provide recommendations for policy. One of its aims is to evaluate whether the future environmental targets can be reached by the current policy. The Environmental Outlooks are therefore long-term assessments. In general, the time-horizon of an Environmental Outlook is 25 years. Because an Environmental Outlook ultimately serves as an input to the preparation of the National Environmental Policy Plan[15], its spatial focus is the Netherlands.

While knowledge accumulates over time, the relevant cause-effect relationships can be described in more detail and more comprehensively in the successive Environmental Outlooks. Looking backward, this is in general the case, except for the 3rd

11 (RIVM 1988)
12 (RIVM1991)
13 (RIVM 1993)
14 (RIVM 1997)
15 In Dutch: *Nationaal Milieubeleidsplan*

Environmental Outlook that focuses on the social developments and emissions, i.e. the starting-point of the environmental causal chains. The first two Environmental Outlooks are structured according to scale. The basic conviction behind this structure was that each scale level has its particular environmental problems. A typical global issue is climate change, acidification is a continental problem, pollution of the rivers pertains to a fluvial scale, waste disposal is a regional issue and noise and odour nuisance are examples of local problems. The 3rd Environmental Outlook is structured according to environmental theme, such as acidification, eutrophication, dispersion, disposal, nuisance, desiccation, and squandering. The 4th Environmental Outlook aims to integrate the various aspects of environmental quality. Instead of a scale-based or theme-based structure, this assessment is structured into three types of environment, i.e.: i) urban area, ii) green area (which involves forests, nature reserves, recreation areas, agricultural area and ground water reserves) and iii) blue area, i.e. wet nature, like lakes, rivers and swamps.

To explore the next 25 years information is needed concerning possible future developments of particular exogenous factors. Such a relevant exogenous uncertainty to the Environmental Outlooks is economic development. The first Environmental Outlook was based on one possible economic future, i.e. the Medium Growth scenario developed by the Central Planning Office (CPB)[16] in 1985. This scenario can be considered a surprise-free extrapolation of current trends. For the 2nd Environmental Outlook, the Medium Growth scenario was updated by means of actual data. The 3rd and 4th Environmental Outlooks used a set of scenarios. In the 3rd Environmental Outlook two scenarios were used that are derived from the CPB's "Scanning the Future" exercise[17], in which four scenarios on the global economy were sketched, i.e. Balanced Growth (BG), Global Crisis (GC), European Renaissance (ER), and Global Shift (GS). Because the prevailing environmental policy at that time differed fundamentally from the policy foreseen in the BG and GC scenario, only the European Renaissance and Global Shift scenarios were used in the 3rd assessment. The 4th Environmental Outlook made use of three scenarios, i.e. Divided Europe (DE), European Co-ordination (EC) and Global Competition (GC), which were derived from the new CPB scenario exercises[18] and further enriched with the 'Water System Outlook'[19] (REF) and the long-term assessment of the Physical Planning Agency[20].

16 In Dutch: *Centraal Plan Bureau (CPB)*
17 (CPB 1992)
18 (CPB 1996)
19 (Rijkswaterstaat 1996)
20 In Dutch: *Rijksplanologische Dienst (RPD)*

The assessment process underlying the Environmental Outlooks is informed by monitoring and measuring. RIVM manages national measuring networks on air, soil, ground water, manure and radiation. Data related to surface water are obtained from the Department of Water Works and the Water Boards. RIVM furthermore participates in the Dutch network of ecological monitoring[21]. In this way, RIVM acquires environmental data on emissions, waste, land use, air-, soil- and water quality, manure, pesticides, noise, radiation, radioactivity and biodiversity. Relevant socio-economic and demographic data are obtained from the Economic Planning Agency (CPB), the Central Statistical Office (CBS) and the Social and Cultural Planning Agency (SCP). The Environmental Outlook process involves analysis of these data and measurements.

Models play an important role in the Environmental Outlook assessment process. Models are used to describe or explain environmental aspects in relation to other developments, to estimate future emissions, environmental quality and impacts from economic and technological scenarios, and to assess possible futures in relation to objectives and targets. RIVM currently employs about thirty models[22], ranging from global models (such as the IMAGE model to assess greenhouse gas emissions), distribution models (such as the OPS model to account for SO_2 and NO_x 'import' emitted by other European countries), deposition models (like the DEADM model), water models (like the NLOAD, LGM and WATNAT models), and local models (like the CAR-VMK model for local air pollution) to models that assess effects, like the SMART/MOVE model that assesses the impacts associated with environmental change on terrestrial ecosystems, the PC-Lake and PC-Ditch models for effects on aquatic ecosystems and the LVB model that calculates noise nuisance. These models are as far as possible calibrated and validated against available monitoring data. RIVM does not possess one fully integrated model, but it uses the available models in cascades in order to assess the relevant environmental cause-effect chains. The model calculations provide the major input to the assessments of the future.

The National Environmental Outlook reports can be considered as a product, because this document is the final output delivered to the government. On the other hand, the National Environmental Outlooks can also be considered from a process point of view. The 'booklet' results out of a development process that usually lasts between 6 months and 1.5 year. Negotiations take place about the goals, structure

21 (RIVM 1999a)
22 (RIVM 1999a)

and contents both within RIVM as between RIVM and the government representatives, especially from the Ministry of Environment and Planning (in Dutch: *VROM*), from the Ministry of Economic Affairs (in Dutch: *EZ*) and from the Ministry of Agriculture and Fishery (in Dutch: *LNV*). RIVM analyses and investigates the state-of-the-art science. Drafts are written, which are revised and reviewed, both within RIVM and by external peers. This underlying assessment process involves different RIVM employees from different laboratories and departments with different responsibilities, as well as from other Dutch institutes (see Table 1), and various government representatives from different ministries. In the 5th Environmental Outlook process about 150 researchers from RIVM are involved.

In general, the review process follows the following course[23]: the laboratories responsible for the results first review the draft chapters. About 1000-1500 pages of copy are then handed over to the project-team, which usually involves about 15 people. These drafts are synthesised by the project-team into a draft document of about 200 pages. It is then circulated again within RIVM, and amongst the collaborating institutes. In the next round, external experts, such as academics from Dutch universities, review the next draft. The draft Environmental Outlook is also reviewed in the policy circuit, first by the so-called expert group (in Dutch: *deskundigenoverleg*), and then by the departmental task force, the steering group and the governmental commission for environmental pollution (in Dutch: *Rijksmilieuhygiëne-commissie*). Finally, it is discussed in the council of ministers (in Dutch: *Ministerraad*), before it is published and presented to the Minister of Environment and the Parliament.

In trying to reproduce how RIVM dealt with uncertainties in the previous Environmental Outlooks, ideally both the product and the process have to be analysed in order to get a fair comprehension. In the course of our analysis, RIVM employees mentioned that the way they are dealing with uncertainty heavily depends on what the expectations policy makers express and the guidelines they set. Although we are aware that the interplay with other institutes, external experts and the policy makers is an important aspect of the process, in this thesis we limited ourselves to the Environmental Outlook process within RIVM. It is beyond the scope of this thesis to address the interplay between RIVM and politics in enough depth[24]. This thesis focuses on how uncertainty was dealt with in the internal scientific assessment process and how it was settled and communicated in the Environmental Outlook reports.

23 Source for our description of the review process: Rob Maas (personal communication)

24 See also Chapter 1.

Collaborating institute	Dutch name	Abbreviation
Advisory board for traffic and transport	Adviesdienst Verkeer en Vervoer	AVV
Central Statistical Office	Centraal Bureau voor de Statistiek	CBS
Central Economic Planning Agency	Centraal Planbureau	CPB
Energy research Centre the Netherlands	Energie-onderzoek Centrum Nederland	ECN
Knowledge Centre Nature Conservation	Informatie- en Kenniscentrum Natuurbeheer	IKC-N
Royal Dutch Meteorological Institute	Koninklijk Nederlands Meteorologisch Instituut	KNMI
Agricultural Economic Institute	Landbouw Economisch Institute	LEI-DLO
National Aviation and Aerospace Laboratory	Nationaal Lucht- en Ruimtevaart Laboratorium	NLR
Public Institute for Coast and Sea	Rijksinstituut voor Kust en Zee	RIKZ
Public Institute for integrative fresh water management and waste water treatment	Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling	RIZA
Physical planning agency	Rijksplanologische Dienst	RPD
Staring Centre	Staring Centrum	SC-DLO
Social and cultural planning agency	Sociaal en Cultureel Planbureau	SCP

TABLE 1 Collaborating institutes in the Environmental Outlook process

4. The case-study methodology[25]

The overall aim of the retrospective analysis of the previous Environmental Outlooks was to assess whether there is a (potential) need for an alternative, probably complementary, approach for uncertainty management in decision-support. With a multiple-case case study we wanted to analyse how uncertainty is managed in RIVM's previous environmental assessments (vertical analysis[26]) and whether, and if so why and how, the approach to uncertainty has changed over time (horizontal analysis[27]). To this end, first a document analysis was performed, involving both argumentation analyses per Environmental Outlook and comparison of uncertainty management between the various Outlooks. To complement the document analyses were complemented by empirical research, in which RIVM's practitioners were used as source of information. Interviews, a focus group and questionnaires were used to gather empirical data. The various materials for the case-study research are all described in more detail in the current section.

25 This section builds upon (Langendonck 1999; van Asselt et al. 2000)
26 'Synchrone analysis' is the term usually used for this kind of case-study analysis (Rob Hoppe, personal communication).
27 'Diachrone analysis' is the term usually used for this kind of case-study analysis (Rob Hoppe, personal communication).

4.1. ARGUMENTATION ANALYSIS

In order to investigate these research questions, we decided first to perform a thorough argumentation analysis on major conclusions of the two most recent Environmental Outlooks. The aim of this vertical document analysis was to assess whether uncertainty affects the major conclusions, and if so how uncertainty is dealt with in the underlying analysis. The Summary chapters of the 3rd and 4th Environmental Outlook were screened in order to discern major conclusions RIVM wanted to convey to decision-making. It turned out beyond the scope of the study to single out every concluding statement and scrutinise the underlying information and justification. For that reason, we decided to select 6 conclusions per Environmental Outlook that could be considered to be representative for the addressed causal chains. To that end, we decided that the set of concluding statements per Environmental Outlook should involve statements pertaining to pressures (i.e. social, economic and technological driving forces that exert pressure on the environment), to states (i.e. physical, chemical and biological changes in the biosphere, or changes in the socio-cultural, natural and economic stocks) as well as to impacts. Apart from that criterion we did not use any selection heuristic, so that our selection of concluding statements can be considered as an a select sample.

The argumentation analysis involved the Environmental Outlook report, background reports[28] and references provided in the Environmental Outlook report or in its background documents. The National Environmental Outlook booklets were used as the basic reference in which at first sources of evidence for the conclusions in terms of logical argumentation, figures, tables, footnotes, and further references were sought. Background documents and other related research reports[29] were used as second set of reference. The selected conclusions were scrutinised along the lines of the following questions:

- *How is the conclusion underpinned?*
- *Can uncertainties be recognised in the argumentation underlying the conclusion, and if so which ones?*
- *How are these uncertainties considered in the assessment underlying the conclusion?*

28 The 3rd Environmental Outlook was accompanied by a set of topical background documents. The 4th Environmental Outlook was supplemented by a full background report, of which the aim was that it provided the scientific underpinning for the policy document

29 Such as those produced by the Central Planning Office and other collaborating institutes.

In addressing the first question, Toulmin's[30] definition of argumentation was used, i.e. an argument consists of a combination of i) information (I), ii) implicit or explicit justification (J) and iii) a statement (S). In the argumentation analysis of the Environmental Outlooks, the statement (S) served as starting point to investigate the underlying evidence (see Figure 2). The argumentation analysis on a specific statement continued until the basic underpinning was found, or until the analysis came to a deadlock, because neither the Environmental Outlook, nor the background documents nor the given references provided any new clues.

The next step involved evaluation of argumentative components by means of the following questions[31]:

- Is the information I solid?
- Is the justification J logical?
- Does the justification J match with the information I and the conclusion S?
- Is the conclusion S based on the given argument (I and J) acceptable?

In doing so, we were able to assess whether the argumentation underlying a concluding statement is weak or strong. "Weak" implies that no underpinning evidence was found or that the given arguments were not solid, logical or did not match. In other words, a statement is classified as weak if one or more of the above questions are answered with 'no'. "Strong" implies that solid, in principle verifiable, evidence underpins the conclusion. A conclusion is thus adequately underpinned, and thus characterised as strong, in case all of the above questions are answered with 'yes'. We would like to underline that it was not our aim or intention to judge the correctness of any conclusion in the Environmental Outlooks; we wanted to explore whether the selected conclusions were acceptably underpinned.

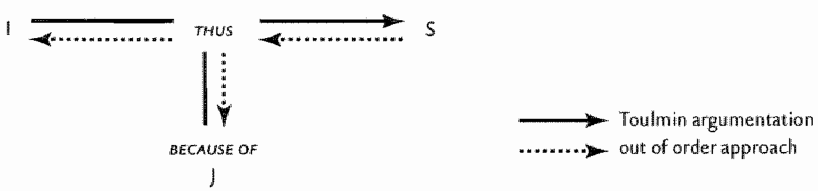

FIGURE 2 Basic argumentation analysis scheme

30 (Schellens and Verhoeven 1988)
31 Compare (Schellens and Verhoeven 1988)

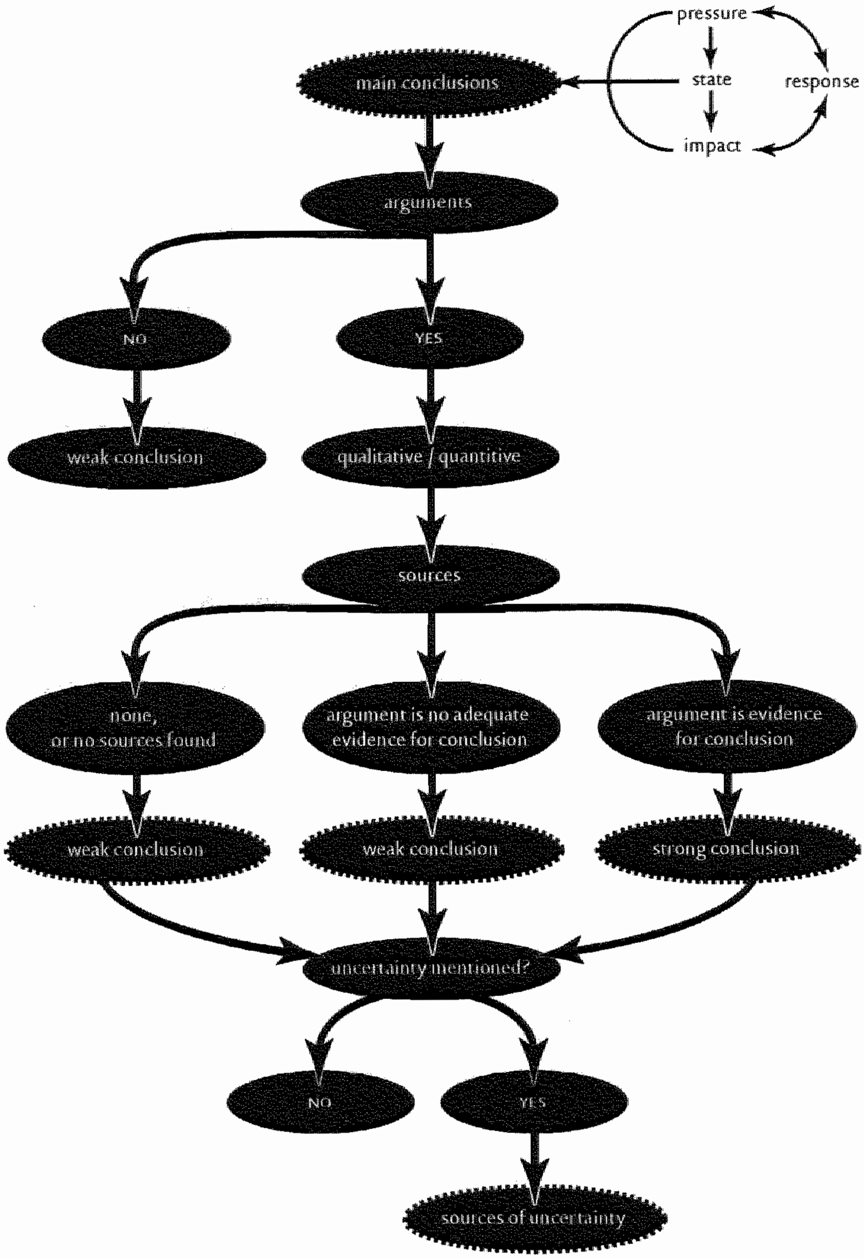

FIGURE 3 Analysis scheme for the argumentation analysis

However, 'strong' does not imply that no uncertainty is involved. 'Strong' implies that the associated uncertainties are mentioned and explicitly considered. In the case of strong statements, it is therefore a straight-forward exercise to identify whether uncertainties impact upon the conclusions, and if so, how they have been considered and interpreted in the underlying analysis. While 'strong' is not the same as certain, likewise 'weak' is not identical with uncertain. The weakness of a statement can also arise due to lack of transparency. It is thus much more difficult to figure out whether, and if so which, uncertainties impact upon the weak conclusions then in the case of strong conclusions. Nevertheless, 'weak' may serve as a kind of signal for hidden uncertainty. In principle one would and could expect that in case solid evidence was available or uncertainties would have been addressed systematically, it would have been used in the assessment.

The next step involves classifying the recognised uncertainties in terms of the sources of uncertainty as identified in Chapter 3A. Such a classification can be useful to characterise the uncertainties involved and to explore whether the adopted approach to deal with the uncertainty in the Environmental Outlook has been appropriate[32]. The full argumentation analysis procedure is summarised in Figure 3. To complement the latter analysis, we have taken the typology of sources of uncertainty as a starting point, and we have searched in the National Environmental Outlooks for concrete examples of each source of uncertainty. The purpose of this exercise was not to create a comprehensive overview, but it allows to indicate which sources of uncertainty in principle play a role in the environmental assessments. The results of the vertical document analysis including the latter exercises are reported in the next Chapter.

4.2. HORIZONTAL DOCUMENT ANALYSIS

The aim of the horizontal document analysis in the context of the current case-study was to investigate whether, and if so, how RIVM's attitude and its approach to uncertainty management, as expressed in, or deduced from, the Environmental Outlook reports, have changed over time. In the horizontal document analysis (see Figure 4) all four Environmental Outlooks have been considered. The use of scenarios is one way to address uncertainty[33]. As discussed above the number of scenarios and the scenarios themselves as used in the Environmental Outlooks differ over time. We furthermore compared the relative magnitude of the margins in future assessments expanded by the scenarios among the four Environmental Outlooks (see Box 1). In that way we can investigate whether the estimated degree of uncertainty for a specific issue differs between the various Outlooks.

32 Compare Chapter 3A.
33 See Chapter 3A.

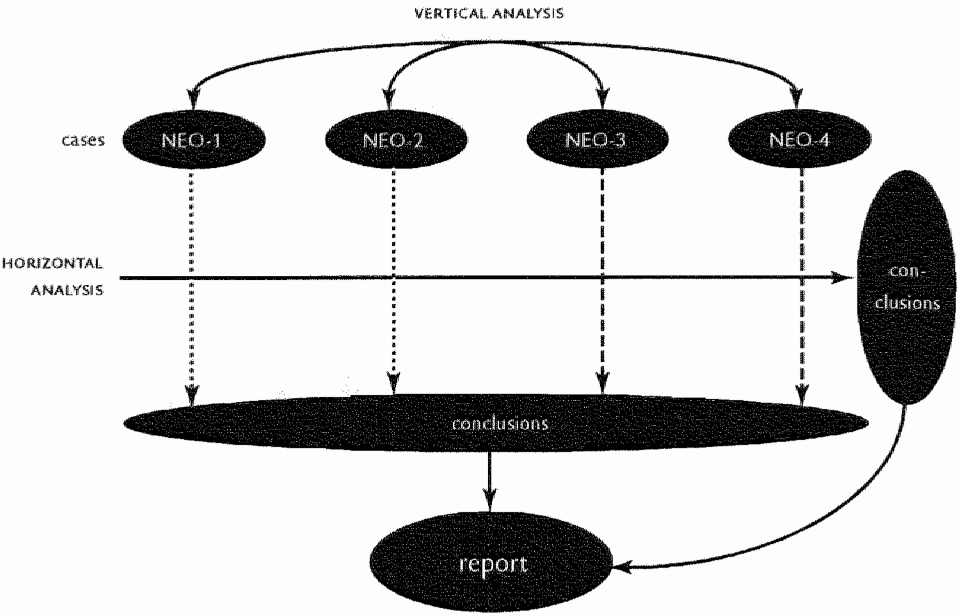

FIGURE 4 Horizontal and vertical document analysis

BOX I

Each scenario implies a trend line. The number of scenarios in a National Environmental Outlook is responsible for the number of trend lines. i.e. one scenario involves one trend line, two and more scenarios imply two lines (only the maximum and minimum values are visualised). For each issue, we compared the margins of the trend lines of the four National Environmental Outlooks. A margin is then the distance between a pair of trend lines of one Outlook at a certain time. This means that if the Environmental Outlook employed just one scenario, no margins are expanded and as a consequence the calculated area is 0. The total magnitude of a margin refers to all margins between a pair of trend lines over a distance of two year dates. In order to allow comparison the four National Environmental Outlooks, while taking the variability of the curves into account, we calculated the area between the pair of trend lines between two years. In general, the areas have been calculated for the year 2000 and the last year that the trend lines have in common, often 2010 or 2015. Furthermore, the total magnitude of the margins, i.e. the area of the field between a pair of lines and two year dates, was analysed in relative terms. Figure 5 visualises the area of a graph and Figure 6 indicates how the area was calculated.

see over »

BOX 1

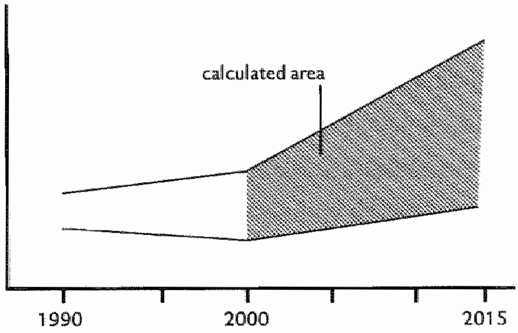

FIGURE 5 Magnitude of margins between two trend lines

The calculations of the total magnitude of the marges (area) are based on the following principle:

Area abcd: (y-x)(d-a) - ½(d-c)(y-x) - ½(b-a)(y-x)

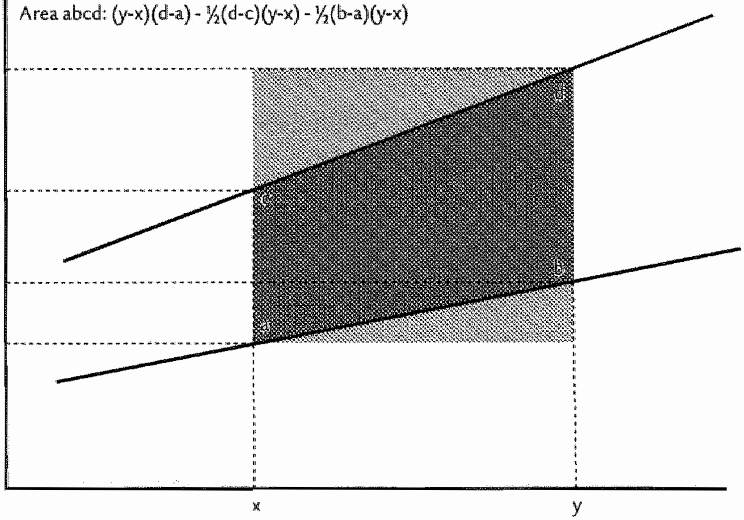

FIGURE 6 Method to calculate the area in a figure

A third way to investigate RIVM's attitude to, and management of, uncertainty over time by means of a document analysis is to analyse whether the number and type of linguistic expressions referring to the presence of uncertainty has changed over time. To that end, we distinguished between wordings indicating inexactness (e.g. 'about', 'approximately', or 'at least') and phrasings hinting at more structural uncertainty (such as 'uncertain/uncertainty' and 'it is expected/assumed'). It was beyond the scope of our study to perform such a complete, time-consuming analysis of the reports. Furthermore, because different issues are covered, such a full analysis would render the comparison more difficult. We therefore decided to perform such a linguistic screening for two issues that were discussed in all 4 Environmental Outlooks, i.e. demographic development and local air pollution. The first issue can be characterised as a pressure, where the second issue represents an environmental impact. We further counted the word 'uncertainty', and directly related words as 'uncertain' and 'not certain', in the summaries of the Environmental Outlooks. Because the summaries have a direct communicative aim, the latter analysis allows assessment of the importance attached to communication about uncertainty.

4.3. INTERVIEWS

Not all research questions can be addressed by means of the vertical argumentation analysis and the horizontal document analysis. Such analyses of the output of the assessment process do not fully indicate how uncertainties are dealt with in the underlying assessment process, and why uncertainties are managed in that way. For that reason, we decided to use practitioners from RIVM with experience in one or more Environmental Outlook processes as another source of information. To that end, we performed a number of interviews and a focus group. The aim of this part of the research was threefold:

- to validate the conclusions of the document analyses
- to assess the attitude towards uncertainty and uncertainty management among RIVM practitioners
- to understand how uncertainty was managed in the assessment process, and why in this way

The interviewees and the participants to the focus group were selected in close interaction with RIVM. At the time of discussing which people to involve, uncertainty was considered to be a controversial topic that could easily confuse people participating in the current Environmental Outlook process, and thereby disturb the ongoing assessment activities. Uncertainty was identified as a topic for the 5th Environmental Outlook, but among RIVM's management there was a shared conviction that it should be handled carefully. On the other hand, we needed a set of respondents that covered experience and insight in Environmental Outlook assessment ever since 'Concern for Tomorrow'. In line with these two ambitions, we identified 11 senior practitioners who were involved in at least one Environmental Outlook in a leading position (such as project leader, senior analyst, senior reviewer, project leader of modelling activities, chapter co-ordinator and integrated assessor), and who were known as conscious of, and open-minded towards, uncertainty in relation to the Environmental Outlooks (see Table 2). This selected, small group of respondents cannot be considered representative for RIVM as a whole, which implies that statistical generalisations cannot be made. This is not a problem for our case-study research, because the ultimate aim is to understand the how uncertainty is managed. To that end, the selected 'elite' is a valuable and essential source of information.

We decided to carry out focused in-depth interviews, in which the respondents were asked for facts, opinions, insights and ideas[34] about uncertainty and the Environmental Outlooks. In the interview three interview techniques were used[35]. An interview guide with *open questions* was used to structure the communication. In addition, a dozen *closed questions* were asked, in the form of statements on which the interviewees could agree or disagree on a five point scale. Some of the statements were on purpose phrased rather extreme in order to trigger a response and to be able to draw conclusions as sharp as possible. Finally, the interview involved a number of *ranking exercises*, in which they, for example, were invited to rank the sources of uncertainty in terms of importance for the Environmental Outlook. The interviews in general took roughly an hour. Apart from some general introductory questions, such as about one's involvement in the Environmental Outlook processes, the following topics were covered:

- general attitude towards science-knowledge-uncertainty
- attitude towards uncertainty in relation to the Environmental Outlook
- sources of uncertainty in the Environmental Outlook
- RIVM's current uncertainty management
- prospects for the future

34 See (Yin 1994)

35 See (Langendonck 1999; van Asselt et al. 2000 (in preparation)) for the interview guide and (van Asten 2000; van Asten and van Asselt 1999) for the questionnaire.

name *(in alphabetical order)*	experience in NEO	inter-viewed	participated in focus group
Ronald Albers	Since '90 at RIVM. Author NEO-2. Chapter co-ordinator NEO 3. Project leader NEO 4. Current position: Head of the division of policy analysis and scenarios.	X	*Invited, other obligations*
Leon Braat	Since '90 at RIVM. Model manager and co-ordinator of data and model use in NEO1-NEO4. Current position: project leader NEO 5. Head of Modelling department.	X	*Invited, other obligations*
Klaas van Egmond	Since 1972 at RIVM. Director Environment in the Board of Directors since 1988, and thus final responsible for NEO 1-5. Since 1996 furthermore part-time professor Environmental Sciences at the University of Utrecht.	-	X
Anton van der Giessen	Since '91 at RIVM. Former head of the Centre for Mathematical Methods, and thereby responsible for the use of models in the assessment process. Currently responsible for uncertainty management in the 5th Environmental Outlook process.	-	X
Janneke Hoekstra	Since '87 at RIVM. Statistician. Project leader State of the Environment reports '97 and '98. Current position:	X	X
Fred Langeweg	Founding father of NEO. Deputy director of the Environmental Planning Agency, supervisor of NEO 1-5	X	X
Rob Maas	Since 1983 at RIVM. Project manager of NEO 2-4. Current position: Head of the Department for Environmental Assessment.	X	X
Dirk Onderdelinden	Since '97 involved in NEO. Senior reviewer. Integrated assessor.	X	X
Jan Rotmans	From '85 to '96 at RIVM. Chapter co-ordinator and author NEO-1. Senior modeller, senior analyst and chapter co-ordinator NEO-2 and 3. Current position: full professor at Maastricht University and director of ICIS.	X	*Not invited*
Rob Swart	Since NEO-1 involved. Scenario analyst. Chapter co-ordinator.	X	*Invited, abroad*
Keimpe Wieringa	Author NEO-1. Member of project team NEO-2. Scenario analyst and chapters co-ordinator. Project leader NEO-3. Was involved in European Environmental Outlook during secondment at the European Environment Agency. Current position: responsible for scenario-management NEO 5.	X	*Invited, interested but principal objection to evening session*

TABLE 2

4.4. change of context – the De Kwaadsteniet affair

The interviews were held in the period January – March 1999. The retrospective study on the National Environmental Outlooks took off in September 1998, and was actually carried out 'behind the curtains'. A small group of people, especially at the top of the institute, knew about the project "Perspectives on uncertainty and risk", and followed it with some interest. Although uncertainty was a recognised agenda point for the 5th Environmental Outlook, at that time it was not at the core of the assessment process. However, on January 20th a national distinguished newspaper (Trouw) published a reader's letter from, and an interview with Hans de Kwaadsteniet, one of RIVM's employees. This inside page content was announced on the front page with the screaming headline 'Environmental institute lies and cheats'. De Kwaadsteniet's had it that RIVM suggests a level of certainty in their environmental reports[36] that cannot be justified. This publication arose a heated media affair that lasted for weeks and kept media attention during the course of 1999. All Dutch newspapers, whether national or regional, as well as news bulletins, current affairs programs and discussion programs on radio and television reported the topic. A wide variety of scientists and policy analysts expressed their views via the so-called 'opinion pages' of the national newspapers[37], or as opponents in media debates[38]. The boom of reactions can be roughly divided into two camps: those supporting De Kwaadsteniet's positivist's argument that measuring is knowing, versus those that acknowledge inherent uncertainty in decision-support on complex issues. The first group advocated more measurements and statistical methods as the way to improvement. The latter respondents usually argued that uncertainty is not a particular RIVM problem; other decision-support institutes struggle with the same problem. In line herewith, it was argued that science, decision-support institutes and politics should work out a new way to deal with uncertainty.

The De Kwaadsteniet affair also had a political impact. The Members of Parliament (MPs) were shocked by the criticism towards RIVM. They interrogated the Minister of Environment[39]. The minister first referred to RIVM for a reaction, but he was forced to come up with a written response, in which he defended RIVM. How-

36 De Kwaadsteniet initially targeted his criticism to the State-of-the-Environment reports (Milieubalans).

37 Also the author of this thesis, together with her PhD supervisor, published an opinion article in which the message of this thesis "Uncertainty is not synonym with bad science" and the inherent problem of scientific decision-support was outlined (see Appendix 1).

38 Examples are Prof. Reijnders, Prof. Hordijk, and Prof. Bomhoff.

39 Which was interesting because RIVM legally belongs to the Ministry of Health.

ever, the MPs were not satisfied by this ministerial reaction, and demanded a parliamentary debate about the RIVM case. In a second meeting between Minister and the Lower Chamber, all political parties supported a motion in which extra control on RIVM's research was requested. In his reaction to this motion, the Minister promised that he would communicate the Parliament's request to RIVM's supervisory board.

The media affair[40] had an enormous impact on RIVM. Their reputation was seriously questioned. The adopted PR strategy can be characterised as defensive, and some serious PR mistakes were made (such as obtaining a court order forbidding De Kwaadsteniet to speak in public and a rather pathetic press conference), which weakened RIVM's image even more. It is no exaggeration to characterise the situation at RIVM in those days as panic. Of course this media affair impacted on our case-study, both in practical terms as well as with respect to the content. Our interviewees were busy, because they had to prepare or attend the press conference, they had to write reports to account for their work to inform the issued review process, or they had to attend internal crisis meetings. Furthermore, the whole affair distracted them from their usual activities, which (further) increased the workload, and impacted on their job satisfaction. Interview appointments were rescheduled or shortened up. We had problems entering the institute because the reception suspected us of being journalists and so on. Nevertheless, all planned interviews were held.

With regard to the contents, the affair had a multitude of effects. It is quite a unique situation that empirical research is crossed by such a public debate addressing the research topic. So far, the project "Perspectives on uncertainty and risk" was looked upon as a theoretical endeavour of primarily scientific value. The advantage was that this affair illustrated the societal and the political importance of uncertainty. Our initial fear was that this whole affair could serve as a bomb, and thereby disrupt the research. De Kwaadsteniet's reproach expressed a positivist spirit[41]. It was quite likely, that this affair would push RIVM towards monitoring and measuring at the expense of modelling and scenario activities. From the point of view defended in this thesis, that would have been a big step backward. However, the opposite happened. The media affair catalysed consciousness and awareness.

As a result of this momentum, the respondents were challenged to have an opinion about uncertainty in scientific decision-support, which increased their interest and their commitment to work with us. This explains why, notwithstanding the

40 See (van Asten 2000) for a comprehensive coverage of this media affair. See Appendix 2 for a track record of the articles in national newspapers.

41 Compare Chapters 3A and 4.

time pressure and panic, all interviews took place. The interviews seemed to have been considered an opportunity to channel their thoughts, opinions and ideas. The actual affair popped up in all interviews. Jokes were made about the timing of the interviews ('right time, right spot'). The affair could have either yielded a rather extremely critical attitude towards RIVM's practise, or a quite closed, even hostile attitude towards discussing the internal practise. The drawback would be that the answers, that should inform us about the state-of-the-art management of uncertainty, might involve either socially desired or 'cover-up' elements. In line with the above observation, our evaluation is that the latter does not correspond with the spirit of the interviews. However, it may be possible that the interviews are biased in a positive sense. The consequence would be that our conclusions deduced from the interviews might be more critical then RIVM deserves.

The potential bias has been accounted for in several ways. As a response to all criticism, RIVM published a report and an addendum referred to as "Measurements, calculations and uncertainty: RIVM's environmental research methodology"[42]. These reports enabled to test the findings deduced from the document analyses and the interviews against RIVM's own account.

4.5. FOCUS GROUP

In addition to our comparison of the interview results concerning the actual practise and RIVM's official accounts, we decided to carry out a focus group. The term 'focus group' results from a combination of two social scientific research methods, i.e. the *focused* interview, in which an interviewer elicits information on a topic without a pre-fixed questionnaire, and the *group* discussion, in which a small rather heterogeneous, but carefully selected group of people discusses, facilitated by a skilled moderator[43]. The focus group is an established social scientific research method, originating from marketing research. The advantages of a focus group are that it in principle allows for collective thinking and that it in principle enhances richer argumentation, because the group members themselves raise questions and sharpen each other's arguments.

In our case, the value of a focus group was that it allowed us to test the robustness of the individual opinions against group pressure, and thereby a focus group

42 (RIVM 1999a; 1999b)
43 (Dürrenberger et al. 1997)

enabled us in a certain way to simulate RIVM's forming of opinion. The focus group consisted of the interviewees (see Table 2) complemented with RIVM's director Environment and the senior analyst responsible for uncertainty management in the 5th Environmental Outlook. Such a focus group can provide insight in how the top of RIVM's environmental division as group thinks and discusses about the uncertainty-problematic. This means that such a group process is likely to provide a more realistic reflection of the 'institute's thinking', then any picture that can be deduced from individual interviews. Furthermore, a confrontation with preliminary research results in the form of an in-depth interview could easily flow in a polarised discussion, in which the researcher/interviewer is too much involved. In this way, the researcher may become an obstacle in his or her own research. It is also difficult to have an external interviewer to hold such an interview, because it requires full-fledged knowledge of, and insight in, the research.

However, this does not mean that the interviews are superfluous. The interviews were a necessary step in the research process. They allowed a first impression and enabled to roughly draw the state-of-the-art in RIVM's uncertainty management. The interviews also served as a source of information to direct and inform the document analysis. On the one hand, the interviews served as a way to 'verify' the insights associated with the document analysis, while on the other hand, they turned out to serve as a preparatory step for the focus group. The results of the interviews were used to surface the discussion. The focus group was confronted with the preliminary conclusions and with tensions and conflicts that arose out of the whole set of interviews, and was invited to react. The input was provided in the form of transparencies presented to the focus group. This set of transparencies was also used as discussion guide. The discussion output, which can thus be considered as collective judgements and opinions, allowed us to clarify points in questions and ambiguities, and to reject, nuance or sharpen the preliminary conclusions.

4.6. QUESTIONNAIRES

In order to have a broader sample of RIVM's practitioners involved in the empirical phase, questionnaires were distributed among some twenty analysts involved in the current environmental assessment process that will result in the 5th Environmental Outlook. RIVM's analysis involved in the 5th Environmental Outlook were invited by the project leader. It was explicitlycommunicated that the project leader and RIVM's environmental management considered participation important. The aim of the questionnaires was to test the current attitude towards science, uncertainty and decision-support. In order to allow for comparison, the same closed questions used in the interviews were posed in the questionnaire. The respondents were confronted with a couple of statements and were asked to express their opinion on a 5-point scale.

4.7. CASCADE OF RESEARCH METHODS

The case-study methodology adopted in the multiple-case case-study on RIVM's Environmental Outlooks is summarised in Figure 7. The various methods may yield conflicting or even inconsistent results. A key ambition is to highlight such conflicts and inconsistencies and to use them to ask further questions.

The cascade of research methods (i.e. document analyses, interviews, focus group and questionnaires) guaranteed a richer, and probably more realistic, picture of how uncertainty was managed in the four Environmental Outlooks. Such a description, accompanied by insight into the current attitude towards uncertainty as can be deduced from the interviews, the focus group and the questionnaires, then provides the basis for addressing the general research question, i.e.:

> *Is there a (potential) need for an alternative or complementary approach to uncertainty management in the decision support practice?*

The above question is addressed in the case study in the following ways:

- by means of the argumentation analysis the quality of the conclusions is assessed, which results provides insights into the question whether the underlying assessment approach, including uncertainty management, adopted in the series of Environmental Outlooks seems to be problematic
- by means of the document analyses and the comparison over the series of Environmental Outlooks it is traced how uncertainty was addressed in the previous Environmental Outlooks.
- by means of empirical research it is analysed whether a need for an alternative approach to uncertainty management is felt by practitioners

Evaluation of the research results associated with the first two bullets against the theoretical insights into uncertainty management and risk analysis (as outlined in Chapters 3-5) allows to address whether their is a latent need for an alternative approach to uncertainty management. The empirical research among practitioners allows to assess whether their is also an overt need. If the current approach to uncertainty turns out to be problematic in view of the quality of the assessment and the data collected among practitioners indicate a positive attitude towards another approach to uncertainty management, the above general question can be answered with 'yes'. This 'yes' does not mean that there is a need for the PRIMA approach outlined in Chapter 5. However, the research results may allow to address whether the PRIMA approach in principle could address the observed (potential) need in the decision-support practice.

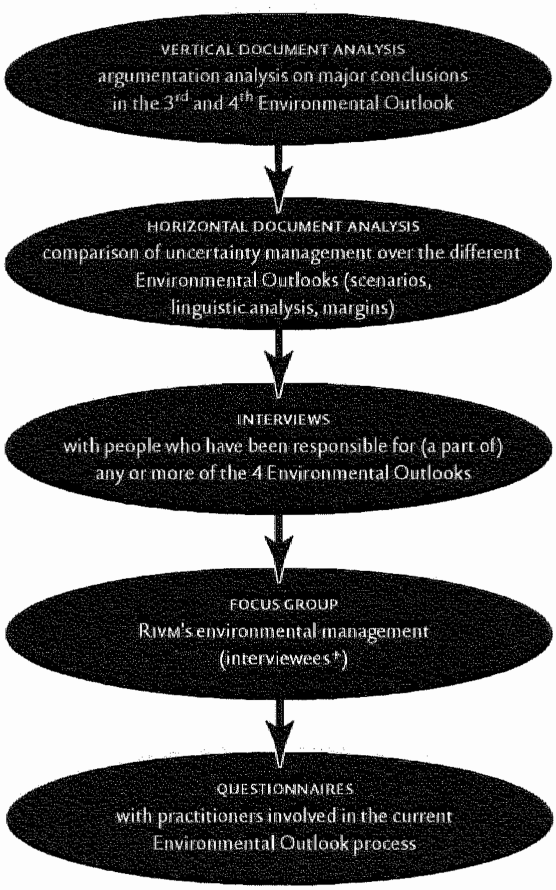

FIGURE 7 Case study methodology

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Searching for uncertainty in RIVM's Environmental Outlooks[1]

As outlined in the previous Chapter, a multiple-case case-study on RIVM's Environmental Outlooks has been performed in order to address the research question whether there is a (potential) practical need for an alternative or complementary approach to uncertainty management. This Chapter reports the case-study research and the conclusions that can be deduced from this empirical research. The first part of the Chapter will focus on the document analyses, while in the second part the state-of-the-art in RIVM's uncertainty management is outlined, which description mainly builds on the interviews, the focus group and the questionnaires.

1. Document analyses

The aim of the document analyses was to figure out how uncertainty is dealt with in RIVM's Environmental Outlooks[2]. The document analysis comprised the following two components:

- vertical analysis
- horizontal document analysis

The first type of analysis implied in-depth studies per Environmental Outlook. The main component of this vertical analysis involved argumentation analysis of selected conclusions. The second analysis, i.e. horizontal document analysis, was focused on the comparison among the four Environmental Outlooks.

1 This Chapter substantially benefits from research carried out by Rian Langendonck and Frank van Asten in the context of their master thesis for the course Environmental Health Sciences. See also: (Langendonck 1999; van Asselt 1999; van Asselt et al. 1999; 2000 (in preparation); van Asten 2000; van Asten and van Asselt 1999).

2 (RIVM 1988; 1991; 1993; 1997), abbreviated to in the analysis as NEO (National Environmental Outlook), i.e. NEO-1, NEO-2, NEO-3 and NEO-4 respectively.

As argued in the previous Chapter, the aim of the argumentation analysis is to understand for some a-select conclusions how they are underpinned, whether uncertainties can be recognised in the underlying argumentation, and, if so, how these uncertainties are dealt with. The quality of the argumentation is evaluated in terms of weak or strong. Weak implies that no underpinning evidence was found or that the given arguments were not solid, logical or did not match with the conclusions. Strong implies that solid, in principle verifiable, evidence underpins the conclusion. We would like to underline that it was not our aim nor intention to judge the correctness of any conclusion in the Environmental Outlooks; we wanted to explore whether the selected conclusions were acceptably underpinned in order to get some insights whether uncertainty was, or may have been, involved.

2. Argumentation analysis

Box 1 outlines which concluding statements have been extracted from the Summary Chapters of the 3rd and 4th Environmental Outlook. These chapters in principle convey the major policy-relevant conclusions. It is beyond the scope of this thesis to report the analysis of all twelve statements. For the sake of brevity, we therefore limit ourselves here to the full description of the argumentation analysis of two illustrative conclusions, i.e. one conclusion that was characterised as weak and one other concluding statement that was classified as strong (next subsections). The other evaluation results are summarised in Box 2.

BOX 1 Concluding statements selected for argumentation analysis

Our selection comprised both conclusions regarding pressures, and conclusions concerning states and impacts, in order to cover some relevant cause-effect chains.

The following quotation indicates the salient driving forces discussed in the 3rd *Environmental Outlook:*

> 'The following sections look at the social developments relevant to the environment, starting with the developments more or less exogenous to environmental policy, such as *population growth* and *economic development*. This is followed by an examination of the developments towards which environmental

see over »

BOX 1

policy in a broad sense is primarily oriented: *energy consumption, mobility, manure production* and *water consumption'* (NEO 3, p.36).

After screening the texts in the Summary Chapter on the underlined issues, the following "pressure conclusions" have been selected for further analysis:

- POPULATION GROWTH

  'The Dutch population is expected to grow more than is assumed in the NEPP[3]. The level forecasted for 2000 was already reached in 1992. The population figures for 2010 in the ER and GS[4] scenarios are about 10% higher than in the NEPP' (NEO-3, p. 12).

- ECONOMIC DEVELOPMENT

  'In the ER scenario GNP[5] remains somewhat lower than is assumed in de middle scenario until 2000, after which it increases more sharply. Economic growth in the GS scenario is significantly lower.' (NEO-3, p. 12).

- MOBILITY

  'The policy that has now been formulated is expected to curb growth and thereby enables to reach the target for the year 2000. After 2000 car use will further increase' (NEO-3, p.12).

The following conclusions pertaining to state or impact issues have been selected:

- CARBON DIOXIDE EMISSIONS

  'Depending on trends in energy prices, CO_2 emissions in the ER scenario will rise by 5-10% between 1989/90 and 2000. In the GS scenario, CO_2 emissions in the same period will rise by 5% if energy prices remain low until 2000' (NEO-3, p.16).

- DEPOSITION OF ACID EQUIVALENTS

  'The deposition target for 2010 of 1400 acid equivalents per hectare (average on woodland) will not be achieved with implementation of the proposed policy. Deposition will be able to fall to about 2400 acid equivalents per hectare in 2010' (NEO-3, p.17).

- NOISE NUISANCE BY ROAD TRAFFIC

  'Despite the increase in car traffic and the expansion of the road network, the proposed policy will reduce the number of people experiencing serious nuisance to 10-15% of the population, between 1990 and 2000. The number of people experiencing some nuisance will fall less sharply. The targets for the year 2000 will easily be achieved. However, the target for 2010 (a negligible level of serious nuisance) will not be achieved' (NEO-3, p.22).

see over »

3 (VROM et al. 1989)
4 European Renaissance and Global Shift scenario; see Chapter 6.
5 Gross National Product

BOX 1

Three conclusions pertaining to pressures have been extracted and selected out of the Summary Chapter of the 4^{th} *Environmental Outlook:*

- CONSUMPTION

  'It is expected that the consumption per head will increase with 45%-100% between 1995 and 2020' (NEO-4, p.12).

- PRODUCTION

  'According to the economic long term scenarios on which this Environmental Outlook is based, the production will increase with 50%-125% in the next 25 years' (NEO-4, p.12).

- ENERGY CONSUMPTION

  'Between 1995 en 2020 the energy consumption will grow with 8%-45%' (NEO-4, p.12).

In the 4^{th} Environmental Outlook, the theme 'environmental quality' is subdivided into three categories: the urban area, the green area and the blue area. In each category environmental state and impact issues are evaluated. From the Summary chapter we chose from each category one conclusion pertaining to state or impact issues:

- PHOSPHATE CONCENTRATION IN THE SOIL

  'With the adopted policy, the area with phosphate accumulation in the eastern, central and southern Sand Region will increase from 22% in 1990 to 50% in 2020' (NEO-4 p. 16).

- IMPACT OF FINE DUST ON HEALTH

  'With the current policy, a slight improvement is expected for photochemical air pollution (ozone) and fine dust. However, this is not adequate to prevent health damage (breathing problems)' (NEO-4, p.16).

- DESICCATION

  'Assuming an advisable rise of the ground water level of 25 centimetre and in case desiccation is adequately prioritised in land structure projects, the target for desiccation (in 2010: a decrease of the natural desiccated area with 40% in relation to 1985) will be almost reached in 2010-2020' (NEO-4, p.18).

see over »

2.1. EXAMPLE OF A WEAK CONCLUSION

The analysis of the statement on economic development extracted from the 3^{rd} Environmental Outlook is discussed in more detail, as an example of a concluding statement that is ultimately characterised as weak:

> *'In the ER scenario GNP remains somewhat lower than is assumed in de middle scenario until 2000, after which it increases more sharply. Economic growth in the GS scenario is significantly lower' (NEO-3, p.12).*

It is argued that the growth in physical units is even more important to environmental assessments than monetary growth:

> *'The development of the GNP (the growth of the added value in guilders) is not as important to the environment as the* growth in physical units. *This physical growth of the economy is determined by the use of energy and raw materials, the end products and the level of recycling of waste products' (NEO-3, p.40).*

Statements, information and arguments on both indicators were analysed in further detail. Notwithstanding the explicit acknowledgement of the importance of physical growth over monetary growth, GNP is used throughout the 3rd Environmental Outlook as the reference indicator. The implication of using solely GNP is that this Environmental Outlook does not allow to assess whether so-called 'de-coupling'[6] of economic growth and pressure on the environment may be a realistic future outlook. In this Chapter, we limit ourselves to the analysis of the concluding statements on GNP[7], which implies that only the left part of Figure 1 is discussed in detail here.

The first place in the 3rd Environmental Outlook where we expected more specific information regarding the development of GNP is section 3.3, entitled 'Economy'. Here, the conclusion is repeated, but now in quantitative terms:

> *'(....) the development of the GNP in ER is somewhat lower than in the Middle scenario (an annual average of 2.7% and 3%, respectively, until the year 2000). (.....) The GS scenario assumes a far more moderate growth (1.5% per year)' (NEO-3, p.39).*

Section 3.3 further comprises graph 3.3.1 (NEO-3, p.39) (see Figure 2) indicating the development in GNP over the period 1970-2015 for the Middle scenario[8], the European Renaissance (ER) and the Global Shift (GS) scenario. References indicate that these ER and GS trends are extracted from the document 'Scanning the Future – A long-term study of the world economy 1990-2015' of the Central Economic Planning Agency (CPB)[9]. We tried to trace more information on and a justification for the GNP trends in this referred report. This 'Scanning the Future' report provides a thorough analysis of the global economy as the basis for scenario-development. Various perspectives on economic development are distinguished and trends are studied. Furthermore, comparative strengths of the current state of the economy of major regions (especially the United States, Japan, Western Europe, Central Europe, dyna-

6 See (Molendijk and Rotmans 1999)

7 A detailed description of the argumentation analysis on physical economic growth can be found in (Langendonck 1999; van Asselt et al. 2000 (in preparation))

8 The scenario used in the 1st and 2nd Environmental Outlooks. Added in this graph for comparison reasons.

9 (CPB 1992b).

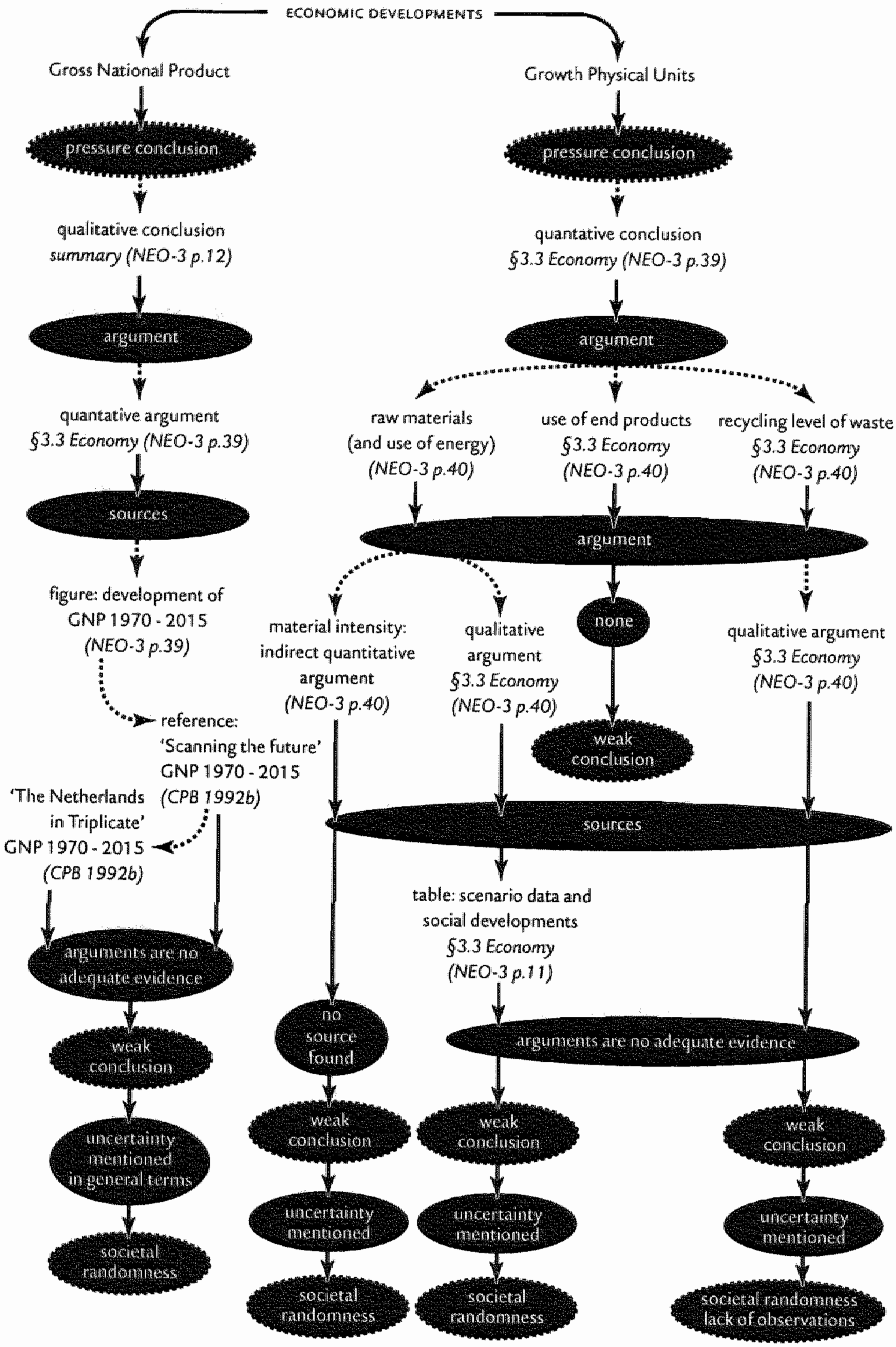

FIGURE 1 Analysis scheme of the argumentation analysis of the statement 'economic developments'

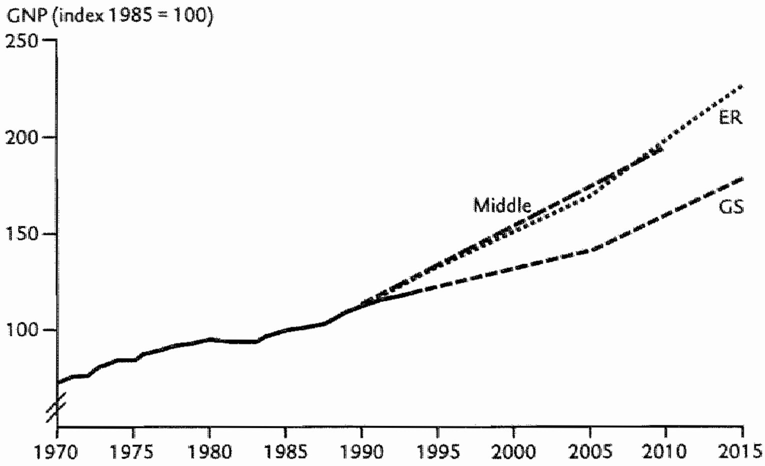

FIGURE 2 GNP trends (Source: National Environmental Outlook-3, figure 3.3.1)

mic Asian Economies, and a cluster of other less-developed countries) are analysed. Based on these analyses, four scenarios have been developed for each world region. The following scenarios were presented for Western Europe: European Renaissance, Global Shift, Balanced Growth and Global Crisis. However, it is not explicitly discussed, nor can it be extracted how the qualitative analysis is translated into quantitative developments in key indicators, such as GNP and use of raw materials. These quantitative trends may be the result of model experiments with the WorldScan model[10], however this cannot be deduced from the report.

The CPB produced a follow-up scenario document 'The Netherlands in Triplicate'[11]. Based on the European scenarios outlined in 'Scanning the Future', this second report discusses three of these scenarios for the Dutch economy. The GNP trends for the European Renaissance and the Global Shift scenario presented in 'The Netherlands in Triplicate' correspond with the trends used in the 3rd Environmental Outlook. However, it is not made transparent how these GNP trends are generated. After a thorough comparison between 'Scanning the Future' and the 'The Netherlands in Triplicate', we conclude that it is most likely that the (unmotivated) quantitative trends for GNP development in Western Europe were down-scaled to the national level. However, it is not clear how this was done: it may be an extrapolation of the current Dutch 'distance' to the European average, or a model of the Dutch economy may have been used?

10 See, for example, (Timmer 1998; Geurts et al. 1995) and www.cpb.nl/eng/
11 (CPB 1992a)

It can be argued that because RIVM took the trends from a report published by the authoritative CPB, the underpinning is strong. However, there are two counter-arguments for this reasoning. First, RIVM provided anyhow the wrong reference: they referred to 'Scanning the Future' instead of the 'Netherlands in Triplicate', where the trends seem to have been taken from. Second, our analysis of the CPB reports indicates that no solid information or logic justification for the trends used in the Environmental Outlooks could be found in the two major documents. It can be deduced from the list of collaborators (see Chapter 6) that analysts from the CPB collaborated in the assessment process underlying the 3rd Environmental Outlook. This implies that RIVM could have questioned the underpinning of the economic scenarios, which obviously played such a dominant role in the whole assessment effort[12]. We therefore conclude that the statement in the 3rd Environmental Outlook regarding GNP development is weak, although the underpinning itself lied beyond RIVM's mandate.

The full argumentation analysis[13] on economic development is summarised in Figure 1. This Figure indicates that the conclusion on economic development as expressed in the Summary Chapter of the 3rd Environmental Outlook is characterised as weak. In view of the importance of this pressure in the assessment process, the observed weakness is problematic, because it is propagated through the causal chains. This means that the weakness of the conclusion on economic development in principle undermines the quality of the full assessment.

In the present case, the observed weakness resulted from lack of underpinning information and justification, or the presented information could not be verified, so that it did not provide solid evidence. It may be that sources of evidence are present, but not further discussed or transparently referred to. 'Weak' is in the first place a judgement on the quality of argumentation, and as such it is not an indicator referring to uncertainty. However, it may be that the weakness of the analysed conclusion is (partly) due to uncertainty: it may be that the importance of the associated uncertainties was not fully recognised, and that as a consequence they were not systematically treated in the assessment process, thereby creating blind spots that could not be covered up in the reporting phase. To that end, it is

12 It should be noted here that the institutional relationship between CPB and RIVM is rather hierarchical. The models and scenarios of CPB are usually used unquestioned by other decision-support institutes or ministries. The above observation with regard to weakness of the selected conclusion may therefore be seen as an example of how institutional arrangements (implicitly) influence the quality of the assessment

13 As said before, we have limited ourselves here to the argumentation analysis on GNP, because it turned out that GNP (and not physical growth) was used throughout the assessment. In other words, notwithstanding the explicit recognition that for environmental assessment the physical growth was more important than GNP, GNP growth was used as indicator throughout the 3rd Environmental Outlook. The full description of the analysis summarised in the right side of Figure 1 can be found in (Langendonck 1999) and (van Asselt et al. 2000).

relevant to investigate whether any uncertainties pertaining to GNP development are mentioned in the 3rd Environmental Outlook.

Section 3.3 'Economy' of the 3rd Environmental Outlook refers to uncertainty in general terms. The following quote indicates uncertainty in the economic scenarios impacting the assessment of future GNP development:

> *'Important uncertainties for the future of (..) the Dutch economy are formed by the* ***development of world trade, European monetary and political unification, the rate of restructuring in Central and Eastern Europe*** *(NEO-3, p.34).*

The bold italic uncertainties refer to uncertain economic, institutional and socio-cultural dynamics. In terms of our typology of sources of uncertainty, it seems adequate to characterise the mentioned uncertainties associated with future GNP as uncertainty due to variability, and more specific societal randomness. In this case, the lack of knowledge resulting from this particular source of variability can be considered structural. This implies that it is important to be explicit how these uncertainties are treated in the assessment, and what it implies for the robustness of the future outlooks sketched in the Environmental Outlook.

These observations combined seem to suggest that in this case it is reasonable to hypothesise that the weakness of the argumentation is partly due to unsystematic treatment of uncertainty.

2.2. EXAMPLE OF A STRONG CONCLUSION

The number of people experiencing noise nuisance by road traffic is an example of an effect on human well being, and can thereby be considered as one of the outputs of RIVM's assessment. The 3rd Environmental Outlook features the following conclusion about noise pollution:

> *'Between 1985 and 1990, the percentage of people experiencing noise nuisance as a result of road traffic rose from 59% to 61% and the percentage of people suffering serious nuisance rose from 19-20% of the Dutch population. Despite the increase in car traffic and the expansion of the road network, the proposed policy will reduce the number of people experiencing serious nuisance to 10-15% of the population between 1990 and 2000. The number of people experiencing some nuisance will fall less sharply. The targets for the year 2000 will be easily achieved. However, the target for 2010 (a negligible level of serious nuisance) will not be achieved' (NEO-3, p.22).*

The conclusion in the specific section about noise pollution in Chapter 4 is more detailed than in the summary:

> *'(..) the percentage of people experiencing noise nuisance or serious noise pollution between 1990 and 2000 will fall below the 1985 levels, which were 59% (nuisance) and 19% (serious pollution). In the ER scenario, these levels will drop to 56% and 15% and in the GS scenario to 51% and 12% (see Figure 4.6.2a)' (NEO-3, p.120).*

The 12% and 15% mentioned here roughly match with the 10%-15% range in the overall conclusion. The phrasing '...will fall...' is here quantitatively argued by the estimates that the level of noise nuisance will decrease from 59% to 51% or 56% respectively. Figure 4.6.2a (see Figure 3) further illustrates the described trend. However, neither the figure, nor the above quote, indicates how these numbers were generated. Chapter 4 does not provide further justification or further references. Nevertheless, we decided to screen the background documents, of which the background document on traffic and transport[14] seemed the most relevant one.

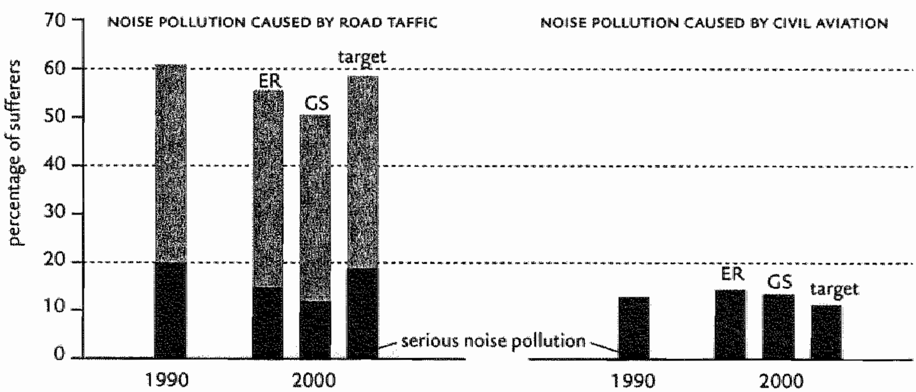

FIGURE 3 Trends in noise pollution (Source: National Environmental Outlook-3, figure 4.6.2)

This background document presented the necessary information and argumentation in a transparent manner. It provides comprehensive and motivated information pertaining to noise nuisance by road traffic that matches with the conclusion on the anticipated effects of policy measures in relation to set policy targets. Factors that determine noise pollution and nuisance are elaborated and assessed in a structured manner. Each step in the calculations, as well as assumptions and references, are made explicit. The report is transparent in a consistent way on the scientific ori-

14 (van Wee et al. 1993)

gins of methods and numbers. Although a specific reference in the 3rd Environmental Outlook to this particular background document in the relevant section would have been in place, we argue that the conclusion in the Summary Chapter on noise nuisance due to road traffic can be classified as strong (see also Figure 4).

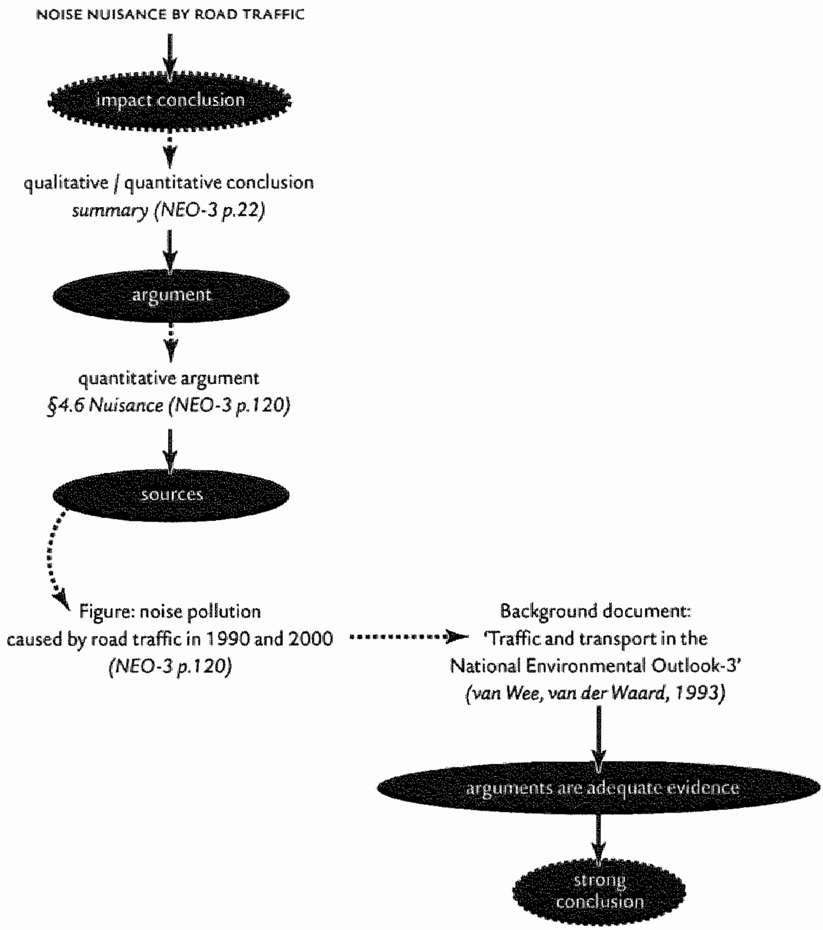

FIGURE 4 Analysis scheme of the argumentation analysis of the statement on 'noise nuisance by road traffic'

Strong is in the first place a quality judgement. It does not say that the conclusion is truth or false, or certain or uncertain. It says that the conclusion is built on a solid and transparent line of reasoning. In other words, strong does not mean that no uncertainty is involved. How can we use the quality judgement in our search to uncertainty? Strong implies that it in principle should be possible to recognise which uncertainties play a role and how they are considered in the underlying assessment. It can however be argued that argumentation that is judged as strong hides uncertainty;

it may be that only experts in the field[15] are able to recognise that the underlying arguments involve uncertainties that are not considered in the assessment. Nevertheless, in view of our aims, it is worthwhile to analyse whether uncertainties are mentioned in case of strong conclusions and how they are treated.

The 3rd Environmental Outlook itself does not mention uncertainties regarding noise pollution caused by road traffic. The many assumptions in the background document on transport and traffic signify uncertainties. The sources of uncertainties can in principle be deduced from the assumptions, which also hint how the uncertainties are interpreted. Such a detailed analysis was beyond the scope of this case study. Apart from being not crucial to the case-study questions and being too time-consuming, it would have required expert knowledge and understanding of this particular topic, which was anyhow not available in the research team. We have limited ourselves to trace sources of uncertainty directly from the text. The background report on transport and traffic, for example, explicitly mentions *conflicting evidence* as a source of uncertainty:

> *'The data used in the noise calculations with respect to the composition of the traffic (see Table 6.3.4) are not fully in agreement with the data that would be gathered from chapter 3 based on the volume developments. In the first place, the volume of heavy goods transport in rural areas will be less than is expected; assumed is that the intensities of this category transport in the future will stabilise with respect to 1990. Secondly, there is a difference between the definition of the transport categories in the mobility data and the prescription of noise calculations' (p.81).*

The case indicates that systematic treatment of uncertainty in the underlying assessment and in the actual report improves the quality of the argumentation, and enables interested readers to understand and accept the conclusion.

15 As opposed to the kind of generalists who performed the reported argumentation analyses.

2.3. SUMMARY OF THE VERTICAL DOCUMENT ANALYSIS

The other 10 selected concluding statements extracted from the Summary Chapters of the 3rd and 4th Environmental Outlooks (see Box 1) have been analysed according to the same procedure[16]. We limit ourselves here to a summary. In Box 2 the major findings are summarised per statement. The accompanying argumentation analysis schemes can be found in Appendix (3).

BOX 2 Main findings per selected concluding statement

POPULATION

The 3rd Environmental Outlook, as well as the CPB reports 'Scanning the Future' and 'The Netherlands in Triplicate', all utilise the same population trends without a reference and without explaining how these trends are generated. A thorough analysis of reports leads us to conclude that certain projections of the United Nations (without any proper reference) are used as starting point of the assessment in 'Scanning the Future', followed by an unmotivated downscaling to 'The Netherlands in Triplicate', which trends are adopted in the 3rd Environmental Outlook. We did not find any proper justification for these trends, and therefore conclude that the concluding statement on population in the Summary Chapter of the 3rd Environmental Outlook should be classified as weak.

USE OF PRIVATE VEHICLES

The statement on the use of private vehicles is comprehensively and solidly underpinned in the background document on traffic and transport[17]. The conclusion in the Summary Chapter of the 3rd Environmental Outlook on the use of private vehicles can therefore be characterised as strong.

CARBON DIOXIDE EMISSIONS

A footnote in the section 4.1 'Changes in global biosphere' (NEO-3, p.67) refers to a background document on climate change. This report 'Background document to

see over »

16 See also Chapter 6.
17 (van Wee et al. 1993)

BOX 2

3rd Environmental Outlook - Climate Change' by Albers, van Amstel and Bouwman was, according to the reference list, still in preparation at the time the 3rd Environmental Outlook was published (1993). However, at the time of our analysis (1999) this particular report could not be found, which lead us first to conclude that it had never been finished. While finishing our research, we found out that the report was eventually published, but the title and the authors had changed: 'Greenhouse gas emissions in the Netherlands 1990, 1991, 1992 and projections for 1990-2010'[18] under authorship of van Amstel. This report mentions that the trend in energy prices is the most important uncertainty with regard to CO_2-emissions. However, although the concluding statement seems to suggest that experiments have been carried out with the two scenarios and variations in energy prices, the background report does not document such experiments. It only says that the prices are higher in the ER than in the GS scenario. With regard to the ranges, the background report indicates a 4.3% increase in CO_2-emissions for the ER scenario (opposed to the 5-10% range in the conclusions) and an increase of 2.7% in the GS scenario (as opposed to 5% in the concluding statement). The background report does indicate other experiments with additional policy; these experiments results into a decrease in CO_2-emissions of 1.1% in the ER scenario and 2.7% in the GS scenario respectively. We therefore argue that the conclusion with regard to CO_2-emissions is weak.

DEPOSITION OF ACID EQUIVALENTS

The scarce information on the deposition of acid equivalents involves a repetition of the conclusion with some, very limited, text on underlying causes. A potential source of information is Figure 4.2.1 (NEO-3, p.77) in Chapter 4 (see Figure 5), in which the amounts mentioned in the conclusion are reflected. However, neither references nor footnotes refer to a background document that indicates how the conclusion, including the quantitative estimates, can be justified. The conclusion on deposition of acid equivalents in the Summary Chapter of the 3rd Environmental Outlook is thus classified as weak.

see over »

18 (Van Amstel 1993)

BOX 2

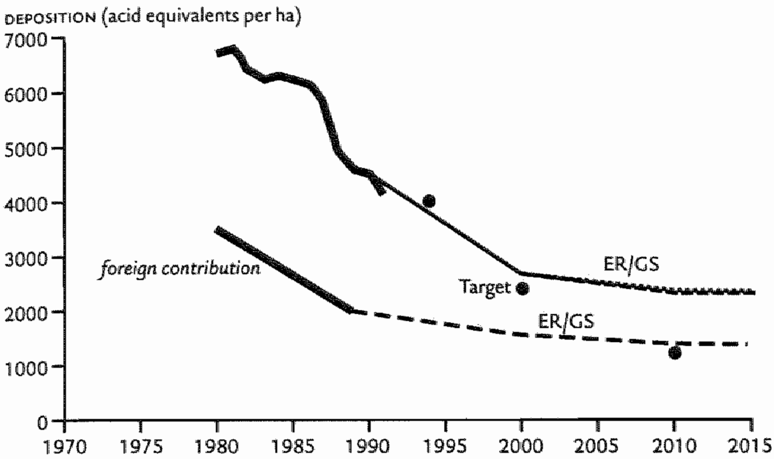

FIGURE 5 Deposition trends (Source: National Environmental Outlook-3, figure 4.2.1)

CONSUMPTION, PRODUCTION AND ENERGY CONSUMPTION

The statements on 'consumption', 'production' and 'energy consumption' in the 4th Environmental Outlook are all assessed to be weak for similar reasons. The information in both the 4th Environmental Outlook and the background document is not transparent at all. For each issue, the determining factors are discussed in both the National Environmental Outlook and the background document. Although the interlinkages between the topical issue and the determining factors are acknowledged, neither of the documents explain how the quantitative estimates for the various factors underpin and justify the quantitative conclusions on consumption, production or energy consumption. Because of this lack of transparency, these concluding statements are characterised as being weak.

PHOSPHATE CONCENTRATION IN THE SOIL

The subject 'phosphate concentration in the soil' is hardly discussed in the 4th Environmental Outlook, even not in the section (NEO-4, section 4.3.3) devoted to this issue. The only argumentation is a more extensive version of the conclusion. The background document does also neither underpin nor justify the conclusion. It repeats the conclusion with the remark that the results are based on an earlier scenario study. The conclusion on phosphate concentration in the soil as extracted from the Summary Chapter of the 4th Environmental Outlook is thereby assessed as weak.

see over »

BOX 2

HEALTH IMPACTS OF FINE DUST

Despite the acknowledgement that little is known about the relation health impact versus fine dust, in section 4.2.5 of the 4th Environmental Outlook it is made transparent on what kind of information and which assumptions justify the conclusion on health impacts of fine dust. The background document presents the underlying assumptions and the associated uncertainties in a transparent and understandable way. The concluding statement on health impacts of fine dust can thus be classified as strong. The following quote indicate that the uncertainties associated with the issue under concern can be categorised as lack of measurements and ignorance:

> 'A lot of uncertainty still exists about the causality of the relationship between the aerosol air pollution and the different forms of health damage. (..) It is unclear which components of the mix are primary responsible for the health effects, and which mechanisms play a role' (background document NEO-4, p.162).

DESICCATION

The 4th Environmental Outlook (see section 4.3.4) contains little information on desiccation that can serve as argumentation for the conclusion. The background document, however, clarifies in a transparent way how the conclusion is generated. The discussed assumptions, determining factors and the additional information match with, and thereby justify, the conclusion. The conclusion on desiccation in the Summary Chapter of the 4th Environmental Outlook can thus be classified as strong. With regard to uncertainty, the following quote matters:

> 'It is unclear to what extent a rise in groundwater level with 25 cm would be enough to desiccation effects' (NEO-4, p.159).

This uncertainty can be classified as structural uncertainty (ignorance, indeterminacy), which may be due to variability in the natural system (i.e. natural randomness).

Table 1 provides a summarising overview indicating the quality of the argumentation, and whether uncertainties are mentioned, and if so, which sources.

Our argumentation analysis of the a-select extracted concluding statements of the 3rd and 4th Environmental Outlook indicate that 8 out of 12 can be characterised as weak, and that only 4 were classified as strong (see Table 1). If we compare the classifications of the selected statements among the two Environmental Outlooks, we

	Analysed Issues	Argumentation		Uncertainties mentioned?	
NEO-3		*Weak*	*Strong*	*No*	*Yes: source*
pressure	Economy	X			• societal randomness
					• lack of measurements / observations
	Population	X		X	
state/impact	Noise nuisance by road traffic		X	X	
	Use of private vehicles		X	X	
	CO_2-emission	X			• societal randomness
	Deposition of acid equivalents	X		X	
	Total	**4/6**	**2/6**	**5/6**	**3/6**
NEO-4					
pressure	Consumption	X		X	
	Production	X		X	
	Energy consumption	X		X	
state/impact	Phosphate concentration in soil	X		X	
	Health impacts of fine dust		X		• lack of measurements • ignorance
	Desiccation		X		• indeterminacy • natural randomness
	Total	**4/6**	**2/6**	**4/6**	**2/6**

TABLE 1 Overview of the results of the argumentation analysis

can conclude that the picture does not differ between the two Outlooks. If the selected conclusions could be considered as representative for the whole Environmental Outlook, this observation would suggest that the quality of argumentation did not substantially improve over time. However, the rather random selection of statements, the number of statements selected, the limited broadness of the performed vertical analysis in view of the available text and the fact that we have limited ourselves to the two recent Environmental Outlooks, do not allow us to address this hypothesis in an acceptable manner.

In the case of strong conclusions, uncertainty is usually acknowledged. In some cases, uncertainties can be clearly identified in the text, in the other cases they can in principle be deduced from a detailed analysis of the assumptions. However, the latter type of analysis requires expert knowledge on the topic. In the context of this case study, this implied that it turned out to be beyond our reach to assess which uncertainties are salient in view of the robustness of the conclusions. Furthermore, the consequence is that it is beyond the average reader's capabilities to understand which uncertainties are considered in the assessment.

In the case of weak conclusions, uncertainties are not recognised, with two exceptions; in the argumentation associated with the statement on economic development and on CO_2-emissions uncertainties are mentioned, although it is unclear how they are treated. We can only wonder whether uncertainty played a role in the analysed weak argumentation. However, our analysis of the weak conclusion on economic development as well as our analyses of the strong conclusions indicate that it is sensible to postulate that a systematic treatment of uncertainty could provide a basis for improvement of the transparency and quality of the argumentation.

The argumentation analysis yields as a general picture that uncertainty is not explicitly nor consistently considered in the Environmental Outlook reports. The vertical analysis did not allow us to recognise which uncertainties are salient to the assessment and how this uncertainty was managed in the underlying assessment process. We thus conclude that the Environmental Outlook reports are not transparent with regard to uncertainty. That does not necessarily mean that uncertainty was not addressed in the assessment process. It only means that the vertical document analysis does not allow us to fulfil two of the key aspirations of the case-study, i.e. to describe the state-of-the-art in rivm's uncertainty management and to provide an overview of uncertainties salient to the Environmental Outlooks.

3. Searching for sources of uncertainty

The consequence of the design of the vertical argumentation analysis is that we only accidentally traced particular sources of uncertainty. To complement this analysis, we decided to scrutinise the Environmental Outlooks again, but this time with the ambition to find concrete examples for each source of uncertainty[19]. In this way we can roughly assess whether in principle all sources of uncertainty played a role in the previous Environmental Outlooks. Box 3 reports the concrete examples for the various sources of uncertainty.

19 See Chapter 3A.

BOX 3 Sources of uncertainty

UNCERTAINTY DUE TO VARIABILITY

Randomness of nature

- '(..) it is not clear to what degree processes such as deforestation, the loss of species variety, acidification, desiccation, the spread of dust particles in the atmosphere, the damage to organisms by ozone at ground level or by UV irradiation, and the introduction of numerous exotic substances into the environment may change the feedback mechanisms in the global climate system' (NEO-2, p.23).
- 'It can therefore not be determined with sufficient certainty what those two trends (i.e. *check*) imply for the number of days with summer smog in 2020' (NEO-4, p.109).

Behavioural variability

- 'There is a great deal of uncertainty as to the degree to which farmers will be prepared to purchase manure from other farmers' (NEO-3, p.61)
- 'There is still little understanding of the degree to which provincial and local authorities (…) implement the adopted environmental policy (…)' (NEO-3, p.34).

Value diversity

- All estimates of future costs in the Environmental Outlooks involve a level of discounting, which by definition reflect differences in norms and values.

Societal processes

- 'No prognoses have been made for the future, partly in view of the uncertainty associated with international developments' (NEO-3, p.122).
- 'Future social developments are, of course, extremely uncertain, particularly when they concern a period of over a decade' (NEO-3, p. 33)

Technological surprise

- 'For trucks and busses it is assumed that emission levels are sharpened in 2000 (stage III). In view of technological uncertainties, stage IV levels have not been taken into account' (NEO-4, p.42).

UNCERTAINTY DUE TO LACK OF KNOWLEDGE

Inexactness

- 'With the current measures, a reduction of approximately 20% will therefore be possible' (NEO-2, p.231).
- 'Agricultural products, foods and fertiliser hold a 40 to 45% share in domestic road haulage' (NEO-3, p.44).
- 'The emission of phosphate increases in all scenarios over the period 1995-2000 with circa 20%' (NEO-4, p.86).

see over »

BOX 3

Lack of observations / measurements

- 'Since a complete overview of polluted locations does not exist, it is impossible to give a reliable picture of the size and costs of a soil cleanup operation' (NEO-3, p.21).
- 'In order to establish the current and future effects of the emission of gases at higher altitudes with more certainty, and particularly the impact of emissions of NO_x and H_2O, more information will have to be gathered about the processes (both chemical and physical) involved and about emission levels. Information on both issues is limited at the present time' (NEO-3, p.47).
- 'lengthy series of measurements of UV-radiation are not available' (NEO-4, p.162).

Practically immeasurable

- 'The health impacts of fine dust will decrease with 25% between 1995 and 2020 assuming that all components of fine dust are equally responsible for health impacts'[20] (NEO-4, p.110).

Conflicting evidence

- 'The composition of the imported animal feed will also change as a result of efforts to reduce the average phosphorus and nitrogen content of roughage. A start was recently made, but the available data about the results vary widely (...)' (NEO-2, p.108).
- 'It has been estimated that there may be 110.000 seriously polluted locations, for which the total cleanup costs would be NLG 50 billion. However, recent data point to even higher costs' (NEO-3, p.21).

Ignorance

- 'A lot of uncertainty still exists about the causality of the relationship between the aerosol air pollution and the different forms of health damage. (..) It is unclear which components of the mix are primarily responsible for the health effects, and which mechanisms play a role' (background document NEO-4, p.162).

Indeterminacy

- 'Important uncertainties for the future of the Dutch environment involve the development of world trade, European monetary and political unification, the rate of restructuring in Central and Eastern Europe and the expected international efforts to protect the environment' (NEO-3, p.34).

20 Informed by Rob Maas, this quote could be characterised as referring to uncertainty due to practical immeasurability.

This source-oriented document analysis indicates that all sources of uncertainty occur in RIVM's environmental assessments so far, although from such an analysis we cannot conclude whether all sources are salient[21]. The examples found for each source nevertheless seem to suggest that all sources of uncertainty at least to some degree matter in the environmental assessment, and may thus to a smaller or larger extent impact the policy conclusions. Furthermore, we did not find concrete examples of recognised uncertainty in any Environmental Outlook, which could not be straightforwardly classified according to our typology. This finding suggests that the typology of sources of uncertainty presented in this thesis has something to offer to the practise of decision-support.

4. Horizontal document analysis

As outlined in the previous Chapter, the aim of the horizontal document analysis was to compare the various Environmental Outlooks in order to understand whether and if so how, RIVM's approach to uncertainty management has changed over time. The horizontal document analysis comprised two types of analysis. First, we have compared the number and type of linguistic uncertainty expressions. Second, we have investigated the scenario approach applied in the four Environmental Outlooks.

4.1. LINGUISTIC ANALYSIS

The source-oriented document analysis as reported above already illustrates that linguistic expressions in the Environmental Outlook reports indicate uncertainty. Uncertainty due to inexactness is quantitatively expressed by margins, but linguistically by wordings such as 'roughly', 'approximately' and 'circa'. Phrasings like 'a possible trend', 'it is assumed' and 'it is not clear' indicate more structural uncertainty. Box 4 provides some illustrative quotes from the 3rd and 4th Environmental Outlook in which uncertainty is hinted at in a linguistic manner.

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21 It would of course have been very interesting to evaluate whether there has been a shift in the sources of uncertainty considered in the various Outlooks. This would have given some insight into how the salience of sources was evaluated. However, due to the fact that we could not list the uncertainties pertaining to the Environmental Outlook, as a consequence it was impossible to perform such an assessment of sources of uncertainty treated in the Environmental Outlooks over time.

BOX 4 Examples of linguistic expressions indicating uncertainty

Examples from the 3rd Environmental Outlook

- '*There are also great uncertainties* about the effectiveness of enforcement (...)' (NEO-3, p.43).
- '*There is still too little data* to allow a reliable opinion of the degree to which the agreed objectives will actually be achieved' (NEO-3, p.35).
- 'In ER, this growth is restricted to 35% between 1986 and 2010 and in GS to *over* 25% (NEO-3, p.42-43).
- 'The ozone layer above the latitude of the Netherlands *is expected* to become *at least* 10% thinner' (NEO-3, p.67).
- 'The banning of lead shot for hunting will cause a radical drop in lead (*approximately* 75%)' (NEO-3, p.102).

Examples from the 4th Environmental Outlook

- 'The private car use will increase between 1995 and 2020 with *roughly* 25 *till* 35% (...)' (NEO-4, p. 39).
- 'the production volume of the whole livestock will decrease with *circa* 10%' (NEO-4, p.47).
- 'In 2010 the emissions will be 52 *to* 55% less than in 1980 (...)' (NEO-4, p.85).
- 'The results of those two trends for the number of days with summer smog in 2020 can therefore *not be determined with sufficient certainty*' (NEO-4, p.109).
- 'This concentration leads to *approximately* 400 cases of lung cancer (...)' (NEO-4, p.113).

With the horizontal document analysis, we compared the use of linguistic expressions indicating uncertainty over the four Environmental Outlooks. We addressed this issue in two ways:

- we selected *two representative issues* addressed in all four Environmental Outlooks (i.e. demography (issue A) and local air pollution (issue B)) for which we compared the use of linguistic expressions hinting at uncertainty. We compared the average number of linguistic uncertainty expressions per effective page to investigate whether the relative use of linguistic uncertainty expressions varies over the different assessments. To that end, the total number of uncertainty expressions was divided by the number of effective text pages. The latter implies that the number of pages was corrected for graphs, figures and tables (see Table 2).

	sections on issues A and B	total effective pages
NEO-1	**A** Demographic developments p.14-17	*7 2/3*
	B Air pollution inner city p.312-322	
NEO-2	**A** Demographic developments p.49-52	*7 5/6*
	B Air pollution in towns p.390-399	
NEO-3	**A** Population p.37-38	*1 2/3*
	B Local air pollution p.122-123	
NEO-4	**A** Population and consumption p.25-28	*3 1/3*
	B Air pollution (urban area) p.108-110	

TABLE 2 Location and number of effective text pages

- we counted the word 'uncertainty', and other directly related words as 'uncertain', 'uncertainties' and 'not certain' in the *Summary Chapter* of each Environmental Outlook. We compared the relative occurrence of 'uncertainty' per effective text page ('uncertainty density') for all four National Environmental Outlooks.

Table 3 summarises the results of the linguistic analysis for the two selected issues, while Table 4 reports the analysis of uncertainty-expressions in the Summary Chapters. Furthermore, Figure 6 shows the uncertainty-density deduced from the latter analysis.

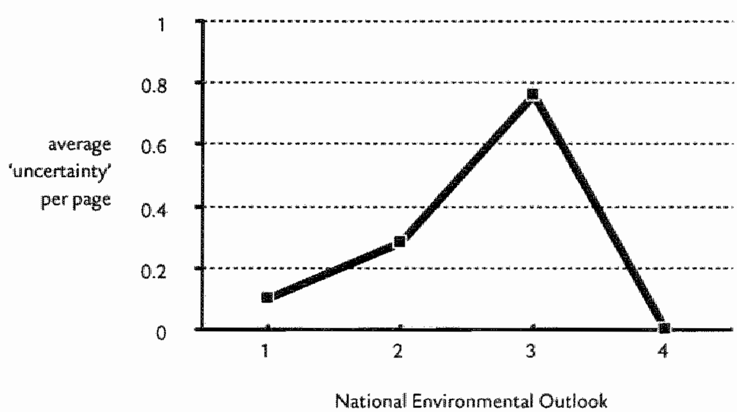

FIGURE 6 Uncertainty density in the summary chapters

Linguistic expressions which..	NEO-1		NEO-2		NEO-3		NEO-4	
...indicate uncertainties	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
It is expected / expectation / expects	2	1	7		3		1	
It is estimated /estimation / estimate	2				2	1		
It is assumed / assumption / assume	1			2				1
.. can not be assessed with a certain level of certainty								1
There is a great deal of uncertainty						1		
It is difficult to describe		1						
It is hard to predict		1						
Not clear is		1						
The uncertainty is		1						
total	5	5	7	2	5	2	1	2
total indications of uncertainties	10		9		7		3	
...indicate estimations	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
Almost	1		2					
Over	1	2	2		3			
Approximately			4		1			
More than			1					
Around			1					1
Probably			1			2	1	
Considerably			1					
At least				1				
At most	1							
More than		2		1		1		
Less than						1		
Somewhere between						1		
About				4		3		
Circa		5						2
Roughly								2
total	3	9	12	6	4	8	1	5
total indications of estimations	12		18		12		6	
ratio 'uncertainty' versus 'estimations'	5:3	5:9	7:12	2:6	5:4	2:8	1:1	2:5
ratio 'uncertainty' versus 'estimations' - A + B	10:12		9:18		7:12		3:6	
total expressions	8	14	19	8	9	10	2	7
total expressions - A + B	22		27		19		9	
number of effective pages	7 2/3		7 5/6		1 2/3		3 1/3	
average number of linguistic expressions per page	2.9		3.4		11		2.7	

TABLE 3 Results of issue-oriented linguistic analysis

In the issue-oriented linguistic analysis, we distinguished two sorts of linguistic expressions, i.e. estimations indicating unreliability, and uncertainty expressions hinting at structural uncertainty. Comparison of the ratio between 'indication of uncertainties' vs. 'indication of estimations' for the two issues together and the total indications of the two types of linguistic expressions seem to suggest that linguistic expressions involving estimations appear more often. However, this picture is not convincingly confirmed if we consider the ratios per Environmental Outlook per issue. In the case of local air pollution, unreliability is more often expressed then more structural uncertainty in all Environmental Outlooks. In the case of demographic developments such a conclusion cannot be drawn: the ratio of the sort of linguistic expressions suggests that structural uncertainty in the 1st and 3rd Environmental Outlook slightly dominates, while the 2nd Environmental Outlook indicates the opposite. These observations suggest that it seems impossible to infer from such a linguistic analysis which type of uncertainty is salient in the assessment of a particular topic.

If we take the Environmental Outlooks as adequate representations of the state-of-the-art knowledge, the results presented in Table 3 do not allow to judge from the number of linguistic expressions whether either demographic developments or local air pollution involve more uncertainty. The number of uncertainty expressions and the ratio between the two types of uncertainty expressions in the 2nd Environmental Outlook suggest that demographic developments are more uncertain, while the outputs of the linguistic analysis of the other Environmental Outlooks would lead to the opposite conclusion.

Building upon the above observations, we argue that there has not been a consistent RIVM strategy whether and how often uncertainty is expressed in the literal text. The linguistic analysis seems to suggest that is more a matter of individual style and preference.

Table 3 reveals that both in absolute and in relative terms the 4th Environmental Outlook involves significantly less linguistic expressions indicating uncertainty, whether unreliability or structural uncertainty, than the earlier Environmental Outlooks. This issue-oriented horizontal document analysis suggests that the 3rd Environmental Outlook report is in its phrasing the most conscious about uncertainty. The average number of linguistic expressions per effective text page in the 3rd Environmental Outlook is more than three times the uncertainty density of the previous Environmental Outlooks and is more than four times of its successor's uncertainty density. It is rather unlikely that the assessment at the time of the 3rd

Environmental Outlook was so much more uncertain than the other environmental assessments. If we compare the uncertainty density over time, we see a slight increase between the 1st and 2nd Environmental Outlook, then an extraordinary peak, and then a decline to an uncertainty density below the level of the 1st Environmental Outlook.

The above picture is confirmed by the summary-oriented linguistic analysis (see Table 4 and Figure 6). In the summary of the 1st Environmental Outlook uncertainty was only once explicitly mentioned. The 2nd Environmental Outlook contains 5 explicit uncertainty expressions in its summary, while 11 of such expressions where found in the summary of the 3rd Environmental Outlook. In the most recent Environmental Outlook **no** uncertainty-expressions were found. The 3rd Environmental Outlook thus communicates uncertainty significantly more explicit than any of the other environmental assessments, both absolutely and relatively speaking.

uncertainty-expressions	NEO-1 'Summary' p.VIII-p.XXVIII	NEO-2 'Summary' p.11-p.39	NEO-3 'Summary' p.9-p.27	NEO-4 'Summary' p.11-p.19
Uncertainty		2		
Uncertain	1		3	
Uncertainties		3	8	
Not certain				
total number of uncertainty-expressions	**1**	**5**	**11**	**0**

TABLE 4 Results of the linguistic analysis of the summaries

As already argued above, the results of horizontal linguistic analysis suggest that the number and the sort of linguistic expressions in the Environmental Outlooks is not indicative of the degree of uncertainty involved in the assessment. We conclude that the linguistic approach to uncertainty is not a systematic strategy employed by RIVM.

We might consider the number of linguistic expressions primarily as an indication of RIVM's attitude towards uncertainty. This means that the horizontal analysis can be used to explore potential attitudinal change since the 1st Environmental Outlook. In case of an open attitude towards uncertainty, we would expect that the word 'uncertainty' would occur in the text of the Environmental Outlook. If we take that view, the above results suggest that RIVM was paying increasing attention towards uncertainty in its summary texts as well as in the selected issue text between

1988 and 1993. Both in the text on the selected cases and in the summary text of the 3rd Environmental Outlook (1993), the average number of uncertainty expressions was about 3 times as high as in the other Environmental Outlooks. This suggests that in 3rd Environmental Outlook, RIVM expressed an unusual openness and tolerance towards uncertainty in its phrasings. The upward trend broke after the 3rd Environmental Outlook. Our analysis seems to suggest that, as a conscious or unconscious (over)reaction, uncertainty expressions were avoided in the 4th Environmental Outlook. If we take the above numbers of uncertainty expression as indicator for attitude towards uncertainty, the results of our linguistic analysis suggest that RIVM at the time of the 4th Environmental Outlook (1997) had a less open attitude towards uncertainty than about a decade earlier when 'Concern for Tomorrow' was produced. This observation sounds quite counter-intuitive, and it is not confirmed by the argumentation analysis[22]. The value of this inconsistency is that it indicates again that it is not at all straight forward to deduce uncertainties and how they are treated from the Environmental Outlook reports.

4.2. ANALYSIS OF THE SCENARIOS

So far, we have focused on argumentation and text analysis. Another way to get insights into RIVM's uncertainty management by means of document analysis is to focus on their scenario-approach and the quantitative outcomes associated with the scenario-analysis. As argued in Chapter 3A, scenario approaches are used in scientific assessments as method for uncertainty analysis[23]. Especially in the 3rd and 4th Environmental Outlook, it is *argued* that the scenarios cover the uncertainty concerning future societal developments, as is illustrated by the following quotes:

'The uncertainty concerning future social developments, including economic growth, is clearly shown in two contrasting future scenarios' (NEO-3, p.9).

'Given these uncertainties, a frame of reference is essential. ER and GS determine this frame of reference within which the CPB suggests future economic developments are likely to take place (NEO-3, p.34).

'To do justice to the uncertainties, three scenarios are developed. The scenarios differ in assumptions pertaining to global economic developments, demographic and socio-cultural developments, and technology development (NEO-4, p.21)

22 And also not by the other document analyses reported in the remaining of the Chapter.

23 See Chapter 3A for a discussion on strengths and weaknesses of the scenario approach to uncertainty analysis.

The key question is whether these scenarios cover the *full* range of scientifically legitimate interpretations of the salient uncertainties adequately. The next question is whether the scenarios have been systematically used to explore the uncertain future and to assess the robustness of conclusions and recommendations.

The use of scenarios in the four Environmental Outlooks has already been discussed in Chapter 6, because this overview was needed as background for the vertical argumentation analysis. The essence of scenario-methodology[24] is that in view of uncertainty multiple possible futures are developed and considered in the assessment. The 1st and 2nd Environmental Outlook did not employ a scenario-approach, because only one of possible pathways into the future was taken into account. In other words, uncertainty about future economic and technological development was acknowledged, but actually denied in the assessment itself. The (adapted) Medium-Growth scenario was in practise used as prediction, which is in full contrast with the argument underpinned in this thesis that prediction in case of complex issues is principally impossible.

Against that background, the scenario-approach adopted in the 3rd Environmental Outlook was a more fundamental change in RIVM's uncertainty management, than we had assumed at first sight. In the 3rd Environmental Outlook, two scenarios, i.e. tailored versions of the European Renaissance and Global Shift, were used throughout the assessment. This scenario-approach was explicitly motivated with reference to inherent uncertainty, as the following quote indicates:

> *'Future social developments are, of course, extremely uncertain, particularly when they concern a period of over a decade. However, possible coherent and consistent future scenarios can be sketched as the Central Planning Bureau (CPB) has shown in its recent long-term studies. The CPB has sketched four scenarios for the long-term development of the world economy, each based on a different vision of the economy and the role the government plays in it: Balanced Growth (BG), European Renaissance (ER), Global Shift (GS), and Global Crisis GC) (..) Current environmental policy is extremely different from the policy foreseen in this BG global scenario, which makes BG less suitable as a reference scenario for policy assessment. The Global Crisis scenario is also less suitable in this respect, based as it is on a lack of international co-operation, as is Global Shift' (NEO-3, p.33)*

24 See also Chapter 2 and Chapter 3A.

Still, scenarios were not used to assess policy options against a wide variety of possible futures. As follows from the above quote, the two scenarios were selected, because they were evaluated as the most likely. In that sense, the scenario-approach adopted in the 3rd Environmental Outlook still suffuses positivist elements. The 4th Environmental Outlook utilised 3 scenarios. It was explicitly recognised that two scenarios were not enough to manage uncertainty adequately throughout RIVM's environmental assessment, as can be inferred from the following quotation:

> *'To do justice to the uncertainties, three scenarios are developed. (..) The scenarios Divided Europe (DE), European Co-ordination (EC) and Global Competition (GC) (..)' (NEO-4, p. 21).*

We thus observe that the number of scenarios has increased over the series of Environmental Outlooks, which means that a broader set of possible futures is taken into account. The next question is whether the scenarios used cover the range of possible futures relevant for the environmental assessment. The scenarios in the 3rd and 4th Environmental Outlook are predominantly oriented towards economy, population, and technology. These scenarios differ in assumptions pertaining to global economic developments, European economic and political developments, technology, and demographic as well as some social-cultural developments.

Assumptions World	DE	EC	GC
Economic main point	USA, Japan, DAE[25]	EU, Japan, DAE	unchanged
Liberalisation markets	only outside Europe	only inside blocks	global
Assumptions Europe			
European integration	slow, fragmentation	more speeds	à la carte
European energy-taxes	no	$ 10 per barrel	no
Migration to EU	low	relative high	moderate
Technological development and diffusion	slow	moderate	fast
Technological focus-fields	unchanged	social	market-orientated

TABLE 5 Main characteristics of the three scenarios

It is clear that the scenario-approach plays a crucial role in RIVM's uncertainty management. The key question then is whether the scenarios cover the social, economic and institutional uncertainties salient to RIVM's environmental assessment. An analysis of the scenarios developed by CPB in the context of a review of European scenarios[26] indicated that the variety expressed by the set of scenarios is quite limited.

25 Dynamic Asian Economies
26 (van Asselt et al. 1998)

The scenarios used in the 3^{rd} and 4^{th} Environmental Outlook presuppose a linear relationship between economic growth and technological development[27]. A high economic growth implies more funds for technology and thus more technology-improvement also in the realm of energy-efficient and environmental technology, which will cause the physical growth of the economy to stay behind the monetary growth rate. The postulated relationship implies that a lower economic growth is associated with fewer funds for technology, and thus less "eco-technology". The consequence is that a low-economic-growth future is associated with a relatively high physical growth of the economy. This means that none of the scenarios developed by CPB involves a future in which economic growth is not a condition for technology improvement, but in which more environmental-friendly lifestyles are adopted, and available technology innovations are applied on large scales. This would result in a scenario with a low economic growth and a physical growth that is lower than assumed in the set of CPB-scenarios. The set of scenarios used in the previous Environmental Outlooks furthermore denies a future in which the physical economic growth accelerates, because potential investment funds are not used for "eco-technology", but solely to increase the short-term wealth of the shareholders and to afford more materialistic lifestyles. Such a future would imply a scenario with a high economic growth, both in monetary and in physical terms. The latter two legitimate scenarios seem to be relevant for RIVM's environmental assessment, because of the severe implications in terms of environmental impacts and thus in the policy recommendations.

Another problem with RIVM's scenario-approach can be deduced from the argumentation analyses on economic development. It was concluded that although physical growth is considered as the most relevant indicator for environmental pressure, it was the monetary growth (i.e. GNP) that was used throughout the Environmental Outlook. So apart from the problems with the scenarios, it seems that associated future outlooks in terms of physical growth are not adequately considered in the assessment.

We conclude that the scenario-approach adopted in 3^{rd} and 4^{th} Environmental Outlook did not systematically reason from the question which uncertainties are salient to assessing the state-of-the-environment. The scenario-approach seemed to be dictated by the CPB's perspective on economic futures.

27 To a certain extent it seems legitimate to relate autonomous technological change in terms of efficiency to economic growth (Jan aRotmans personal communication). What we question here is that all three scenarios involve the assumption that all technological development is a linear function of economic development.

The consequence of a scenario-approach to assessment is that the quantitative conclusions are in principle expressed with margins, because of the difference between the outcomes associated with the various scenario runs. In order to understand whether uncertainty has increased or decreased over time, we compared the smallest and the largest uncertainty ranges found in the Summary Chapters in the four Environmental Outlooks. The following quotes indicate the extreme margins per Outlook:

ENVIRONMENTAL OUTLOOK 1

- *"With a high economic growth, an increase in the global energy use of* **2 – 2.5 %** *per year is expected." (NEO-1, p.21)*
- *"To prevent health damage by ozone, it is necessary to achieve a drastic reduction of acidifying emissions of about* **70-90%**.*" (NEO-1, p. 22).*

ENVIRONMENTAL OUTLOOK 2

- *"In 2010 there will be an estimated* **35%-40%** *less energy" (NEO-2, p.12).*
- *"The consumption of energy and raw materials will increase by* **10%-20%***" (NEO-2, p.12).*

ENVIRONMENTAL OUTLOOK 3

- *"The number of private vehicle kilometres could end-up* **10%-15%** *higher" (NEO-3, p.12).*
- "The number of breeding pigs and chickens will fall by ***10%-40%***, depending on the amount of manure distributed within the Netherlands" (NEO-3, p.14).

ENVIRONMENTAL OUTLOOK 4

- "(...) the energy consumption of the households increases between 1995 and 2020 with ***60%-140%*** in case of unaltered policy, the use of private cars increases with ***15%-25%***, the aviation with ***140%-300%*** and the total household waste with ***15%-35%***" (NEO-4, p.12).

The ranges reported in the 1st Environmental Outlook range from 0.5 to 10% (i.e. 2.5% - 2% = 0.5%, and 75%-65%= 10%). In the 2nd Environmental Outlook the spread in ranges is somewhat more condensed to 5% to 10% (i.e. 40%-35%=5%, and 20%-10%=10%). In the Summary Chapter of the 3rd Environmental Outlook, the smallest margin also comprised 5% (i.e. 15%-10%), while the largest margin had grown to 30% (i.e. 40%-10%=30%). The 4th Environmental Outlook, however, denoted consequently larger ranges. The margins reported ranges from 10% (i.e. 25%-15%=10%) till 160% (i.e. 300%-140%= 160%).

This could mean that the uncertainty has increased over time. Testing this potential explanation is beyond the scope of the study. However, if such a dramatic increase in uncertainty in the underlying knowledge has occurred compared to the previous Outlook, one would expect that such a difference is explicitly acknowledged and explained. This is, however, not the case[28].

To get more insight into the development of uncertainty ranges over time, we decided to further analyse the margins expressed for ten issues covered at least in the latter two Environmental Outlooks. To that end, we compared the distance between future trends in terms of total magnitude of the margin[29]. Because the 1st and 2nd Environmental Outlooks use only one scenario, and thus report only one pathway into the future, the total magnitude of the margin equals zero. The latter can also occur, if the outputs associated with the various scenarios overlap, as is, for example, the case in the quantitative estimates in the 3rd Environmental Outlook concerning livestock volume, NH_3-emissions and CH_4-emissions. Table 6 reports the results of this comparison-exercise.

	total magnitude of margin				**ratio**
issue	*NEO-1*	*NEO-2*	*NEO-3*	*NEO-4*	*NEO-4 / NEO-3*
Economic growth	0	0	19	27	1.42
Energy consumption	0	0	7483	9102	1.22
Transport volume	0	0	413	825	2.00
Private car use	0	0	65	83	1.28
Livestock volume	-	-	0	10375	(10375)
NH_3-emission	0	0	0	135	(135)
CH_4-emission	-	-	0	465	(465)
CO_2-emission	-	0	280	315	1.13
Deposition acid equivalents	0	0	413	1113	2.69
Noise nuisance by civil aviation	0	0	1.9	7.5	3.95

TABLE 6 Results of comparison of quantitative forecasts over ten selected issues

From this Table it can be concluded that the uncertainty ranges consistently increase between the 3rd and 4th Environmental Outlook. As the ratio in the last column indicates, the degree of uncertainty (as expressed by the total magnitude of the margins) increased over all selected issues. The increase differs from about 15% larger margins to four times the 3rd Environmental Outlook uncertainty range. The comparison of quantitative forecasts for the ten issues reinforces the observation that the uncertainty ranges expressed in the 4th Environmental Outlook are significantly

28 Compare also the results of the linguistic analysis.
29 See Chapter 6 and (Langendonck 1999) for a more detailed discussion of the method employed to calculate these total magnitudes.

larger than in the previous Environmental Outlooks. It is interesting that this increase in quantitative uncertainty assessment is observed both on the level of the Summary as well as consistently for selected issues.

The increase in margins over time, i.e. the sprinkler-effect, has also a problematic dimension. Very large margins, such as the reported 140-300%, become meaningless in communication terms. The increase in margins cannot continue indefinitely, because it will eventually deprive the Environmental Outlooks of its decision-support dimension. Uncertainty management should be more then ever-increasing margins; it should provide information on robust policy strategies.

To get some more insight into the above issue, we thought to compare uncertainty ranges in inputs versus those in outputs. The broader ranges are partly due to the larger set of input scenarios that have been considered in the 4th Environmental Outlook. Initially, our evaluation was that the uncertainty ranges associated with the outputs are consistently smaller than those of the inputs, of which the latter can be directly associated with the scenarios (see Box 5). At first sight, one would not expect that the output margins are smaller, due to accumulation of uncertainty throughout the causal chains. Because of delays and non-linearity, such as buffering effects, it is possible that the margins shrink during the analysis[30]. Ideally, the uncertainty ranges should have been explained in terms of causes (what is due to the scenario-input, and how much originates from uncertainty assessment in the environmental causal chains) in the Environmental Outlooks themselves. This is however not the case. This implies that an analysis of the increase in uncertainty ranges would necessitate at least analysis all underlying (model) calculations, a qualified assessment of the outputs, a sensitivity analyses on the full model chain and an overview of the outputs of the performed uncertainty analyses. Evaluation of the Environmental Outlooks and the background reports teaches that a detailed analysis of how much of the uncertainty ranges is due to the scenario-input implies that the assessment processes of the 3rd and 4th Environmental had to be repeated, which is of course practically impossible.

It seems legitimate to conclude that if the margins in the outputs are smaller than those associated with the scenario-input, that the scenarios predominantly explain the uncertainty ranges in the output, and that the contribution of uncertainty in the environmental assessment itself is marginal. This would imply that either the uncertainty pertaining to the environmental chains is marginal, or that

30 As argued by RIVM experts in the interviews and in the focus group.

uncertainty pertaining to the environmental chains is not systematically and not adequately managed.

BOX 5 Analysis of margins

Figure 7 indicates the margins presented for some representative pressure issues, which can be considered as inputs, and some state/impact issues, which can be considered as outputs, i.e. calculated in rivm's assessment process[31]. We have compared the relative uncertainty ranges, i.e. the absolute numbers and units were not taken into account. Table 7 summarises the comparison between the uncertainty ranges reported in the 3rd and 4th Environmental Outlook.

	uncertainty range	
issues	*NEO-3*	*NEO-4*
pressure		
Economic growth	22.0%	37.5%
Energy consumption	9.3%	14.6%
Transport volume	7.8%	12.1%
Private car use	3.1%	2.0%
Livestock volume	0%	11.3%
mean	**8.4%**	**15.5%**
state / impact		
NH_3-emission	0%	3.4%
CH_4-emission	0%	4.6%
CO_2-emission	4.5%	9.1%
Deposition acid equivalents	1.2%	6.4%
Noise nuisance by civil aviation	1.8%	14.3%
mean	**1.5%**	**7.5%**

TABLE 7 Uncertainty ranges for representative pressure issues ('inputs') versus state/impact issues ('outputs')

Both the graphs and Table 6 indicate that the reported uncertainty ranges associated with inputs are on average smaller than the uncertainty ranges reported on outputs.

see over »

31 For a full overview of all margins considered see (Langendonck 1999) and (van Asselt et al. 2000 (in preparation))

BOX 5

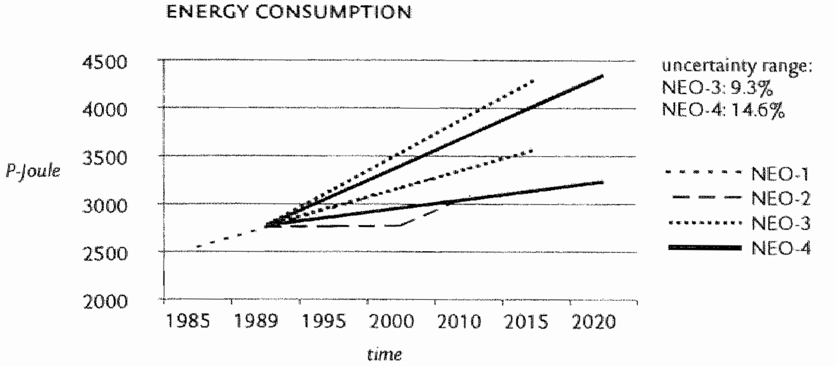

FIGURE 7A Example of margin pressure issue

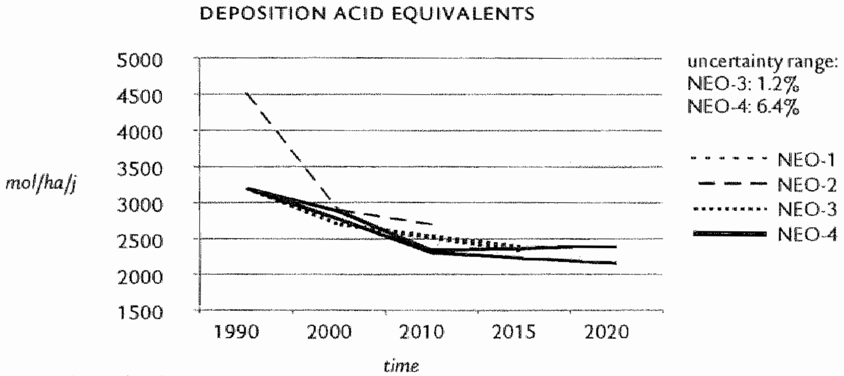

FIGURE 7B Example of margin impact issue

The analyses on the scenario-methodology, the scenarios employed and the evolution in quantitative uncertainty ranges seem to suggest that uncertainty pertaining to social and economic uncertainty is receiving more attention in RIVM's environmental assessment, which observation seems to be at odds with the results of the argumentation and linguistic analyses. Furthermore, the above analysis on the scenarios employed in the series of Environmental Outlooks also raises serious questions with regard to the adequacy of the actual scenario methodology as uncertainty method. It can be argued that after all the scenario methodology is not systematically used as method for uncertainty management, but more as a way to consider some pathways into the future that are known in the Dutch policy arena. The latter notwithstanding the explicit claim made in the Environmental Outlooks that the scenarios are employed to do justice to uncertainty.

4.3. RIVM'S UNCERTAINTY MANAGEMENT AS DEDUCED FROM THE DOCUMENT ANALYSES

The general questions framing the document analyses pertained to RIVM's attitude towards uncertainty and to the actual uncertainty management employed in the Environmental Outlook process. What picture do the above document analyses yield?

A change in attitude towards more uncertainty consciousness and tolerance is not consistently observed in our document analyses. As reported in the previous section, the text analyses indicate that the 4th Environmental Outlook suffuses a less open attitude towards uncertainty than its successors. Also, the argumentation analysis does not reveal a significant increase in RIVM's attitude towards uncertainty. On the other hand, the investigation into scenarios and uncertainty ranges seem to suggest some attitudinal change to more uncertainty consciousness and tolerance. The result of this tension is that RIVM's communication about uncertainty is very ambivalent, if not inconsistent. The messages on uncertainty expressed by linguistic expressions fundamentally conflicts with those associated with the quantitative conclusions. To give an example: the word 'uncertainty' is not even mentioned in the summary of the 4th Environmental Outlook, whether it is at the same time expressing margins up to 160%, which range in common language communicates that it is more uncertain than fully uncertain.

The conclusions with regard to RIVM's uncertainty management as deduced from both the horizontal and vertical document analyses of the four Environmental Outlooks are:

- the Environmental Outlooks involve weak argumentation (i.e. adequate argumentation and information justifying the conclusions is lacking)[32]
- the Environmental Outlooks are not transparent with regard to uncertainty; it is impossible to discover which uncertainties played a role (or should have played a role) in the assessment and how they are managed throughout the underlying assessment.
- uncertainty is not consistently, nor systematically treated in the Environmental Outlooks; there seems to be no strategy for uncertainty management.

32 This has just been proven for the 3rd and 4th Environmental Outlooks, but it seems logical to suppose that it also holds for the 1st and 2nd Environmental Outlook.

- the set of scenarios employed is inadequate in view of the aims associated with an Environmental Outlook.
- uncertainty is communicated in a confusing, and even inconsistent, manner.
- although the Environmental Outlooks show some traces of a growing uncertainty consciousness, the paradigm most associated with the Environmental Outlooks is clearly positivism.

In view of the above, we conclude that the way uncertainty is dealt with in the Environmental Outlooks is problematic. As a consequence, RIVM is very vulnerable to criticism targeting uncertainty, even in cases the critic is wrong. Our document analysis thus provides an explanation why affairs like De Kwaadsteniet-affair could happen and could persist for such a long time. An environmental assessment that involves systematic, consistent and adequate treatment of uncertainty, transparent and clear communication on uncertainty, and strong argumentation is much more difficult to discredit.

5. Empirical research

From the extensive document analyses we concluded that uncertainty was not systematically treated in the four Environmental Outlook *reports*, but this doesn't necessarily mean that it was not systematically treated in the underlying assessment process. We could not deduce how uncertainty was managed in the assessment underlying the Environmental Outlook. We therefore decided to use practitioners in the previous Environmental Outlook processes as another source of information. As argued in the previous Chapter, a number of responsible RIVM people has been interviewed[33], a focus group session[34] has been performed and questionnaires[35] have been distributed among analysts in the current Environmental Outlook process, of whom the majority has participated in previous assessment processes. This empirical research output[36] was analysed to address the following research questions:

- how was uncertainty managed in the previous environmental assessment processes?
- whether, and if so why and how, the attitude towards uncertainty and uncertainty management has changed over time?

33 See (Langendonck 1999; van Asselt et al. 2000)
34 See (van Asten 2000)
36 Preliminary analyses of the empirical output were presented in (van Asselt et al. 1999) and van (van Asten and van Asselt 1999)

- which sources of uncertainty relevant to the assessment process are recognised by the experts themselves?
- whether there is a (potential) need for a new or complementary approach for uncertainty management among RIVM practitioners?

5.1. UNCERTAINTY IN THE ENVIRONMENTAL OUTLOOK PRACTISE

Our respondents argued that it was an explicit choice of the management of the Environmental Outlook not to bother the readers too much with uncertainty. The interview data yielded that this attitude can be explained by the idea that policy-makers cannot handle uncertainty. As a consequence, the respondents argued, uncertainty is only mentioned in the Environmental Outlook reports in case it is estimated by RIVM to be salient to the policy recommendations. Uncertainty ranges were thus only presented in the Environmental Outlooks in case RIVM was convinced that the uncertainties substantially influenced the conclusions, and thereby had consequences for the policy recommendations. There were no explicit criteria that facilitated this selection; in the interviews it was explicitly stated that the evaluation of the policy relevance of uncertainty was a rather intuitive process. Some heuristic rules involved that uncertainty is more important in case forecasts come close to the targets, and in case trends are unclear. The following examples were provided during the interviews:

- "In the time of the 1st Environmental Outlook, the emission levels were so high that they anyhow had to substantially decrease. At that moment, precision was not important i.e. in such cases it is not significant whether the emission have to decrease with 70%-80% or 83%. (..) Now, for some substances (SO_2) for which targets are almost reached, it is interesting to assess whether it is efficient to continue with the policy. The last percentages of reduction have to be studied more precisely."
- "It is important to describe the trend correctly. (..) For example, an expectation is that the forest will decrease with 35-43%. In this case this range is not important, because the conclusion is that the forest decreases. But when you are not sure about the direction of the trend, (..) the ranges become more important."

Furthermore, how uncertainty was dealt with also seemed to relate to the level of impact. The rule of thumb used seemed to be, as one of the interviewees phrased it:

> "you can better forecast something disastrous with a big uncertainty than something harmless with less uncertainty".

This implies that uncertainty is used as a kind of heuristic.

The above implies that almost by definition the Environmental Outlook reports do not reflect how uncertainty is dealt with in the assessment process. The interviews, the focus group and the RIVM report describing its practice, which was produced during our case-study as RIVM's official response to the media and political pressure[37], taught us that uncertainty in the Environmental Outlooks was addressed in the following ways:

QUANTITATIVE METHODS FOR UNCERTAINTY ANALYSIS

- economic-technological scenarios, sometimes complemented with specific model simulation runs (such as with low and high energy prices)
- sensitivity analysis on inputs[38] for individual models[39] (reported in research reports)
- uncertainties in parameter values are checked by means of standard uncertainty analysis techniques

QUALITATIVE APPROACHES

- expert judgements
- consensus formation with other institutes (like the Central Economic Planning Office (CPB))
- contra-expertise, from external experts like the Royal Institute for Metrology (KNMI)
- internal and external reviews

PRESENTATION APPROACHES

- the word 'prediction' is taboo
- linguistic expressions
- graphical representations such as blocks instead of smooth curves and uncertainty ranges
- careful with the presentation of maps, because maps suggest certainty

With regard to statistical analysis, some of the respondents argued that pure statistics cannot be applied in a prognostic manner, and that therefore statistical methods

37 (RIVM 1999a; 1999b)

38 In the focus group, it was explicitly said that sensitivity analyses on model parameters in the context of the Environmental Outlook assessment are rare.

39 It was explicitly said in the focus group, that a systematic sensitivity analysis for the modelling framework (i.e. the cascade of models) used in the assessment has never been performed.

played a minor role in the assessment process underlying the Environmental Outlooks[40].

The next question is how the above methods were applied. Expert judgements, internal expert discussions and consensus formation processes are usually not reported. There is a tendency to view the Environmental Outlooks as products of measurements and models; however, in the focus group it was argued that the most important ingredients are the brains and mental models of RIVM's analysts. Because of lateral thinking[41], the brainwork is not a linear step-wise process, and is thus anyhow difficult to report. Nevertheless, it was agreed that lines of reasoning are not adequately reported. The focus group discussion concluded that the use of RIVM's knowledge base and expertise is difficult to trace.

With regard to the actual use of quantitative methods, the discussions in the focus group made clear that within RIVM two groups of uncertainties are distinguished, i.e. societal uncertainties and uncertainties in the environmental system. Uncertainty in the environmental causal chains is not systematically addressed, which implies that accumulation of uncertainty is not analysed. The working hypothesis underlying the practise had it that because societal uncertainty dominates the major uncertainty with regard to the state-of-the-environment is already discounted for in the scenarios. From the focus group discussions, it can be concluded that this point of departure is currently highly debatable and questioned within RIVM. In the history of the Environmental Outlooks, it was never systematically analysed whether the models and theories utilised in the assessment process involved uncertainty. In the cases in which the impact of uncertainty in inputs was explored in the form of sensitivity analysis for particular models simulating parts of the environmental system, it has been done in isolation. In other words, interlinkages and interactions with other causal chains were not considered, nor were the cumulative effects of uncertainty throughout the whole environmental system addressed. In some cases, analysts experimented with worst-case scenarios beyond the CPB scenarios. However, full analysis of the consequences of such a worst case scenario was never performed. The respondents argued that the level of uncertainty is thus roughly known for the isolated components, in either qualitative or in quantitative terms. However, these uncertainties in the environmental system are not systematically accounted for in the overall assessment.

40 It is beyond the aim of the study and the expertise of the researchers to discuss this argument in-depth. However, it should be noted that this respondents' argument doesn't do justice to the current state-of-the-art in statistics (Jan Rotmans personal communication; see also the contributions of statisticians to the DeKwaadsteniet affair).

41 (de Bono 1968; 1969; 1970)

The document analysis yielded that scenarios were used as uncertainty method. This observation was confirmed by the interview data: the respondents argued that societal uncertainties are assessed by means of the scenarios. The document analyses taught us that the scenario method as employed turned out to be inadequate in view of the aims associated with the Environmental Outlooks. In the interviews, the question was therefore asked whether the respondents considered the scenarios used as an adequate treatment of the salient uncertainties. Both in the interviews and in the focus group, the adequacy of the CPB scenarios for the environmental assessment was questioned. A number of problems inherent to CPB's scenario methodology were brought to the fore. The CPB scenarios cover merely extrapolation of trends. Bifurcations and surprises are not considered, because the CPB models could not stand up to that kind of experiments. The resulting 'boring' character of the scenarios is questioned, as the following quote from the interviews yields:

> *"The past teaches us that developments are non-linear. The scenarios do not incorporate this lesson."*

Furthermore, the CPB-scenarios reasoned from the consumption-side, which means that developments in the production sectors were derived from GNP calculations. However, not all sectors are sensitive to variations in GNP. An example is the agricultural sector. The implication is that the variety of futures for the agricultural sector as derived from the CPB scenarios is quite limited. According to the focus group, starting from the production side would yield a broader variety of scenarios, which would be more distinctive for the environmental assessment.

It is furthermore discussed that the CPB scenarios involved certain assumptions that caused a narrowing-down of the future outlooks in terms of physical growth and emission patterns. The fixed relationship between economic growth and technology development[42] implies that the emission scenarios are condensed. Something similar holds for the assumed relationship between economic growth and population growth. Because of the actual Dutch population structure, the major uncertain variable is migration. CPB postulated that a high economic growth in the Netherlands correlates with economic growth worldwide, which will cause the economic stimulus for migration to weaken. As a consequence, the CPB forecasted either high economic growth - low population growth, or low economic growth and a relatively higher population growth. Such a set of scenarios implies that the range associated with the physical growth of the economy is narrowed down. A future that involves

42 See also discussion on the scenarios in the document analysis part of this Chapter.

high economic and population growth combined with limited technological development, implying that a scenario featuring an increase in pressure on the environment was ignored in the set of scenarios. The same holds for a future characterised by low economic and population growth combined with substantial technological improvement, esp. concerning environmental-friendly technology. Another crucial issue in the environmental assessment involves deposition patterns. These patterns are not only dependent on Dutch emissions. Emissions in other European countries, but with regard to particular substances such as ozone even emissions in other continents, are relevant to the assessment of the state of the Dutch environment. The scenario methodology as applied in the previous Environmental Outlooks merely accounted for one emission scenario that was derived from the emission estimates from the countries themselves. This means that severe uncertainties associated with the societal development in other countries were not considered.

Some of the above limitations of the scenario-approach confirmed our conclusions derived from the document analysis. In sum, in the light of RIVM's job to assess the future state of the environment, the scenarios used in the previous Environmental Outlooks suffered from the following disadvantages can be deduced from the case-study research:

- extrapolative, linear character of the scenarios
- consumption-driven calculation of production trends
- rigid assumptions with regard to relationships between economic growth, population development and technological innovation
- limited discount of radical uncertainty abroad
- the dominance of the scenario indicator GNP growth over physical growth in the use of the scenarios throughout the assessment

As a result, the variety of scenarios used in the Environmental Outlooks is far too limited to account for an adequate treatment of economic-technological uncertainties, let alone for relevant socio-cultural uncertainties. Building upon the focus group discussions, it can therefore be concluded that the adopted scenarios appeared to be an inadequate approach for managing societal uncertainty in RIVM's assessment. This kind of problems was never systematically considered in the collaboration between RIVM and CPB. The respondents argued that so far RIVM has behaved rather authority abiding, which resulted into uncritical use of the CPB scenarios in their environmental assessments[43].

43 The particular argumentation analysis on economic development as reported in the first part of this Chapter also reveals such an uncritical use of the CPB input.

The interviews and the focus group data (see Box 6) yield that the practitioners themselves concluded that uncertainty was not *systematically* managed in the Environmental Outlook assessment processes. This conclusion is reinforced by the output of the questionnaires among analysts involved in the 5th Environmental Outlook process.

BOX 6 Uncertainty in the assessment process: Interview, focus group and questionnaire data

SINGULAR QUOTES FROM THE INTERVIEWS

- "There could be more attention for uncertainty in the assessment".
- "We are not so attentive to uncertainty."
- "In all sincerity, uncertainty so far has played a minor role."
- "There is more sense about uncertainty than is written down in plain numbers and words."
- "If something is too uncertain, we don't mention it."

ANSWERS TO THE OPEN QUESTION:

Do you think uncertainty is adequately managed in the Environmental Outlook during the process and in the product?

- " We could do better. We talked about paying more attention to uncertainty in the Environmental Outlook, but you don't see that back. We are not real naturals in dealing with uncertainty. The Environmental Outlooks are in fact a summary of all available knowledge. (..) Also the other institutes (i.e. decision support institutes like the CPB, MvA) didn't find a way out either. It is not a matter of solution, but learning how to deal with it (i.e. uncertainty, MvA)."
- " In the Environmental Outlook, not enough. Maybe it is an unconscious fear to make them (i.e. uncertainties, MvA) explicit."
- "No, we can do better."
- "We think it can be done better, and that it therefore should be done better."
- "Yes, but we can always do better. But taking into account the time and the financial means, we are doing OK."

see over »

BOX 6

SINGULAR QUOTES FROM THE FOCUS GROUP IN THE ORDER OF THE DISCUSSION

- "It (i.e. paying explicit attention to uncertainty, MvA) indeed does not happen."
- "No, not systematically.
- "I know that it (i.e. how uncertainty is managed, MvA) is not explicitly written somewhere, so it is rather unlikely that it (i.e. managing uncertainty, MvA) is done."
- "Uncertainty in models or theories is not systematically analysed."
- "I may bother too less about the theory behind it (i.e. uncertainty, MvA), we are working intuitively." "Very intuitively."
- "We can doubt to what extent uncertainties manifest themselves in the scenarios."

In the *focus group* it was argued that the statements in the interviews expressing that uncertainty was adequately addressed in the assessment process, should be explained by wishful thinking.

THE LITERAL TEXT OF THE CONCLUDING REMARK IN THE FOCUS GROUP that was subscribed by all participants:

"It (i.e. managing uncertainty, MvA) is in any case not done in a systematic way, not explicitly either, I think..."

SCORES ON 5-POINT SCALE QUESTIONNAIRE ITEMS

Total number of respondents: 15

The questionnaire data[44] below indicate that the analysts involved in the 5th Environmental Outlook processes doubt that uncertainty was adequately managed in the previous Environmental Outlooks.

see over »

44 It could have been possible to use statistical methods for small samples to calculate the significance of the scores. It can be argued that this would have improved the argumentation, although it can be asked how much stronger it would have become (personal communication with Rob Hoppe). In other words, it is questionable whether it would have been worth the effort. On the other hand it would have suggested that the group of respondents is a small, but representative sample, which is not at all the case. The absolute frequency distributions that we used in our analysis of the survey data do far more justice to the exploratory character of our research and they provide enough information to illustrate our arguments.

BOX 6

0-2 | 3-4 | 5-6 | 7-8 | 9-10 | 11-12 | 13-15

	strongly disagree	disagree	neutral	agree	strongly agree
Uncertainties were treated adequately in the Environmental Outlooks.	1	2	8	3	0
Uncertainties were treated adequately during the Environmental Outlooks' process.	1	9	3	2	0
Uncertainties were treated adequately in the translation from process to product.	0	10	5	0	0
Uncertainty is important in the current Environmental Outlook practise.	0	1	2	8	4

The document analysis alone did not provide enough evidence that systematic uncertainty management lacked in RIVM's assessment practise. However, building upon both the document analyses and the empirical data, we can conclude that uncertainty was not systematically managed in both the assessment process and in the Environmental Outlook reports. A framework for uncertainty management was lacking. There was not a coherent strategy towards applying the recognised approaches and techniques for uncertainty analysis. Not all approaches were used purposively, consequently and consistently. The scenario-approach was used consistently throughout the assessment, but serious concerns question the adequacy of the set of scenarios used. In sum, we conclude that uncertainty did not get systematic attention in the series of Environmental Outlooks.

5.2. EXPRESSED ATTITUDE TOWARDS UNCERTAINTY

From the document analysis we have tried to deduce RIVM's attitude towards uncertainty. The document analyses showed an ambiguous picture. Nevertheless, building upon the observed increase in margins and the development in scenario-methodology, we postulated that RIVM's attitude towards uncertainty changed towards more uncertainty consciousness and tolerance. One of the aims of the empirical research was to test whether the attitude towards uncertainty has changed over time, and if so, how and why. It is the first time, however, that RIVM's attitude towards uncertainty is addressed by empirical research. This means that no longitudinal data is available. For that reason, it is difficult, if not impossible, to sketch a reliable picture of attitudinal change over the Environmental Outlook history. In the context of the case-study, we have followed two routes: i) the interviewees and the focus group were asked whether they perceived an attitudinal change over time, and ii) the current attitude towards uncertainty among practitioners involved in the Environmental Outlook assessments was tested in the interviews and questionnaires.

The interviewees agreed that uncertainty management had not fundamentally changed over time. Two of them saw no change at all, as is revealed by the following quote:

> *"I think nothing had changed, till two weeks ago (i.e. the beginning of the De Kwaadsteniet affair, MvA)."*

The other respondents thought some minor change took place. It was argued that at the time of Concern for Tomorrow the analysts were convinced that what they wrote was certain. With regard to the present situation, the respondents observed more communication about uncertainty. They considered the development in scenario-methodology as a change in the attitude towards uncertainty. These respondents also mentioned the role of the media affair as catalyst in the current attitude towards uncertainty:

> *"We will pay more attention to uncertainty. The media affair has definitely contributed to this..."*

These practitioners' assessment confirms the ambiguity revealed by the document analysis. This ambiguity may be interpreted as that uncertainty is bubbling under the surface and that it is becoming a theme in RIVM's assessments. This seems to imply that an attitudinal change is under way. With the available data, it is beyond the scope of this thesis to explain this postulated movement to change. In the following, we will focus on RIVM's current attitude towards uncertainty.

Table 8 shows the scores on a 5-points scale on items that tested the current attitude towards knowledge and uncertainty. The questions were derived from the theoretical detour reported in Chapter 3 to 5 of this thesis. The same closed questions were asked both in the interviews and in the questionnaire to allow for comparison.

From the Table, it can be concluded that the general attitude towards uncertainty and science as expressed by the respondents goes beyond the positivist attitude, because constructivist answers (i.e. "strongly disagree") dominate. On the other hand, the spread of the scores indicates that the collective expressed attitude involves

Statement	Interviews					Questionnaire Workshop				
	strongly disagree				*strongly agree*	*strongly disagree*				*strongly agree*
Knowledge is truth	1	5	1	1	0	6	7	1	1	1
Science is solving uncertainties	1	2	1	4	0	1	6	1	4	3
Not knowing is lack of knowledge	2	0	0	6	0	2	7	2	2	2
More knowledge implies less uncertainty	0	3	3	2	0	3	5	4	2	1
Uncertainty is poor science	4	4	0	0	0	12	2	1	0	0

TABLE 8 Expressed attitudes towards uncertainty

positivist elements (i.e. "strongly agree"), although not one of the respondents gave pure positivist answers (as can be deduced from the zeros in the strongly agree columns). The expressed attitude prevailing among this sample of RIVM practitioners involved can thus be characterised as rather constructivistic. This implies that recognition of uncertainty as inherent to science and scientific decision-support seems to be part of RIVM's culture.

Apart from their general attitude, the attitude towards uncertainty and uncertainty management in relation to the Environmental Outlooks was explored. Table 9 summarises the empirical data gathered via the interviews and the questionnaires. Because the results of the interviews informed the design of the questionnaire, some new questions were added to the questionnaire handed out

From the scores on the opinion questions, it can be deduced that transparency towards uncertainty is considered to be a quality improvement. The majority of the respondents furthermore agreed that making uncertainty explicit is not in conflict with the policy relevance of the Environmental Outlook. This is in flat contradiction with the 'publication strategy' that according to the respondents can be associated with the previous Environmental Outlooks. It was argued that with regard to the preceding assessments, it was the explicit choice not to bother the readers too much with uncertainty, because it was assumed that policy-makers cannot handle uncertainty. This implies that either the practitioners did disagree with the publication strategy, or there has been a fundamental change in reasoning about policy-makers, uncertainty and Environmental Outlook, or the respondents gave socially desirable answers in the survey. The fact that the majority of the respondents (see Box 6)

statement	interviews					questionnaire workshop				
	strongly disagree				*strongly agree*	*strongly disagree*				*strongly agree*
The more uncertainties are made explicit, the better the Environmental Outlook	1	3	0	3	1					
Making uncertainties transparent in the Environmental Outlook is at the expense of the quality	5	3	0	0	0	8	4	3	0	0
An Environmental Outlook full of uncertainties is irrelevant for the policy.	0	5	0	3	0	4	4	3	4	0
In the Environmental Outlook, more attention should be paid to uncertainty.						0	0	2	7	6
It is possible to make uncertainty explicit in the Environmental Outlook.						0	1	2	7	5
More external review is the solution to the uncertainty problem.						8	5	1	1	0
RIVM should measure more.						1	7	5	2	0
There is a need for another approach to manage uncertainty in the Environmental Outlook.						1	2	1	9	2

TABLE 9 Expressed attitudes towards uncertainty in the light of the Environmental Outlooks

were not satisfied with the treatment of uncertainty in the actual reporting of the assessment in the Environmental Outlook report seems to provide some support for the first argument. On the other hand, we should not forget that the interviews and survey were held during the De Kwaadsteniet affair. It might be the case that inspired by the exchange of arguments in the debate, RIVM practitioners have, consciously or unconsciously, reconsidered their thinking about uncertainty. On the other hand, the same debate and the political pressure at that time on RIVM could also imply that the statement that expressing uncertainty does not conflict with the policy relevance was implicitly or explicitly considered most socially preferred. As any interview or questionnaire research the empirical research discussed in the current Chapter also runs the risk of such biased responses. Nevertheless, the observed tension confirms RIVM's ambivalence towards uncertainty. It furthermore indicates how important the policy and political dimension of RIVM's position is to the assessment process and product[45].

45 As discussed in Chapter 1, it has been an explicit decision not to incorporate the policy and political dimension as research theme in the current PhD thesis. So we leave it with the above observation, and we do not go into any further reasoning about it.

Table 9 indicates that the majority of the respondents consider uncertainty an important issue that should receive more attention in the assessment. This attitude is also reflected by answers to open questions in the interviews, as is illustrated by the following quote:

> *"More attention could be paid to uncertainty in the assessment, and right away more attention could be paid to communication uncertainty in the Environmental Outlooks. The latter is the easiest. Reliability can be reflected in documents as the Environmental Outlooks with simple, editorial means. Besides, I think more uncertainty research can be done, or more should be measured."*

One of the research questions framing the empirical research has been our interest in identifying uncertainties salient to the Environmental Outlook assessment. It turned out that the document analysis of the series of Environmental Outlooks did not allow us to identify salient uncertainties. The source-oriented document analysis suggested that all sources of uncertainty play a role in the Environmental Outlook, however this analysis did not provide any clue which sources are crucial.

To that end, interviewees and the questionnaire respondents were asked to prioritise the sources of uncertainty in order of importance. Table 10 summarises the results.

sources of uncertainty	ranking in interviews						ranking in questionnaire*													
Behavioural variability	4	9	8	9	7	9	9	6	1	7	7	2	1	5	6	9	5	6	8	6
Societal randomness	5	6	9	7	8	8	8	7	1	7	7	1	1	4	6	5	6	9	7	1
Technological surprise	7	3	7	8	5	7	2	5	1	4	7	3	5	1	4	7	7	8	3	2
Conflicting evidence	9	5	1	5	9	5	7	1	3	5	7	5	1	9	1	2	8	2	1	7
Natural randomness	3	8	4	4	6	6	3	4	1	7	1	4	9	6	8	6	1	7	4	4
Value diversity	8	1	5	1	4	4	1	8	9	6	7	6	1	3	4	8	9	5	9	8
Inexactness	6	7	2	3	2	1	4	2	6	4	4	9	5	8	2	3	2	3	6	3
Lack of observations/ measurements	2	4	6	2	3	3	5	3	9	5	2	8	9	7	2	1	3	1	2	5
Practically immeasurable	1	2	3	6	1	2	6	9	9	6	3	7	5	2	9	4	4	4	5	9

LEGEND Scale 1-9, 1 highly important - 9 not important

*one respondent did not answer this survey question

TABLE 10 Ranking of sources of uncertainty in the interviews and questionnaires.

Taking the input of each respondent, whether manager, integrated assessor or disciplinary/sectoral expert, equally serious, each source has been ranked by one or more persons as being extremely important (i.e. 1s in each row). The spread in the scores in Table 9 – each source was also scored as not important (i.e. an 8 and/or 9 in each row)- furthermore indicates that there is no consensus what so ever about the salience of the various sources. Building upon these two observations, it is at least legitimate to argue that all sources are seem to be relevant to RIVM's assessment of the future state of the environment.

5.3. RIVM'S LEARNING PROCESS

Both in the scholarly literature on uncertainty[46] and in the interviews, it was noticed that consciousness on, and awareness of, uncertainty do not necessarily evoke that uncertainty is adequately addressed in the assessment. Taking this notion of phasing into account and in line with the steps proposed with the PRIMA-approach, it was postulated that uncertainty management involves a learning process in phases[47]. Taking the historical development on thinking about uncertainty and science into account, we sketched a transition from assessment in a positivist mood towards uncertainty management as central to the assessment (see Figure 8). In phase 1 uncertainty is qualified as 'bad work', which implies that uncertainty reduction is the key ambition. Awareness of uncertainty starts to develop in the second phase. In this phase uncertainty is becoming a theme on the assessment agenda, but it is not systematically addressed. Uncertainty is acknowledged, but it does not play a major role in the assessment. In the third phase, uncertainty is receiving more systematic attention. Instead of treating uncertainty as a black box, uncertainties are specified in terms of types and sources, which allows a more targeted use of available methods for uncertainty management. The 4th phase features the learning process in which the degree of uncertainty can be systematically assessed, preferably in quantitative terms. This implies that experts are trained to express their knowledge in terms of qualitative statements, or in terms of quantitative uncertainty ranges. Furthermore, uncertainty is not just assessed at the level of components, but at the level of the full assessment. Building upon the previous phases, phase 5 features a situation in which the policy relevance of specific uncertainties is not any longer assessed intuiti-

46 See especially (Funtowicz and Ravetz 1994)

47 It was suggested by Jan Rotmans that this learning curve in one way or the other relates to the phases in policy making as sketched in Chapter 2. Testing this hypothesis would necessitate theoretical and empirical research that is far beyond the current case-study.

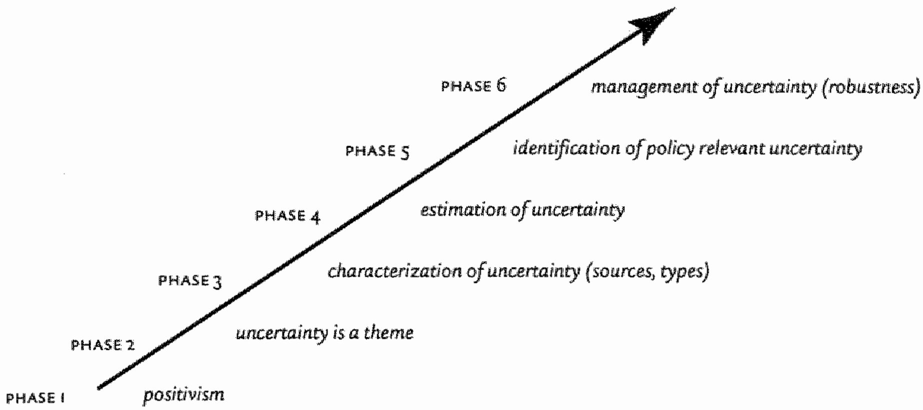

FIGURE 8 Learning curve in dealing with uncertainty

vely, but in a systematic manner sufficiently informed by the underlying assessment. In the final phase, uncertainty management is fully integrated into the assessment methodology and framework.

Informed by the case-study research, we tried to characterise RIVM's current attitude towards uncertainty in terms of this learning transition. That does not mean that every single RIVM practitioner is in that phase, but it indicates where RIVM's leading group is about. The expressed attitude as derived from the interview and questionnaire data implies that RIVM is beyond phase 1. The document analysis and the empirical research indicate that uncertainty is acknowledged, but that it is not yet systematically treated in the assessment. As discussed above, the interviewees were confronted with the typology of sources of uncertainty. We hypothesise that they recognised the various sources and felt themselves able to prioritise the various sources[48]. The document analysis also indicated that the uncertainties considered in the assessment could quite straightforwardly be characterised in terms of sources. On the other hand, the interviewees were invited to estimate in qualitative terms the degree of uncertainty for the various components in the causal chains, but it turned out difficult or even impossible for them to assess the degree of uncertainty in relative terms. From this observation we conclude that RIVM is not (yet) in phase 4. From this induction, we can conclude that the current attitude towards uncertainty in the

48 It could be argued that the interviewees performed prioritising the sources of uncertainty as kindness to the interviewer (as is always the risk of interviews). In the same line of reasoning, it could be argued that the distribution of priority judgements can be considered as a bad sign for the respondents' ability to judge. However, all interviewees except one refused to perform some of other rankings they were asked to do (see (Langendonck 1999)), which refusal they explicitly motivated with the argument that they did not recognise the ranking criteria and that they did not feel capable. This experience seems to be an indirect demonstration that they recognised the sources of uncertainty and felt comfortable to rank them. Also the discussion in the focus group and the feedback on the workshop (see Chapter 8) were the typology was presented, seem to provide support for our hypothesis.

leading group of RIVM is possibly best characterised by phase 3, while building upon our retrospective case-study the previous Environmental Outlooks can definitely be associated with phase 1, or at maximum phase 2.

6. A need for the PRIMA approach?

From the above multiple-case case-study research, we can conclude that both uncertainty due to variability and uncertainty due to lack of knowledge matter to RIVM's environmental assessment. However, both the document analyses and the empirical research consistently yield that uncertainty is not systematically managed in the assessment process and it is not transparently communicated in the Environmental Outlook reports. The relevant question is whether this implies that the quality of the policy recommendations is violated. It is beyond our expertise and capabilities to judge whether the conclusions that provided a basis for the policy recommendations in the four Environmental Outlooks lacked robustness. In the focus group, it was argued that with hindsight RIVM's environmental management does not regret any of the policy recommendations suggested in the series of Environmental Outlooks. This is explained by the rather conservative and no-regret attitude RIVM took; in view of uncertainty their concrete policy recommendations have been on the safe side in terms of costs[49]. In the last decade, only two of the many policy-relevant conclusions have been doubted afterwards, i.e. the environmental value of public transport and ploughing down of manure.

Notwithstanding the apparent robustness of the actual policy recommendations in the previous Environmental Outlook, the lack of systematic uncertainty management is problematic in view of RIVM's decision-support aim. Questions as to whether and how uncertainty was accounted for cannot be answered by means of reference to either the Environmental Outlook or the process documentation. This implies that RIVM cannot prove by means of scientifically credible arguments that the robustness of conclusions is *not* violated by some salient uncertainties. This is not a problem as long as RIVM's authority is unquestioned. However, the De Kwaadsteniet affair teaches that in our current society authority is not (anymore) a solid basis. This media affair furthermore yielded that uncertainty management is not only relevant from a philosophical point of view, but that it is critical to RIVM's deci-

49 It should be noted that conservative and no-regret attitude of RIVM might have been due to policy intervention in the assessment process or to political pressure on RIVM. As said it is beyond the scope of this research to analyse this dimension to RIVM's Environmental Outlooks.

sion-support role in the policy arena. Reasoning from the political commotion that directly grew out of De Kwaadsteniet's accusations, it is to be expected that RIVM's future products will be accompanied by critical questions about uncertainty management. The recent media affair illustrated that RIVM's vulnerability due to lack of systematic uncertainty treatment is real. De Kwaadsteniet did not create the vulnerability; the media affair only brought it to the (public) fore[50].

The retrospective case-study on the RIVM's Environmental Outlooks as discussed in this Chapter indicates that there is a potential need in the practice of Integrated Assessment for a methodology that allows to manage uncertainty in a systematic and adequate manner. There is a revealed need for improvement of RIVM's uncertainty management (see also box 7). The next crucial question for the currrent thesis is whether this need could be satisfied with the PRIMA-approach as presented in this thesis. This question will be addressed in more detail in the next Chapter. Here we limit ourselves to summarising ideas for improvements that directly follow from the case-study research reported in the current Chapter:

- more systematic treatment of uncertainty in the argumentation underlying the policy conclusions (from weak to strong)
- a consistent linguistic strategy
- a broader set of scenarios that includes futures salient to the environmental assessment
- explanation of increase/decrease of uncertainty ranges compared to the previous environmental assessment
- a more transparent and accessible Environmental Outlook by means of a transparent policy summary accompanied by a scientific compendium, which is an extensive version of the policy summary in which the policy conclusions are justified at the right level of abstraction (which means that irrelevant details, but nevertheless interesting from a more sectoral or scientific view point do not occur in the scientific compendium).

50 That this happened, turned out to be an advantage for the current thesis: it was not any longer considered as potentially 'explosive' research, because the bomb had already exploded (Rob Maas, personal communication).

BOX 7

Furthermore, the interviewees were explicitly asked whether they see a need for another approach to uncertainty management in the Environmental Outlook practise. The interviewees answered:

- *"It is interesting to explore the possibilities of other approaches, but I don't rule out that eventually we have to decide that a more subjective approach doesn't work. (..)"*
- *"I think there is a need to get to grips with uncertainty. There should come an easier and univocal way of communicating uncertainty. Concepts like accuracy, uncertainty, reproducibility should be used unambiguously defined. I don't really have an idea how this could be worked out..."*
- *"Yes, in two ways. In explicitly considering uncertainty in the computations, as well as in communicating uncertainties in the final Environmental Outlook. To do so, more money should be invested in research into uncertainty. Further, RIVM needs a protocol for managing uncertainty in a consistent manner. (..) It is a learning process."*
- *"(..) Another way should be phased in. (..) In fact it is a communication problem. There is an overload of information. In keeping the message simple, you attempt to communicate the message as clearly as possible. (..) It is our duty to organise the underlying information, and there is yet quite a lot we should do about it."*
- *"Yes. (..) We should consider it in science-philosophical terms. (..) It is a challenge (..). We should think more in narratives, imaginary futures that are coloured with some data."*
- *"It is my ideal. I hope there is also a need for another approach within the policy community. I would like to have more interaction and communication with policy makers and politicians. I would like to explore strategies in game-like sessions. There should be more creativity. We should think about potential surprises, so as to broaden scenarios. We need such interaction to decide which uncertainties are policy relevant."*
- *"It is very difficult to teach policy makers in the Netherlands how to deal with the scenarios of the RIVM, but it is even more difficult to interest them in the models the RIVM applies and their potential arbitrary underlying assumptions. (...) For an effective communication you need two parties. It is remarkable that this is lacking on national level. Within international relations there is a lot more bilateral communication. Maybe this originates from the CPB traditions. The CPB is placed on a pedestal and is independent of different parties. Because of that it is 'not done' to deepen in the matter of the CPB and this has to be accepted. Now RIVM has acquired the status of environmental planning agency, there is also no interest in deepening the understanding of the environmental models of the RIVM."*
- *"(..) more attention could be paid to communication uncertainty in the Environmental Outlooks. The latter is the easiest. Reliability can be reflected in documents as the Environmental Outlooks with simple, editorial*

see over »

BOX 7

means. Besides, I think more uncertainty research can be done, or more should be measured. An important issue in this context is the finances and the priorities. If there is not enough money, issues as uncertainty are the first that go."

In the course of the interview, the interviewees expressed ideas and opinions on how uncertainty management could or should be improved:

- *"Anyway, we have to arrange that the models are validated and reviewed."*
- *"(..) to underpin the expert-judgements statistically and to review them".*
- *"The scientific review and the network have to be better mobilised and reported."*
- *"At the start (i.e. societal developments and policy scenarios, MvA) and the end (i.e. effects on human environment, on ecosystems and on human health, MvA) of the causal chain, we have to invest extra work because there our models are least robust and least tested."*
- *"There should be more attention for the quality of the data and the scientific review, and for the communication with external knowledge institutes. It is also important how to communicate the information adequately to the press. (..) This all should be better organised."*
- *"The role of RIVM is to facilitate strategic decision-making. Models and measurements are means to achieve this. One has to take care that the models are validated and reviewed. (..) The disadvantage is that this can turn into reductionism (..) The ultimate aim is to soar numbers and models, they are just means."*

Building upon the interviews, two closed 5-point scale questions were formulated that were integrated in the questionnaire in order to get a richer understanding of RIVM's perception of the need for an alternative approach:

	strongly disagree	disagree	neutral	agree	strongly agree
A fundamental different approach of uncertainty is desirable.	1	4	4	2	4
There is a need for a different approach to uncertainty management in the Environmental Outlooks.	1	2	1	9	2

total number of respondents: 15

colour code: 0-2 | 3-4 | 5-6 | 7-8 | 9-10 | 11-12 | 13-15

The above empirical interview and questionnaire data (see box 7) indicate that there is an interest in another approach for managing uncertainties in the Environmental Outlook. The analytical problems revealed with the multiple-case case study are to a more or lesser extent recognised by RIVM practitioners. However, the respondents differ with regard to the necessary level of change.It is clear that the majority of RIVM practitioners at this point in time does not advocate a fundamentally different approach to uncertainty management, notwithstanding some support for change found by some individual practitioners. The above is illustrated by the following:

- *"any new approach should contain classical methods, or at least indicate the contribution of classical methods"*
- *"work that has already been done will not be thrown overboard"*

Some see it primarily as a communication problem that can be solved relatively easily. Others see a more fundamental need, and refer to the need for uncertainty research and the need to explore new approaches. The respondents indicate that this has implications for priorities and financing; there is a risk that uncertainty management is considered a luxury that will be cut down in times of budget pressure. A clear conclusion that can be drawn from the interview data is that the success of any alternative approach to uncertainty in the Environmental Outlooks will ultimately be determined by the interaction with policy makers and their attitude towards uncertainty management.

It can be inferred from the empirical data that a "protocol" for uncertainty management should address the following issues in order to be able to satisfy RIVM's expressed need:

- data quality
- model validation and review
- transparent documentation of expert judgement and scientific review (i.e. documentation of the assessment process[51])
    - creative scenario-development
    - explanation of ranges
    - relative importance of sources and types of uncertainties in relation to the conclusions
        - reporting uncertainty in the Environmental Outlook report
        - communication with other knowledge institutes
        - interaction and communication with policy makers and politicians

51 See also Chapter 7.

Some of the above issues also resulted from our document analysis, such as the transparency about uncertainty in the Environmental Outlook and the need for a broader set of scenarios. The first three issues involve *organisation of qualified information*, the second cluster of three pertains to the *assessment itself*, while the last cluster pertains to the *reporting and communication*.

7. Conclusions

The case-study research discussed in this Chapter teaches us that there are fundamental limits to RIVM's current management of uncertainty. The retrospective analytical study and the empirical data show that the way RIVM is currently dealing with uncertainty is problematic, both from a theoretical point of view and also from the practitioners' viewpoint. Extrapolation of the current practise implies that future Environmental Outlooks would feature 'sprinkling' margins that will violate the policy relevance of the Environmental Outlooks. Furthermore, there is not yet a legitimate set of scenarios available that is adequate in view of the Environmental Outlook ambitions. Last but not least, uncertainty can only be transparently communicated when it is systematically considered. Acknowledging uncertainty is just a first step. The latter two improvements thus require a significant change of the assessment methodology and process.

A systematic strategy and protocol for uncertainty management are currently lacking within RIVM. The empirical data indicate there seems to be a cautious openness towards an alternative approach for uncertainty management. In sum, we conclude that there is both a revealed and expressed need for improvement of RIVM's uncertainty management in the context of the Environmental Outlooks. The next question is then whether the PRIMA-approach has something to offer to RIVM's assessment practise.

References chapter 7

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Exploring PRIMA's first steps in practice

the case of the 5^{th} Environmental Outlook

The retrospective study on RIVM's series of Environmental Outlooks as discussed in the previous Chapters indicated a potential need for a systematic framework for uncertainty management. One of the ambitions of this thesis is to test whether the proposed PRIMA approach can satisfy this need, not only theoretically, but also in practical terms. In the first part of this thesis we argued that from a theoretical, philosophical point of view applying the PRIMA approach would improve the quality of Integrated Assessment endeavours. In the current Chapter, we will explore whether and how this potential improvement can be realised in practise. The key question addressed in this Chapter thus holds: Is it possible and if so in what way, to use the PRIMA approach in assessment practice in a practically feasible manner as to improve the quality of the assessment?

To this end, we explored how the PRIMA approach could be implemented in RIVM's current environmental assessment process that will ultimately result in the 5^{th} Environmental Outlook. In this endeavour we restricted ourselves to the first two phases of PRIMA, i.e. definition phase and "uncertainties-in-perspective" phase. The RIVM case enables to get some insight into some practical constraints, conditions, expectations and ideals of practitioners. This kind of insights about assessment practise will help us to further develop the PRIMA approach as outlined in Chapter 5.

1. Research approach

The retrospective case study on RIVM's Environmental Outlooks indicated that there is an observed need for an alternative mode of uncertainty management. Furthermore, there has been an a priori interest in the perspective-based approach to uncertainty management[1], and the media-affair[2] created a niche and momentum to experiment with the PRIMA-approach in the 5th Environmental Outlook assessment process.

The flow chart of the PRIMA-approach (see Figure 1)[3] served as starting point for the prospective research. It was clear from the beginning that within the scope and time frame of the PhD project, it would be impossible to explore the full cycle. We therefore decided to limit ourselves to phase 1 (the definition phase) and phase 2 (the "uncertainties-in-perspective" phase). It is argued in Chapter 5 that PRIMA was explicitly designed in such a way as to enable output of particular phases to serve as input to the assessment process, even if the cycle is not completed. Next to testing the two first phases in practise, we will therefore explore the implications of the associated output for the 5th Environmental Outlook.

The PRIMA framework outlines phases and provides some ideas about how these phases can be carried out in practise. The PRIMA approach is not a rigid methodology in which all successive steps are defined. It is explicitly meant to be a flexible framework that can serve as a heuristic for uncertainty management in assessment practises. In Chapter 5, we made clear that dependent on the context and the chosen perspective on pluralism specific design choices have to be made. In other words, there are different ways to carry out the PRIMA phases. So our first job was to design concrete steps that would allow carrying out the first two phases of PRIMA in the 5th Environmental Outlook practise.

The first step involves definining the complex issue at stake and the perspective on pluralism that will be adopted throughout the pluralistic assessment process. Informed by the case-study research, we outlined the points of departure, which seemed to comply reasonably with RIVM's attitude and organisation culture. In the second part of the focus group[4], the perspective on pluralism proposed to adopt for the 5th Environmental Outlook process was shared with RIVM's managers involved

1 See Chapter 6 and (RIVM 1999)
2 See Chapter 6 and (van Asten 2000)
3 See Chapter 5 for a full description.
4 See also Chapter 6 and 7.

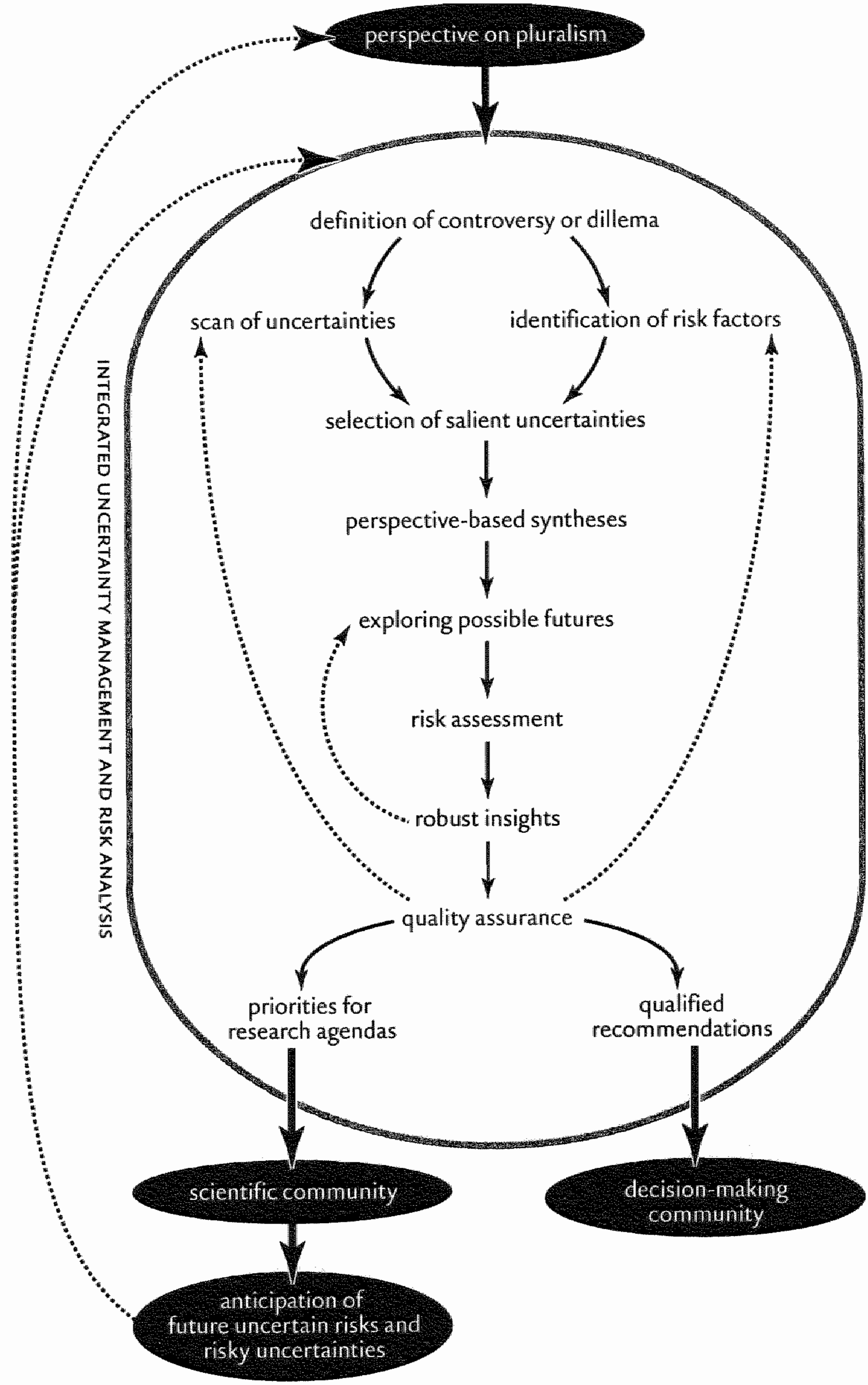


FIGURE 1 The PRIMA approach

in, and responsible for, the Environmental Outlooks. It was discussed with the focus group whether the proposed points of departure were considered to be appropriate in the eyes of the practitioners.

The retrospective research on the previous Environmental Outlooks has taught us that RIVM's expertise was needed to outline salient uncertainties[5]. It was explicitly said that there is more knowledge on uncertainty in "the heads of the assessors" than in the assessment reports. Secondly, we were not interested in individual opinions, but we aimed to mobilise the collective expertise to arrive at a judgement on the salience of uncertainties. As a consequence we preferred a group research method above individual methods (as surveys and interviews). Thirdly, we were especially interested in studying whether practitioners were able to perform PRIMA activities. The aim of the "uncertainties-in-perspective" phase is to scan uncertainties and to interpret them from different perspectives. This implied that we were not so much interested in a group discussion, but that we wanted to create a group setting in which exercises are performed[6], in the plenary and/or in facilitated subgroups. We therefore decided to carry out the second phase of PRIMA, i.e. "uncertainties-in-perspective", by means of a workshop with practitioners from the various departments and laboratories within RIVM involved in the 5th Environmental Outlook assessment process. In its general form, a workshop involves an introduction and explanation of the work to be done, a central part in which the group does the exercises and a plenary closure, in which the results of the exercises are presented and discussed.

The workshop involved about 20 practitioners, and it lasted half a day. The PRIMA-workshop with RIVM practitioners involved the following exercises:

- brainstorm on uncertainties relevant for the 5th Environmental Outlook
- clustering of the uncertainties
- interpretation of the uncertainties from the view point of one perspective per subgroup

In the closing plenary, the subgroups presented their results, and the workshop and its output were discussed in view of the 5th Environmental Outlook. Because of its character, a workshop results in a wealth of information involving notes of the workshop facilitators, audio or videotapes, pictures, and, most importantly, the material produced by the participants in the course of the workshop. The workshop was furthermore accompanied by two questionnaires. The participants filled out a question-

5 We tried to distract salient uncertainties by the analyses of the previous Environmental Outlooks, but as discussed in Chapter 7 due to the weaknesses observed in crucial lines of argument we could not induce salient uncertainties in this way.

6 I owe this clear and appropriate definition of 'workshop' to Frank van Asten.

naire before the workshop[7], in order to be able to sketch the group profile and control for bias. A second questionnaire was completed after the workshop, in order to use the participants' evaluations to explore practical constraints, conditions, expectations and ideals[8].

In sum, we tested the first two phases of PRIMA-approach, i.e. the definition phase and the "uncertainties in perspective" phase, in the following way:

- in the definition phase the major controversy guiding the environmental assessment was formulated and the approach to pluralism was chosen building upon the case study on the previous Environmental Outlooks. These preliminary choices were shared with and modified by the focus group.
- a representative group of practitioners involved in the 5th Environmental Outlook process carried out the "uncertainties in perspective" phase through a workshop.

2. Definition phase

Building upon our analysis of the previous Environmental Outlooks, we formulated the dilemma RIVM seems to address by way of the following central question that in principle spans different visions on the current and the future state of the environment:

> *Is a high environmental quality reconcilable with social-economic targets? And if so, to what extent can the government contribute to this? And if so, with what kind of policy measures?*

This problem description was shared with, and discussed in, the focus group[9] consisting of people who are or have been in charge of one or more Environmental Outlooks. It was considered a good description of the problem description of the 3rd and 4th Environmental Outlook. One of the focus group participants brought forward that every phrasing inhibits a paradigm about society. He argued that RIVM indeed presupposes that society can be influenced, or even managed, by policy. The issue would be defined differently from another perspective. Another participant argued that it is more realistic to say which environmental quality is attainable in the light of

7 Part of the questionnaire data was already incorporated in Chapter 7.

8 See (van Asten and van Asselt 1999) and (van Asten 2000) for the full questionnaire responses.

current economic and social goals. Someone else suggested that a way out could be to phrase the dilemma in a symmetric way. A phrasing in this spirit would be:

> *If and, if so, in what ways are environmental quality and social-economic targets reconcilable? And if so, to what extent can the government contribute to this? And if so, with what kind of policy measures?*

Such a formulation of the dilemma in principle leaves room for the above interpretation of assessing which environmental quality is attainable in the light of current economic and societal goals. It also allows to emphasise the economic goals over environmental quality, as one of the participants would like to incorporate. In other words, the above formulation leaves room for fundamentally different perspectives. There was a slight preference in the group to define the starting point from different perspectives, instead of reasoning from one overarching dilemma. On the other hand, the focus group agreed that the proposed phrasing basically covers the crucial ingredients addressed in RIVM's environmental assessment endeavours. This experience yields that developing problem definitions for each perspective might be an alternative way to carry out the first PRIMA phase, next to the manner proposed in Chapter 5 (i.e. to formulate an overarching problem definition[10]).

The second step involved the proposition of an approach to pluralism. The spectrum of attitudes towards pluralism is discussed in Chapter 4. In order to figure out what perspective matches best with RIVM's perspective, we further analysed the data from the interviews, the focus group and the questionnaires. From the attitudinal data towards knowledge and uncertainty discussed in the previous Chapter, it can be concluded that the attitude of the respondents goes beyond the objectivist perspective. Building upon the empirical data, it can be argued that either the "theory in perspective" or the "science in perspective" attitude seems to be most appropriate. Because RIVM had gained experience with the "science in perspective" attitude via the TARGETS endeavour[11], we proposed the "science in perspective" attitude as philosophical starting point for the pluralistic exercise.

Consensus was achieved about the pluralistic starting point, as is illustrated by the following quote:

> *"I think it is a good proposal to cluster uncertainties you will never get rid of, with perspectives. (..) In this way you cluster the things you do not know. You then get some extreme variants. Then you vary: what if the pessimist is right in*

9 See Chapter 6 for the list of participants to the focusgroup.
10 And which approach was used in the TARGETS endeavour, see Rotmans and de Vries (1997).
11 See Chapter 4.

that the farmers will never co-operate. And in my policy instruments I reason from the assumption that human beings are in principle good, and that you have to inform them about the consequences for the Third World. Where do I get then? Nowhere. Maximal misfit.(..) This is a more sensible way of dealing with uncertainties (..) then to turn the handles of models."

The focus group also agreed that not only scientific perspectives should be considered; they were especially interested in societal perspectives, as follows from the following quotations:

- *"I can imagine: there are some actors in society, which have a certain perspective? Wouldn't it be better to know these perspectives. (..) My question is thus whether it would be good to consider actual societal perspectives."*
- *"We could try to do something with the ministries (..) We could ask them what is your worldview, what is your preferred management style. (..) The advantage of creating perspectives with ministries is that they are forced to think about their choices."*

From these quotations, it follows that the focus group advocated a pluralistic attitude that goes beyond the "theory-in-perspective". This means that the proposed "science-in-perspective" perspective seems to be appropriate for a pluralistic exercise within RIVM. The next question is whether the perspectives have to be revealed empirically, as the above quotes suggested, or whether it would be acceptable to start with stereotypes. In the focus group discussion, it was argued that it is not so easy to reveal perspectives, and thus basic assumptions, from a discussion with societal actors. The discussion resulted in some consensus that the difference between the two approaches is not fundamental. In the end, the focus group supported the idea to experiment with pre-defined perspectives.

The next step is then to come up with a set of socio-cultural perspectives that could be used throughout the assessment. We proposed to use the three perspectives[12] associated with Cultural Theory[13], i.e. the controllist, the market-optimist and the environmental worrywart. We proposed this scheme of perspectives to the focus group. One of the participants suggested other labels, i.e. the economist, the ecologist and the democrat or governor. The market optimist and the environmental worrywart were no point of discussion. The focus group had some problems with the controllist, as expressed by the following quotation:

12 Deduced from Cultural Theory. See Chapters 4 and 5.

13 See Chapter 5.

"I do not have so much sense for the controllist. I think this perspective is quite different from the other two. (..) The controllist is a strange figure. I can't associate it. (..) It seems to be a bit from this and a bit from that."

Notwithstanding the above reservations, after thorough discussion the majority of the focus group considered it worthwhile to test out the first steps of the PRIMA-approach in a workshop with RIVM practitioners along the lines of the proposed pluralistic stand and with the proposed set of perspectives.

3. Uncertainty in perspective - workshop

The aim of the workshop was to explore the phase "uncertainties in perspective" in practice. To that end, the workshop addressed practitioners in the 5th Environmental Outlook process. The 18 participants were selected and invited by the project management of the 5th Environmental Outlook[14]. The workshop took place on June 8th 1999, at RIVM and lasted the afternoon. Prior to the workshop, the participants received a questionnaire and a discussion paper "Uncertainty and the 5th Environmental Outlook"[15], in which the major ideas underlying the PRIMA-approach were summarised.

The programme involved the following components:

- opening by Leon Braat, the project leader of 5th Environmental Outlook, and Fred Langeweg, director of the Environmental division
- introduction to the workshop
- brainstorm on uncertainty and the Environmental Outlook
- clustering
- working groups per perspective
- plenary reporting
- closing discussion

In this section, we will focus on the heart of the workshop, i.e. the brainstorm and clustering, the working groups' output and the closing discussion[16].

14 See (van Asten and van Asselt 1999) and (van Asten 2000).
15 See (van Asten and van Asselt 1999). This discussion paper is a Dutch abstract of Chapter 3 of this thesis.
16 For the full workshop report, see (van Asten and van Asselt 1999) and (van Asten 2000).

Workshop participants

3.1 SURFACING IMPORTANT UNCERTAINTIES

The objective of the brainstorm and clustering was to get insight into uncertainties salient to the 5^{th} Environmental Outlook. To that end, each participant was given a number of Post-Its[17]. On the front of these, the participants wrote down which uncertainties they thought to be important and on the back they wrote the source of uncertainty and whether they could imagine a range. Next, the Post-Its were collected and divided into 4 categories: Institutional, Social-Cultural, Environment and Nature, and Economy[18].

In total, the participants filled in 99 Post-Its[19]. In the tables given below[20], the various Post-Its have been clustered into the above categories. The number of Post-Its addressing that uncertainty is given in the last column (#). For 46 uncertainties, the source of the uncertainty was also given. On 29 Post-Its, an attempt was also made to give an accompanying range. The number shown in superscript shows to which range or source the mentioned uncertainty corresponds. Per cluster, the order is according to the number of times this particular uncertainty was mentioned.

17 These are small yellow sheets of paper with a sticky strip on the back.

18 This division is generally used by ICIS for IA studies to structure the various components of complex problems, see for example: (ICIS 1998; ICIS 1999a; ICIS 1999b; RIVM and ICIS 1998; Rotmans 1997; Rotmans et al. 2000; van Asselt et al. 1998). As any structuring device, it is limited in the sense that it seems to suggest that the allocation to a particular cluster can be done unambiguously and it does not indicate the mutual interrelationships. It is not say that this is the ultimate categorisation to be used in Integrated Assessment studies.

19 Some Post-Its did not feature a specific uncertainty, but pointed to methodological issues pertaining to scale and spatial issues, integration (e.g. multi-stress effects), modelling, indicators, input of external calculations, norm and standard setting, and time pressure. See (van Asten and van Asselt 1999) for literal reporting of these post-its.

20 We limit ourselves here to the most important and clearly expressed uncertainties. For a full overview see (van Asten and van Asselt 1999).

INSTITUTIONAL

uncertainty	range	source	#
Effect and implementation of measures, degree of implementation / effectiveness of measures[1] / effectiveness of policy /degree of enforcement		Conflicting evidents[1], Lack of measurements[1]	5
The role of the state (who makes decisio / degree of influence on politics / rulers/ translation of policy from national government to local councils[2]/ Institutional developments[3]	Large: a lot to Brussels[1], Range, 0-100%[2]	Behaviour[2], Lack of measurements/ information[3]	5
Openness of Europe 2030 (borders no longer exist) / global agreements and EU policy / foreign policy / lack of clarity in relationship between international policy - national policy[1] / influence of foreign environmental policy and behaviour[2]		Lack of knowledge[1], Unpredictable human actions[2]	4
Escalation of conflicts in the Third World / instability (war)[1] / discrete, once-only changes "disasters"[2] / Discontinuity of social developments[3]	Small chance[1], 10-90%[3]	Variability[2], Human actions[3]	4
Policy objectives: Prevention versus broad considerations	Increasingly more considerations	Policy/behaviour	1

TABLE 1 Institutional uncertainties

SOCIAL-CULTURAL

Uncertainty	Range	Source	#
Behaviour[1] / behavioural changes / interaction knowledge[2], with technology - behaviour / realisation of desired behaviour / Human factor (policy, behaviour) / Human actions (whether or not according to the rules)[2] / Reaction of society to the policy[3] / Reaction actors to policy and the instruments [4]	50%[2]	Human actions[1], Lack of Unpredictability of human actions[3], Variability[4]	9
Attitude of citizens to improvements in the quality of the environment / response of people to the decline of the environment (+ eco) policy/ Social preferences[1]	Large[1]	Shifting standards and values	3
Consumer behaviour / pattern of consumption 2030[1] / reaction of producers and consumers to the consumption pattern (+ consumption of nature)[2]		Unpredictability[1], human behaviour[2]	2
Social development	Stable to very unstable (ghettos rich/ poor),Range 30%	Societal variability, unpredictable human actions [2]	2
Demography / Migration[1]	Small, approximately a couple of million for the Netherlands[1]		2
Inner city traffic problems			1

TABLE 2 Social-cultural uncertainties.

ENVIRONMENT AND NATURE

Uncertainty	Range	Source	#
Climate variability[1] / climate system variability[2] / occurrence of climate changes[3] / Long term (100 – 1000 years) fluctuations in the climate and ecosystems[4]	Small for the Netherlands[1], influence/no influence[2], Range 50%[3]	Natural randomness[2], lack of/ inaccurate objectives[3], lack of data[4]	6
Collective (basic) emission (ERC)[1] / predictability of emissions / emissions, in particular spatial differentiation / air emissions[2] / emission information, e.g. fine dust, ammonium		Inaccurate data, lack of data[1], Lack of measurements, practical workability[2]	5
Human + ecological effects[1], /Effects on humans and ecosystem[2] / Dose-effect relations	> 500%[1]	practical immeasurability, indeterminability[2]	3
Response of ecosystem (fauna + flora) to the decline of quality of the environment[1] /Unfamiliarity or uncertainty of functions of ecosystems[2]/ Environmental pressure → ecosystems	30%[2]	Unpredictability of nature[1], lack of knowledge of long-term developments of nature[2]	3
Speed of change of ecosystems to climate changes / feedback mechanisms climate-hydrology-ecology			2
Relation of CO_2 and threats via weather/climate, influences of weather	Factor 2	Limited knowledge, insufficient measurements	1
Global supplies, water, energy, food production			1
Natural variability (in contrast to highly authorised indicators)	Depends on who asks	System knowledge/ translation between scale levels (variability)	1

TABLE 3 Nature and environmental uncertainties

ECONOMY

Uncertainty	Range	Source	#
Technology[1] / technological development[2] / technological innovation (speed & extent)[3]/	Large potential effect, large uncertainty[2]	Variability[1], technology[3] Indeterminacy[4]	6
Technological developments in relation to behaviour[4]			
Economy, behaviour of the economic sectors			3
Structure + size of Dutch industry		Unforeseen technological and economic developments	1
Occurrence of global economic recession		Unpredictable	1

TABLE 4 Economic uncertainties

NOTE Empty boxes imply that no remarks were made on the Post-Its regarding range and source.

The sources of uncertainty[21] mentioned on the Post-Its are given in Figure 2, with the number of times mentioned between brackets. It appears that many of the articulated uncertainties involve variability and structural uncertainty[22] more than reliability. However, the document analyses as reported in Chapter 7 suggested that in those rare cases uncertainty was made explicit in previous Environmental Outlooks, the sources of uncertainty primarily referred to uncertainty due to unreliability (inaccurate measurement or calculations). This seems to imply that an 'articulation' of uncertainty by means of such a structured brainstorm yields sources of uncertainty that are overlooked or neglected in traditional assessment processes. This idea is confirmed by the results of the ex-ante questionnaire: 10 of the 15 respondents (out of the 18 participants) argued that the workshop helped them to systematically consider uncertainty[23].

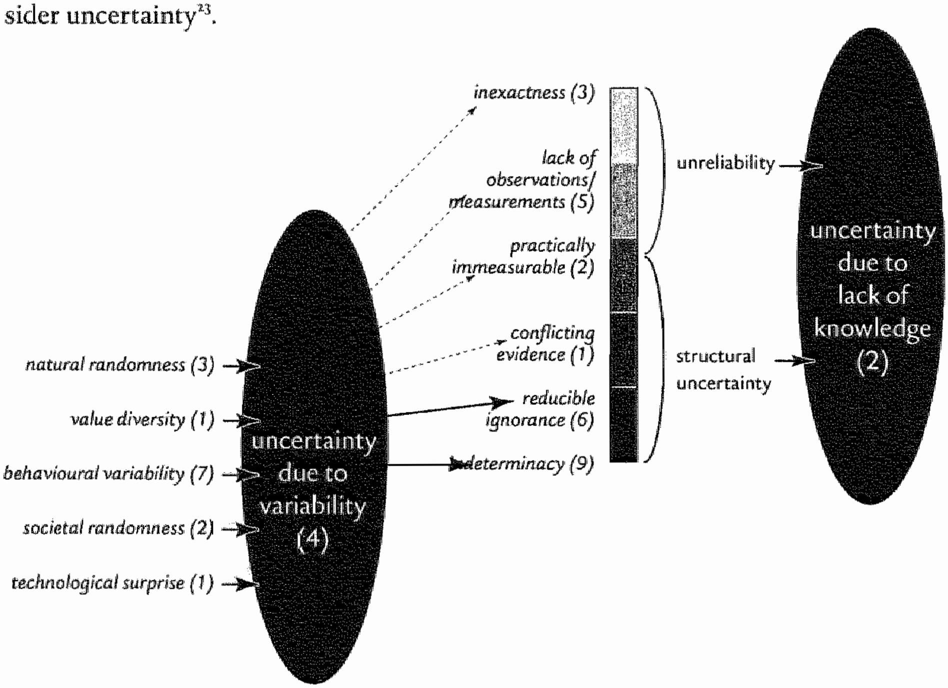


FIGURE 2 The number of times the sources of uncertainty were mentioned on Post-Its

The brainstorm and clustering surfaced an interesting list of uncertainties. The expressed variety is broader than that derived from the previous Environmental Outlooks. On the other hand, it has to be concluded that the uncertainties mentioned are on a high abstraction level and involve so-called 'container notions'. It is clear that

21 At the time of the workshop we did not yet distinguish between reducible and irreducible ignorance (compare Chapter 3A).
22 See Chapter 3A for the used definitions.
23 See (van Asten and van Asselt 1999) and (van Asten 2000).

Brainstorming

a second check of the list is needed, before it can be decided whether the above of clusters are the most relevant, and whether the set of surfaced uncertainties is comprehensive enough in view of the dilemma the 5th Environmental Outlook aims to address.

In the discussion following this brainstorm and clustering, it turned out that the participants considered the classification of uncertainties (economic, institutional, social-cultural, and nature and environment) useful. The same can be concluded on the typology of sources of uncertainty. We tested the typology as a tool to stretch thinking about uncertainty and as a means to facilitate communication about uncertainty. In the closing discussion of the workshop, it was concluded that the variety of uncertainties has been widened through this exercise. All respondents reported in the ex-post questionnaire that they considered the workshop useful and that about a 50% responded that the workshop helped in systematically thinking about uncertainty.

It was furthermore argued that the produced list of uncertainties, although it was a first attempt, enables to derive which uncertainties can be addressed through scenario analysis or with standard statistical methods, and which uncertainties will remain that must be addressed in another way.

24 Compare Chapter 5.

3.2. UNCERTAINTIES IN PERSPECTIVE

The aim of the second exercise was to interpret the surfaced uncertainties. As motivated above, we proposed to use the three perspectives derived from Cultural Theory (i.e. the controllist, the market-optimist and the environmental worrywart) as perspective framework. Following the PRIMA approach this implies that the surfaced uncertainties relevant for the Environmental Outlook had to be interpreted according to these three perspectives, with ultimately three internally consistent knowledge patterns as the result[24].

How to arrive at perspective-based interpretations of the surfaced uncertainties? We had to design an exercise so that the RIVM practitioners would produce three perspective-based chains of interpretations of the surfaced uncertainties. We decided to divide the workshop group into three working groups. Each working group was assigned one of the three perspectives. The task for each working group was to interpret the most important uncertainties from the assigned perspective. In each group, key statements in line with the heuristic rules as outlined in Chapter 5 were used to introduce the perspective. In order to put themselves in the perspective, each group held a brainstorm about what their perspective was associated with. The idea was that through the brainstorm the participants had put themselves in the shoes of the perspective, from which 'standpoint' they then would interpret the uncertainties. The main task for the group was to attribute interpretations of uncertainties in line with the assigned perspective, through discussion. Facilitators familiar with the perspectives and the PRIMA-approach[25] introduced the perspective to the participants and facilitated the group work; with regard to the latter, it was the explicit guideline not to interfere with the interpretations but just to enhance discussion and group thinking.

Below, the output of the three perspective working groups will be discussed. First, the associations with the assigned perspective will be given followed by the descriptions of the produced perspective-based chains of interpretations of uncertainty. Because the perspective-based patterns form the basis for further steps, they are described here in full length. At the end of each subsection the key lines of reasoning associated with the assigned perspective are summarised.

25 Marjolein van Asselt, Frank van Asten and Nicole Rijkens, see (van Asten and van Asselt 1999).

3.3. OUTPUT OF THE CONTROLLIST WORKING GROUP

Associations the working group participants had with the controllist are given in Box 1.

BOX 1 Associations with the controllist's key statements

- RIVM
- Conservative
- CDA (Christian Democratic Party)
- IPCC
- Agricultural sector
- No referendum
- Present emissions policy (environmental policy in a restricted sense)
- Prime Minister Kok
- EU
- Switzerland
- Water authorities
- Management of Directorate General Environment
- Big brother is watching you

The working group argued that if RIVM had to make an *Environmental Outlook* within a controllist society, it would pay special attention to measurements, gathering knowledge and measuring the policy objectives.

With regard to the Environmental Outlook, the controllist would make agreements with the institutions that provide information. These institutions should indicate which topics are uncertain and which ranges should be employed for this. This is very similar to the Environmental Outlook as it is being made now. According to the controllist, the 'Business as usual' scenario should be drawn up in the standard way and the other information should be included in the way that the other authorities have indicated.

In the vision of the controllist, *science* is based upon knowledge and experience. The starting point for the controllist is that aggregation and integration can be carried out to the highest level. 'The system' can be described in detail at various levels.

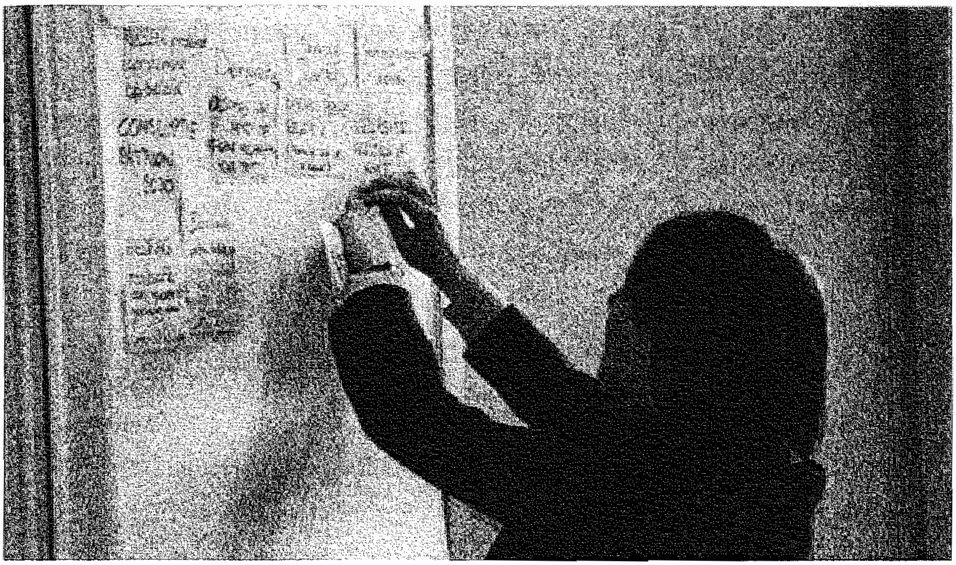
The controllist will always try to gather more knowledge about uncertainties and will attempt to quantify uncertainty associated with estimates. Therefore all statistics are up-to-date. The controllist believes in science's ability to solve problems. A lot of money is therefore needed for research. He cannot do anything with uncertain answers. He is only interested in uncertainties that can be quantified ('certain uncertainties'[26]). It is unscientific, if it cannot be calculated. The controllist is difficult to convince of the idea that uncertainties must be dealt with. Value is attached to validation, verification, explicit observations, and to statistics. The competence of the analysts is important, so certification and quality control play an important role. Both models and institutions have been decided upon by law. The controllist believes in the trustworthiness and the predictable nature of models: models and institutions are beyond all doubt.

The controllist will try to make sure that the policy is 100% effective. Policy objectives will always be formulated as clearly as possible and strict compliance will be demanded. To achieve this, the controllist will set up and enforce regulations to restrict uncertainties to a minimum. The controllist thus prefers traditional standards (in terms of high-low) to more functional standards. For the noise problem, for example, the peaks shall be removed, but the noise cover will possibly be accepted, if this lies below a certain level and if no demonstrable effects are attached. The controllist has typical end effect indicators, such as nature and health. The level is not so important since this is a question of necessity. He will always remain on the safe side (avoiding risk). An example of this is the MTR (Maximum Tolerable Risk) divided by 100. This is very much like the way in which we now deal with environmental policy in the restricted sense, such as emission policy.

The behaviour of people must be guided in a fixed direction as much as possible. Not only will the behaviour of people be regulated, but also the behaviour of the economic sectors and the pattern of consumption. The controllist will try to regulate the pattern of consumption by, for example, placing levies on environmentally unfriendly products and products which are associated with health effects. The economic sector will not be allowed much freedom of movement. Covenants fit well into the image: they are used where strict rules do not work. Tolerance will definitely not fit into the controllist's perspective.

The controllist expects the translation of the national government's policy to the lower governments to work. In the controllist's perspective, the central govern-

26 Compare Chapter 3.



Clustering brainstrom output

ment can largely enforce its policy by making use of hierarchy. International policy, especially EU policy, is of increasing importance for the controllist. If an international policy is developed, then this will in principle be translated into national policy. Another point is that the society's reaction to national policy is very uncertain, but also very important. Inner cities are an example: the central government has ideas, but lower governments and/or commercial parties make most of the policy. The contollist worries in case no policy is introduced for a certain problem, or if the policy is delayed.

In the controllist's vision, continuity and stability play an important role. Sudden events, disasters, migration, wars and the occurrence of worldwide depressions do not fit into the controllist's perspective. The controllist generally tries to avoid surprises and discontinuity, by drawing plans for dealing with exceptional situations. If a disaster will actually take place in the future and the plans cannot adequately deal with this, then the controllist does not know what he has to do.

Another example is the problem of Schiphol airport. The controllist will not move Schiphol to another location, or to the sea, because this does not reduce the (environmental) risks. Schiphol will be extended, and as a result, houses will be moved and be better insulated against the noise. In the project for the Betuwelijn (freight railway line from Rotterdam to Germany), the controllist is confronted with larger economic uncertainty than was expected. The initial research predicted that the Betuwelijn would not be so expensive and would fit in well as regards its effects.

Fairly soon afterwards, however, it was known that the project would be considerably more expensive and that it would generate much less economical profits. Since an abrupt change of policy does not fit into the image of the controllist, the project will be slowly reduced. He will not take the decision to stop it abruptly.

According to the controllist, *politics* must be a constant, almost orderly, process. There should not be too many changes from left wing to right wing, because this creates risks. The fact that Paars 1[27] actually carried out the CDA's[28] policy is grist to the mill for the controllist.

Nature and climate are strongly regulated, which is why the controllist can reasonably estimate the emissions. The controllist is ambivalent as regards the climate problem. On the one hand, an attempt will be made to work out the system in fine detail, including all the uncertainties surrounding this. On the other hand, there will be inherent uncertainty, which makes it difficult for the controllist to deal with. The climate, especially its variability, is a large problem for the controllist. It is an external influence and little can be done to control it, except for taking preventive measures, such as reducing CO_2 emissions, higher dykes, widening rivers, etc. The controllist sees climate change as a threat that develops gradually and which might only become acute at the end of the next century. He does not believe that the series of floods in the last few years has anything to do with climate changes. World supplies, such as (drinking) water, energy and food production, are long-term problems and should be strongly regulated now, so that they do not become risks in the future.

The controllist will invest in *technology*. He is forced to do so, because otherwise he will not be able to regulate certain problems. Radical innovations and breakthroughs, also in knowledge, however, do not fit into this image. Technological development is a gradual, almost evolutionary process in the eyes of the controllist. The controllist shall, therefore, continue to build on known principles and invest in these. In the course of time, innovations may possibly appear, but he keeps avoiding risks, so innovations will have to be tested thoroughly.

Spatial arrangements concerning human activities will be regulated and managed. On a national level, the controllist still does not know which direction it will take. Will the Netherlands become a delta-metropole or a large inter-connected city? These are questions to which the answers are still very unclear. On a local and regional level, the controllist stands for a strict spatial arrangement.

27 The first Dutch coalition government under prime minister Kok without the Christian democratic party (1994-1998).
28 The Christian democratic party that was reigning since the second World War, but does not participate in the Paars coalitions.

Finally, society does not necessarily have to be materialistic for the controllist. Resources are needed as means to control.

In sum, the controllist perspective applied to uncertainties relevant for the Environmental Outlook involves the following interpretations of uncertainty, where risky uncertainties are those that are considered to be threatening to the perspective under concern:

uncertainty	**associated controllist's interpretation**
Effectiveness of policy and degree of enforcement	100% effectiveness of policy; strict enforcement
International and EU policy	Translation from higher levels (international, national) to lower governments (national, local) works
Instability, disasters	*Risky uncertainty*
Who decides?	governments
Type of policy	Standard setting; Regulation of economic sectors and consumption patterns by levies and convenants; No drastic measures/changes in policy: no Schiphol in the sea; slowing down of Betuwelijn
Behaviour	Behaviour according to rules and fixed patterns. *risky uncertainty*
Consumption patterns	Regulation of economic sectors and consumption patterns by levies and convenants
Demography	Migration: *risky uncertainty*
Climate variability	*Risky uncertainty*; series of floods do not relate to climate change
Emissions	Strongly regulated, thus predictable
Dose-effects	On the safe side
World wide supplies water, energy and food	Strongly regulated to prevent future risks
Technology	No radical innovations and breakthroughs; gradual process; innovations have to be tested
Behaviour of economic sectors	Regulation of economic sectors and consumption patterns by levies and convenants
Global recession	*Risky uncertainty*

TABLE 5 Summary of output of controllist working group

3.4. OUTPUT OF THE MARKET OPTIMIST WORKING GROUP

Associations resulting out of the brainstorm in the market-optimist working group are given in Box 2.

BOX 2 Associations with the market optimist

- Microsoft
- Enterprise/entrepreneurs/business
- Shell (large companies)
- Banks
- Favourite magazine: Elsevier
- Export promoting measures
- Ministry of Economic Affairs
- VVD (Liberal Party)
- Government that negotiates and corrects market imperfections

The working group argued that the market optimist strongly believes in company dynamics and less in management by government. He is not necessarily interested in something that stops at the Dutch border. The fact that the EU has no economic borders must be taken into consideration. At the moment, the boundary is drawn at the Dutch border and foreign influences are only included to a limited extent. The uncertainties associated with foreign developments are not included. The environmental assessment should be drawn up much more in terms of risk contours, resulting in a sharper view of the local environment within the Netherlands and the rough contours outside the Netherlands. According to the market optimist, there is a market for an Environmental Outlook for Northwest Europe.

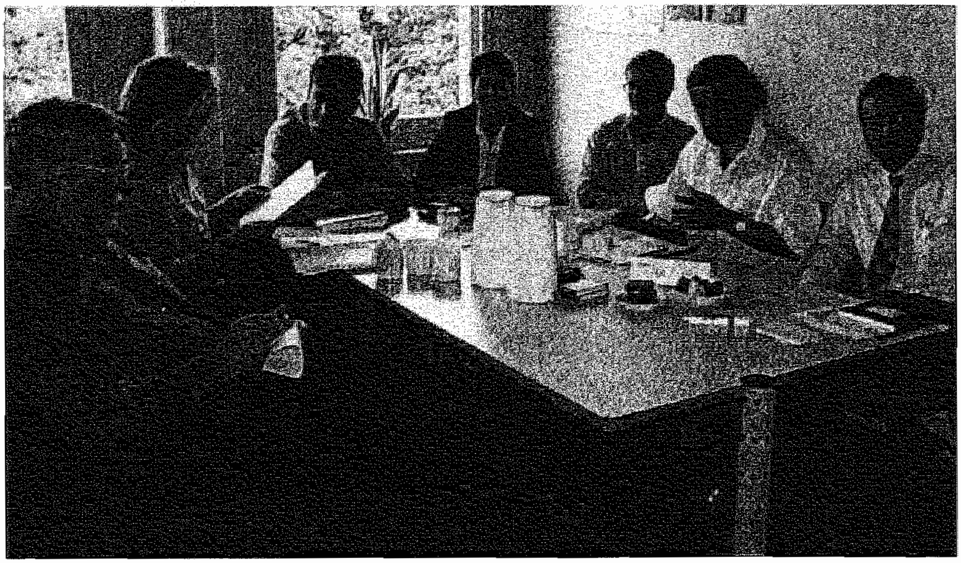
The market optimist believes in technological innovations. The necessary technology will appear by itself. The speed of technological development depends on investments in the form of time and money and this is clearly something that the market optimist can influence. Environmental technology will certainly arrive as a result of pressure from consumers.

The short-term economic situation is an important uncertainty in the market optimist's vision. The location of the production factors determines an important part of the market and, therefore, his possibilities. The risks that result from economic fluctuations, the changing of regions and the associated impacts, also for the environment, are very important in the market optimist's perspective. Additionally, it is uncertain how the world economy will develop until the year 2030. Will this period of boom continue or will there be a recession? And when will this take place? For a market optimist, it is important that this kind of questions is included in the scenarios.

The role of multinationals and large investors in finding solutions causes uncertainty. A crucial question for the future is what multinationals situated in the Netherlands will do: will they stay or leave? The market optimist thinks that there should be less regulation in order to stimulate the multinationals to stay. The latest developments indicate that water companies, energy companies and waste companies are being purchased by Dutch companies as well as by foreign companies. For example, a French company has purchased Van Gansewinkel, a waste processing company. The question is to which rules this company will have to comply? The Dutch rules are stricter than the European or French rules. Multinationals do not have anything against standards if they are clear and if they are set on a European level, which means that they are the same in all European countries. The standards can be set fairly high, because then a competitive advantage can be obtained, The concept of effectiveness will have to be looked at from a completely different context, not only from the position of the government, but also from the position of business.

The market optimist is worried about taking risks concerning where to set up a business. It is not a problem that demands are placed on the *location* of a business in the Netherlands varying from average to high, as long as they are not exceptional or constantly changing. A pig farmer will not locate in the Netherlands with the present (environmental) regulations, but will migrate to Canada, unless he can sell the pork at the highest price here. The green market value is very important. The market optimist will want to know the intended policy and the uncertainties associated with it; for example, it is still uncertain to what extent companies can pay off national environmental regulations with environmental regulations in foreign countries. This can also have an influence on the Netherlands becoming a country in which to locate a business.

There must not be a threat from *environmental risks*, such as floods every year, to the location of a business. RIVM has a tendency to place the emphasis on accumulation in the Environmental Outlook, which results in the emphasis being placed on places in the Netherlands where the situation is really disastrous, for example the



Working group in action

Randstad[29]. This is not very interesting for the market optimist. He looks for areas where he can develop, where opportunities are and where his employees like to live. The market optimist wants to know which problems may occur and which policy will apply for a specific area. To prevent problems with the location of business, environmental risks must be mapped out in the Environmental Outlooks.

The location of business is also very important for the people who work there. On the other hand, people will become more mobile, they will choose to live in a different area to the one in which they work. Local councils can address this, for example, by refusing pig farmers so that it will be more pleasant to live there. Special attention is given to see whether it is nice to live there, if there is nature nearby and if there is not too much disturbance. It concerns not necessarily large areas such as the Hoge Veluwe[30], but small nature areas surrounding cities. Biodiversity is not valued, but nice trees are. People want to have good nature, but above all they want well-organised nature and there does not necessarily have to be any wild buffaloes walking around. Nature reflects our wellbeing. Companies can invest in it: nature and the consumption of nature will become a new market.

In sum, health, welfare and nature are very important. The spatial arrangement then becomes very important. It makes a difference where pressure on the environ-

29 An urban conglomeration in the west of the Netherlands, involving Amsterdam, Rotterdam, The Hague and Utrecht.

30 A Dutch nature reserve

ment is placed in the Netherlands. However, a radius of 500 m around one's house will determine the perception. National averages lose their value as a result of this. The natural value in the Netherlands on the 'Ten Brink' scale[31] is well thought out, but what the direct surroundings are more important to people. As follows from the above, the emphasis will be placed more on *local, human problems*. The climate problem is of no interest whatsoever unless there is a good chance that the Netherlands will be flooded.

The Environmental Outlooks so far aimed address solutions associated with the government, but nothing is said about *environmental programs initiated by business*, such as eco-labelling and green programs by Albert Heijn[32]. The multinationals will look after the environment themselves if it suits them to do so. They can even fulfil a leadership role here. This possibility must not be underestimated; the market optimist will definitely want that the Environmental Outlook comprises an inventory of environmental initiatives taken by companies creating win-win situations. The controllist argues that the market can regulate itself: For Albert Heijn, for example, it is important that the Dutch government will not introduce strict rules on the country of origin of oranges, the use of packing materials, etc. Albert Heijn will respond that clearly telling the consumers what a product contains, where it comes from and what has happened to it, will have much more of an effect than if the government implements strict rules or even bans the product.

Uncertainties concerning the behaviour of citizens, the actions of people and the reaction of people to policy are important for the future. This is a weak link. The market optimist will be particularly interested in the consumption pattern of people and factors related to this. The environment as such will only be a small link in this. The appreciation of nature, however, does play a role here because people can adapt their behaviour to this. RIVM must also not be scared to say something about uncertainties in consumer behaviour.

The market optimist would like to know more about uncertainties in the perception of environmental problems. What causes social distrust in relation to environmental problems? He is not concerned about risks themselves, but more about the perception. For example, everybody thought that anybody who ate chickens that were infected with dioxin would die, but they had probably been eating them for years. The market optimist asks from the Environmental Outlook to address about

31 (Schouten et al. 1999; ten Brink et al. 1998; van Vliet et al. 2000)

32 A large Dutch supermarket chain

which issues people worry about and whether this is justified. The pure market optimist can profit from this and anticipate this sort of perception. The market optimist dislikes commotion about implausible disasters. They should not be ignored, but expressions such as "in fifty years time all the fossil fuels will be used up" and "in ten years time all the roads in the Randstad will be completely congested" should be dealt with carefully. Otherwise, it may cause a panic reaction and this can disturb the market.

In sum, the market optimist perspective applied to uncertainties relevant for the Environmental Outlook by the associated working group resulted in the following interpretations of uncertainty, where risky uncertainties are those that are considered to be threatening to the market optimist and important uncertainties those posing challenges:

uncertainty	**associated market optimist interpretation**
Effectiveness of policy and degree of enforcement	Effectiveness should be considered on European level; market regulates itself.
Who decides?	companies
Type of policy	Clear and competitive rules that do not change all the time; preferably European regulation
Behaviour	*Important uncertainty*
Consumption patterns	*Important uncertainty*
Attitude towards environment	Nature as commodity; nature close to cities; perception of environmental problems is important
Climate variability	Not important, unless the good chance that the Netherlands will be flooded
Dose-effects	Emphasis on local, human problems
Technology	Technological innovations; can be influenced by time and money; eco-technology will result out of consumer pressure
Behaviour of economic sectors	Role of multinationals; environmental programs initiated by companies
Global recession	*Risky uncertainty*

TABLE 6 Summary of output of market optimist working group

3.5. THE ENVIRONMENTAL WORRYWART

Associations put forward by the third working group as regards the environmental worrywart are given in Box 3.

BOX 3 Associations with the environmental worrywart's key statements

- Preservation of nature / romance / lover of nature
- Deep ecology – submissive to nature
- Romantic Calvinist
- Respect for nature and humans
- Austerity
- Economy as a means of control
- Think global-act local
- Precautionary principle
- Cautious with covenants and market orientated regulations.
- The environmental worrywart is nice to the person behind the consumer and strict with companies.
- Believe first, then command (information)
- Development aid is important (solidarity)
- Do not purchase emission rights in other countries

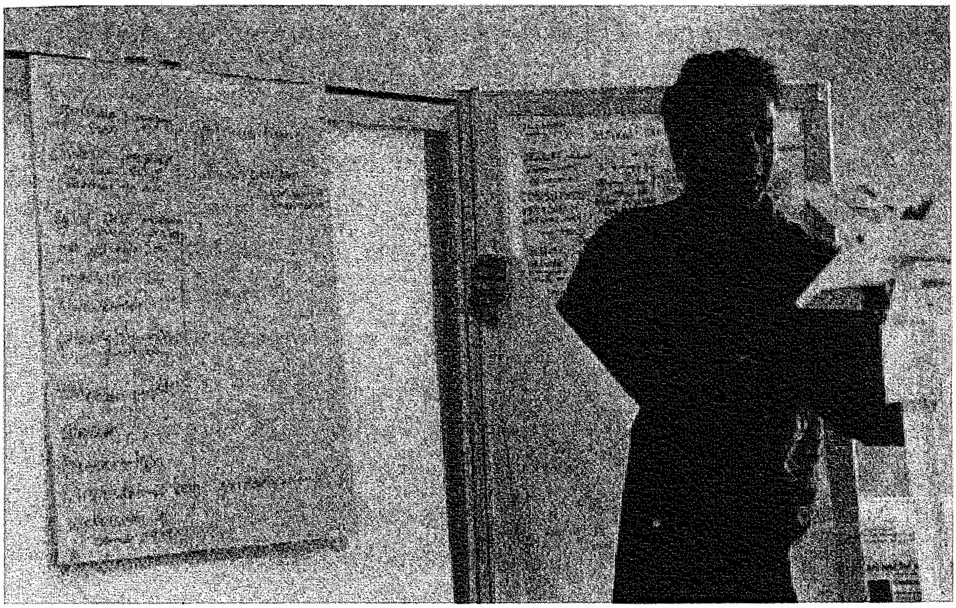
The environmental worrywart working group argued that this perspective would question the role of *RIVM*. In this view, RIVM collaborates with the enemy. This does not have directly to do with its competence, but more with the direct relationship with the government and the implied protection of business: RIVM must constantly be aware of cabinet agreements and arrangements that the government makes with the business community. As a result, figures and statements are formulated more carefully than is actually needed for the sake of the environment.

According to the environmental worrywart, nature is a very dynamic system that is difficult to understand. It is likely to be harmed by human interventions. It is therefore better to remain on the safe side. This means that people must consider the top of the uncertainty range in order to avoid environmental risks. The environmental worrywart takes *nature* as its starting point. He will always be concerned about nature, but more so if something abnormal takes place, such as an increase in temperature by a couple of degrees, despite high enforcement and world-wide agreements. The environmental worrywart emphasises the vulnerability of nature. *Environmental pollution*, such as air pollution, noise disturbance, disruption of the ecosystem and vulnerability, is an important theme about which the environmental worrywart is particularly concerned. The environmental worrywart is also anxious about spatial claims on nature and the irreplaceable stocks of natural resources. He tries to protect nature against threats, especially those caused by humans, of less known or unknown causes. He is worried about all sorts of unknown artefacts in the environment, such as genetically modified organisms, electromagnetic fields/radiation, dioxins, etc., which involve threats that people cannot see or smell. It is better to make sure that they are not released, or better still, that they do not exist. "Fear the unknown, worry about the known". The environmental worrywart does not want artificial nature created by humans: he tries to have large, connected nature areas with high biodiversity that can sustain themselves.

The environmental worrywart is directly concerned about high dose-effect relationships. He will stay on the cautious side here. Dose-effect relationships cannot always be measured and this is where uncertainties appear. In face of uncertainty, the environmental worrywart will immediately introduce the doom scenario. The environmental worrywart always needs information, otherwise he does not know if there are new problems that need to be addressed. The environmental worrywart will therefore invest heavily in dose-effect research. This can be compared to DGM[33] in the seventies. Strict standards must therefore be set. For example, the environmental worrywart worries about the dose-effect relationship between CO_2 and the increase in temperature. Will a disaster take place and will there actually be any climatic changes?

The environmental worrywart will aim for a "limits to growth" policy, because the Earth's carrying capacity is physically limited. The environmental worrywart's greatest concern is that people continue to consume more space per capita and that this will take place at the expense of nature areas. He is worried about the unrestrained growth of cities. The environmental worrywart considers control of demography as important; this implies freezing the size of the population. The environmental worrywart chooses prevention through information. For a "limits to growth" policy, the environmental worrywart tries to freeze the production acreage for agri-

33 Directorate General Environment of the Ministry of Housing, Spatial Planning and Environment (VROM).



Reporting back

culture, tries to freeze the production of food, strives for a steady-state economy, sustainability and closed cycles. The environmental worrywart would try to introduce CO_2 limits for each country or each type of industry.

The *economy* is a means, not an aim in itself. The environmental worrywart especially worries about the unrestrained speed of the economy. The environmental worrywart is concerned about *consumption patterns*. Consumption increases, because more people purchase the same things, want more appliances and replace and get rid of appliances more quickly. He has more a problem with the behavioural element of people and the controllability of this behaviour since this is unpredictable. If society develops as it did, there will probably be more cars, but more importantly, people will drive more. People also want to travel further on holiday and travel more often by plane. In short, growth in consumption should be restricted.

The environmental worrywart will aim for some technological innovation, because eco-technology is needed. Environmental technology is seen as a necessary evil: ideally environmental technology is unnecessary. A water purification company should not be needed at all. The water should not be polluted and a marsh should be created for the natural waste products, since this does exactly the same as a water purification company. An environmental worrywart does not believe that problems can be solved by technology. The environmental worrywart thinks it is very important that no deals are made: some industry is permitted, because a certain technology can (partly) undo the associated negative effect. An example of this is the car. In order to save energy, more efficient engines must be produced as well as clean cars, but this does not mean that more cars can then be driven. The environmental space must not be filled up again. The environmental worrywart is not in favour of end-of-pipe technology; he favours integrated process technology. The environmental worrywart will mainly be concerned with closing cycles, using natural processes, saving energy and recycling.

Enforcement is an important principle for the environmental worrywart. Before environmental policy can be set, a lot of thought must be given to whether it can be carried out and/or enforced, if it can be cheated and whether it will completely disappear through pressure from the European Union. With regard to consumption patterns and spatial claims, the environmental worrywart is actually a pessimist: there is a natural tendency to growth, so it cannot be monitored strictly enough to prevent that. Environmental violations by both companies and individuals must be dealt with severely. Money earned through enforcement must primarily be used for even better enforcement and control, and secondly for other environmental policy.

The environmental worrywart is *fairly locally oriented*, but is also concerned with the 'outside world', because this influences his local community. The environmental worrywart, therefore, strives for global agreements. He places a lot of importance on the principle of justice. He will not like it if other people emit the CO_2 that he tries not to emit, or use pesticides that he refuses to use. He wants to make reliable agreements with the G7 countries about the consumption pattern, demography, CO_2 emissions and oil prices, even though he has doubts about whether this can be achieved. He would like to give development aid to preserve the Amazon rainforest.

In sum, the environmental worrywart perspective applied to uncertainties relevant for the Environmental Outlook was associated with the following interpretations of uncertainty, where risky uncertainties are those that are considered to be threatening to the perspective under concern:

uncertainty	associated environmental worrywart's interpretation
Effectiveness of policy and degree of enforcement	Effectiveness should be tested before environmental policy can be set; environmental violations must be punished.
International and EU policy	Reliable global agreements; development aid to preserve Amazon
Type of policy	Environmental policy
Behaviour	Natural tendency to growth; Actors must be controlled;
Consumption patterns	*Risky uncertainty*
Attitude towards environment	Nature as starting point; large connected areas with high biodiversity; no artificial nature
Demography	Limits to growth; prevention
Climate variability	Global problem
Emissions	Will increase if the economy continues to grow
Dose-effects	Worried about unknown artefacts in the environment (GMO, electro-stress); Doom scenario; strict standards
World wide supplies water, energy and food	Freezing of production of food; closed cycles
Technology	Problems cannot be solved by technology; eco-technology is necessary evil; integrated process technology
Behaviour of economic sectors	Steady-state economy; economy is not an aim

TABLE 7 Summary of output of environmental worrywart working group

4. Analysis of the workshop

Analysis of the surfaced uncertainties yields that the output involves other uncertainties and other sources of uncertainty then usually considered in the Environmental Outlook. Examples of such uncertainties that have not been addressed in previous Environmental Outlooks[34] are e.g. effectiveness of policy, foreign policy, instabilities (in terms of disasters and accidents), environmental attitude of citizens and actors, and inherent unpredictability of responses of humans and ecosystems related to environmental change. The list of uncertainties produced in the workshop questions the scenarios that so far have been used in RIVM's environmental assessments. It also indicates that there are uncertainties considered relevant that could not be addressed by statistical methods. On the other hand, the surfaced uncertainties are on a high level of abstraction and need further crystallisation.

The output of the working groups is rich, which implies that we should analyse it from different angles to do justice to this richness. In the following we will analyse the empirical data from two points of view:

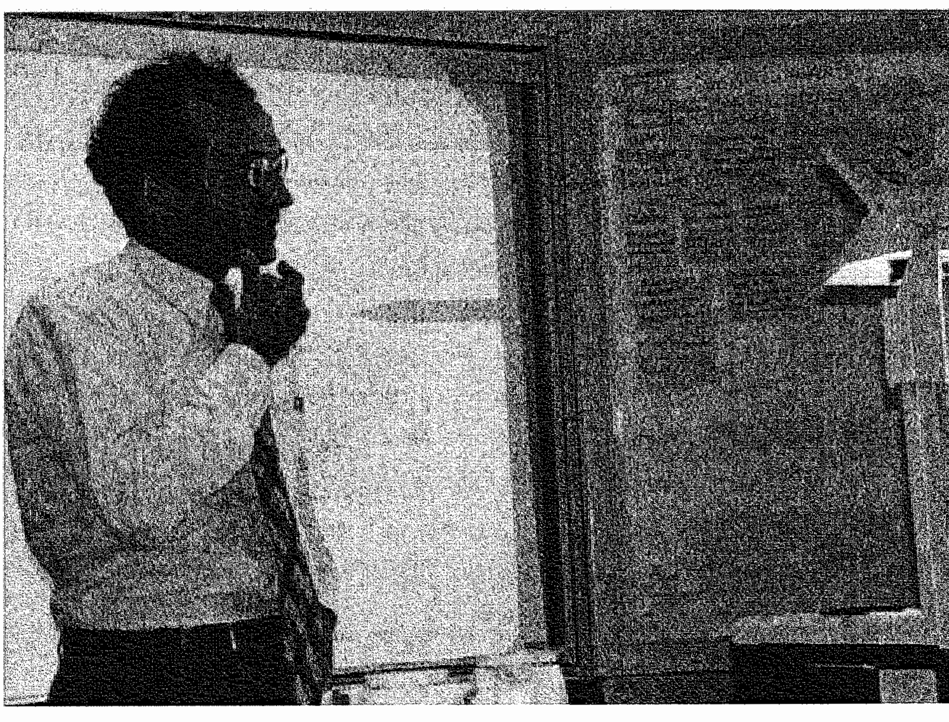
34 Which we can conclude on the basis of the retrospective research reported in Chapter 7.

- review and analysis of the perspective-based interpretations in terms of consistency and bias (output-oriented)
- evaluation of the process in terms of lessons to be learned for implementing PRIMA (process-oriented)

Furthermore, in Chapter 5 we argued that the intermediary product of the "uncertainties-in-perspective phase" as such could provide a valuable input to the decision-support process. We will try to address this hypothesis by assessing how the output could be used for the Environmental Outlook.

4.1. ANALYSIS OF THE WORKING GROUPS' OUTPUT

Any interpretation exercise is biased. To be able to get insight into potential bias, we have explored the attitude towards the perspectives among the participants prior to the workshop. To that end, a perspective questionnaire comprising six statements (two per perspective) with a 5-point scale had been included in the questionnaire that the participants completed in advance[35]. The answers have been decoded in order to characterise the expressed attitudes in terms of the three perspectives[36]. The results are presented in Table 8.



Reporting back

Respondent	% Controllist	% Market optimist	% Environmental worrywart
1	17	-33	50
2	-12	-38	0
3	25	-38	38
4	40	-20	40
5	33	33	11
6	20	40	-40
7	0	-33	0
8	0	-50	50
9	22	-33	44
10	-50	-25	25
11	-11	-33	33
12	50	0	50
13	38	-38	25
14	29	0	-14
15	20	-40	40

TABLE 8 Characterisation of respondents' statements in terms of perspectives

NOTE A positive score implies correspondence with the key statements associated with that perspective, while a negative score indicates that the answers of the respondent showed opposing values than those associated with that perspective. The highest positive score of a respondent indicates which perspective is the most preferred.

If we consider the highest scores per respondent, we can conclude that all perspectives are present in the group of participants. The environmental worrywart perspective dominated in the responses (11 out of 15), while two-third of the respondents also have a controllist orientation. A very small minority of the respondents positively approached the market-optimist perspective, while 11 respondents reject the market optimist perspective. The questionnaire results suggest that we can expect an 'environmental worrywart bias' in the whole perspective-exercise. To control for this bias, it would be theoretically interesting to repeat the exercise with a more balanced group and see whether there are significant differences in applying the Cultural Theory perspectives.

It is true that an environmental view can be observed from the workshop output. However, such a bias is not necessarily the consequence of preference for the environmental worrywart perspective, but is also due to the context of application, i.e. the *Environmental* Outlook. Furthermore, the value attached to environment and nature in the controllist and market-optimist patterns of interpretation cannot at all

35 See (van Asten and van Asselt 1999) and (van Asten 2000) for a full discussion on the questionnaire and the results.

36 In this decoding the perspective questionnaire developed in the context of the TARGETS project was used, see TARGETS CD-ROM (Hilderink et al. 1998).

be characterised as "deeply green". The set of perspectives covers a spectrum of attitudes towards environment and nature[38].

Tables 9 to 12[39] summarise the perspective-based interpretations of uncertainty per category. Empty cells imply that the working group did not address that particular uncertainty in terms of a perspective-based interpretation or evaluation.

INSTITUTIONAL UNCERTAINTIES

uncertainty	**controllist**	**market optimist**	**environmental worrywart**
Effectiveness of policy and degree of enforcement	100% effectiveness of policy; strict enforcement	Effectiveness should be considered on European level; market regulates itself.	Effectiveness should be tested before environmental policy can be set; environmental violations must be punished.
Who decides?	governments	companies	
International and EU policy	Translation from higher levels (international, national) to lower governments (national, local) works		Reliable global agreements; development aid to preserve Amazon
Instability, disasters	*Risky uncertainty*		
Type of policy	Standard setting; Regulation of economic sectors and consumption patterns by levies and convenants; No drastic measures/changes in policy: no Schiphol in the sea; slowing down of Betuwelijn	Clear and competitive rules that do not change all the time; preferably European regulation	Environmental policy

LEGEND Empty cells mean not addressed by working group

TABLE 9 Perspective-based interpretation of institutional uncertainties

38 In case PRIMA would be applied in a broader Integrated Assessment endeavour, one would expect that mapping out the perspectives would also yield patterns of interpretation in which environment and nature are marginal.

39 The order of the uncertainties is the same as in Tables 1-4. In the current tables the clusters of uncertainty are summarised by key words in order to provide convenient Tables.

SOCIO-CULTURAL UNCERTAINTIES

uncertainty	**controllist**	**market optimist**	**environmental worrywart**
Behaviour	Behaviour according to rules and fixed patterns. *risky uncertainty*	*Important uncertainty*	Natural tendency to growth; Actors must be controlled;
Attitude to environment		Nature as commodity; nature close to cities; perception of environmental problems is important	Nature as starting point; large connected areas with high biodiversity; no artificial nature
Consumption patterns	Regulation of economic sectors and consumption patterns by levies and convenants	*Important uncertainty*	*Risky uncertainty*
Social development			
Demography	Migration: *risky uncertainty*		Limits to growth; prevention
Inner city traffic problems			

LEGEND Empty cells mean not addressed by working group

TABLE 10 Perspective-based interpretation of socio-cultural uncertainties

NATURE AND ENVIRONMENT UNCERTAINTIES

uncertainty	**controllist**	**market optimist**	**environmental worrywart**
Climate variability	*Risky uncertainty*; series of floods do not relate to climate change	Not important, unless the good chance that the Netherlands will be flooded	Global problem
Emissions	Strongly regulated, thus predictable		Will increase if the economy continues to grow
Dose-effects	On the safe side	Emphasis on local, human problems	Worried about unknown artefacts in the environment (GMO, electro-stress); Doom scenario; strict standards
Feedback mechanisms			
Response of ecosystems			
World wide supplies water, energy and food	Strongly regulated to prevent future risks		Freezing of production of food; closed cycles

LEGEND Empty cells mean not addressed by working group

TABLE 11 Perspective-based interpretation of nature and environmental uncertainties

ECONOMIC UNCERTAINTIES

uncertainty	**controllist**	**market optimist**	**environmental worrywart**
Technology	No radical innovations and breakthroughs; gradual process; innovations have to be tested	Technological innovations; can be influenced by time and money; eco-technology will result out of consumer pressure	Problems cannot be solved by technology; eco-technology is necessary evil; integrated process technology
Behaviour of economic sectors	Regulation of economic sectors and consumption patterns by levies and convenants	Role of multinationals; environmental programs initiated by companies	Steady-state economy; economy is not an aim
Structure and size of Dutch industry			
Global recession	*Risky uncertainty*	*Risky uncertainty*	

LEGEND Empty cells mean not addressed by working group

TABLE 12 Perspective-based interpretation of economic uncertainties

Analysis of the above summary of the interpretations of uncertainties by the three working groups yields that some of the uncertainties were not at all addressed by any of the working groups, i.e. feedback mechanisms, response of ecosystems, social development, inner city traffic problems, and structure and size of the Dutch industry. It cannot be deduced from the empirical material why exactly these uncertainties have been ignored in all three working groups. It could imply that these uncertainties are not salient after all, that these uncertainties are difficult to interpret, that expertise and knowledge about these particular uncertainties were lacking or that the time span available was too short. If we consider the number of times that a cluster of uncertainty was mentioned in the brainstorm session, all ignored clusters were not mentioned that often, just 1-3 times[40]. So there is some support for the argument that these uncertainties were not considered that salient after all. It is nevertheless surprising that issues that are considered to belong to RIVM's competence, such as response of ecosystems and feedback mechanisms, were not addressed in the perspective exercise.

The second observation is that some uncertainties are left aside from a particular perspective, while they were addressed in the other working groups. These empty cells seem to suggest that these particular uncertainties are considered not that important for the assigned perspective. This especially holds for the market

40 See Tables 1-4.

optimist, in which working group the following uncertainties were not addressed: international and EU policy, instability, demography, emissions, and global supplies of food, water and energy. These are all issues that are probably considered as solvable in the market optimist perspective, and thereby not seen as crucial uncertainties in future outlooks.

The output of the other working groups showed that uncertainties and risks preferably denied by the controllist are of significant relevance and importance in the other perspective-based assessments. Where the controllist is not interested in any scenario about instabilities and disasters, the market optimist would like economic fluctuations, i.e. booms and recessions, to be considered in the scenarios. Where the controllist assumes 100% effectiveness, the other two perspectives, for different reasons, question this assumption and are interested in assessments that include partial or complete failure of implementation. The controllist is not interested in new risks that cannot be adequately calculated, while those risks associated with new anthropogenic artefacts or processes (such as genetically modified organisms and electrostress) are the central focus of the environmental worrywart.

It is remarkable that in the environmental worrywart perspective it is not made clear who is taking decisions. The output of the environmental worrywart working group breathes a kind of fatalism, in which the environmental worrywart is seen as a kind of Don Quichotte fighting windmills. The controllist and market-optimist working groups produced patterns of interpretation that can be characterised as utopian in the sense that they imply a world that perspective would like to live in. The environmental worrywart chain of interpretation as produced in this workshop could be considered as dystopian in suggesting doomsday outlooks. On the other hand, the output of the environmental worrywart working group could be filtered as to provide ingredients from which also a utopian outlook could be created.

In order to use the perspectives in the next phase of PRIMA, the distinction between world view and management style matters[41] in order to assess utopian and dystopian outlooks in a systematic manner. If we consider the above uncertainties, most of them refer to uncertainties concerning the underlying systems, which implies that the associated perspective-based interpretations delineate worldviews. The following two uncertain issues clearly refer to management style, i.e. 'who decides?' and 'type of policy'. The output of the working groups involves management style issues, such as strict enforcement in the controllist perspective, business environ-

41 See Chapter 3A and 5.

mental programmes and investment in technology in the market-optimist perspective, and control of actor behaviour and strict regulation of new risks in the environmental worrywart perspectives. The policy options that can be derived from the output of the working groups are summarised in Table 13.

controllist	**market optimist**	**environmental worrywart**
Regulation by governments	*Self-regulation by markets*	*Nature as starting point*
Strict enforcement	European regulation: clear and competitive	Punishment of environmental violations
Standard setting	Nature close to cities	Control of actors
Strong regulation of emissions and global supplies	Emphasis on local human problems	Preventive demographic policy
Levies and convenants	Investment in technology	Reliable global agreements
No radical change of prevailing policy	Business environmental programmes	Strict standards towards new environmental risks
		Closing of cycles
		Integrated process technology

TABLE 13 Policy options per perspective (derived from workshop output)

It has to be noted that articulation of management style was not an explicit exercise in this workshop. The above enumeration indicates the management style aspects that can be derived from this workshop, and that can be used as input to follow-up steps.

The workshop yielded an interesting set of internally consistent patterns. The assessment of the perspective-based interpretations does not yield specific statements that inherently conflict with the Cultural Theory description of that perspective. On the other hand, the interpretations are original as well, in the sense that these interpretations do not logically arise from the Cultural Theory descriptions. Examples of such original ideas are the suggestions that in the market optimist perspective environmental issues as such are not important, but the perception is, and the suggestion that eco-technology will result out of consumer pressure and that companies will initiate environmental programs. Also the ideas of the controllist working group that international, esp. European, policy will be implemented on the national and local level and that the economic sectors are regulated by convenants are such creative applications of the abstract and aggregated Cultural Theory descriptions. Such fresh suggestions can also be found in the environmental worrywart working group output, such as the ideas of development aid to preserve the Amazon or the concern on GMO. With hindsight these interpretations may seem not very difficult to consider and quite straightforward, however as far as our knowledge extends from Cultural Theory applications they are nevertheless 'new'[42].

The set of perspective-based chains of interpretation furthermore shows a wider variety of legitimate interpretations of uncertainty than the set of CPB scenarios employed in the previous Environmental Outlooks. For example, the environmental worrywart working group actually sketched a scenario in which economic growth results in higher emissions that cannot be counteracted by technological development. On the other hand, the market optimist scenario is also richer than a one-dimensional high economic growth scenario in which technology slows down environmental pressure. The market optimist working group described underlying developments, such as eco-technology arising from consumer pressure, leadership by multinationals resulting in environmental programs initiated by business and nature as a kind of pull factor, or even commodity, in the market mechanism. Finally, the output of the controllist workgroup indicates that the controllist is not just a middle-of-the-road way, but a perspective in its own right. The participants generally agreed that RIVM's current practise could be characterised as controllist. Furthermore, this perspective was assumed to be only interested in uncertainties that can be quantified and that can be reduced by plans and regulations. The working group actually associated the positivist/objectivist paradigm[43] with the controllist perspective: lack of knowledge and uncertainty are considered to be a threat, but it is believed that this could be solved through research. These observations together suggest that the implicit controllist bias could (partly) explain the observed hesitation[44] to address uncertainty in the previous Environmental Outlooks. From the plenary discussion and from the ex-post questionnaires it can be concluded that the uncertainties-in-perspective endeavour made the participants (more) aware that the controllist perspective is just one way of considering uncertainty.

42 These interpretations might be used to further develop the basic descriptions of the Cultural Theory perspectives. However, such an exercise goes beyond the scope of this thesis.

43 See Chapters 3a and 3b.

44 As extensively discussed in Chapter 7.

4.2. EVALUATION OF THE PROCESS: LESSONS FOR IMPLEMENTING PRIMA IN PRACTISE

As argued before, salient uncertainties could not be derived from the case-study analysis, because RIVM's expertise on environmental issues turned out to be vital. The workshop provided the floor to interact with experts and the exercises enabled to articulate tacit knowledge.

The experiences discussed in the current Chapter teaches us that a brainstorm session as included in the workshop is a valuable first step in an articulation process. Both the Post-It approach and the classifications of uncertainty turned out to be useful in facilitating a collective brainstorming. However, evaluation of the output yield that the uncertainties mentioned do not immediately translate into variables used in the assessment underlying the Environmental Outlook; uncertainty is articulated at a high level of abstraction and aggregation. Furthermore, it turned out to be difficult to attach ranges to the uncertainties, which could relate to the high level of abstraction. Next to that, both in the workshop and in the participants' feedback afterwards, it was made clear that approaches and techniques are needed that enable to articulate knowledge on uncertainty into estimates of ranges.

The above experience indicates that surfacing uncertainties in a PRIMA process probably should be a three-step approach. In the first step uncertainties are articulated on a general level with a brainstorm approach as employed in the discussed workshop. In a second, more technical step, the uncertainties should be reviewed by specialists and further crystallised in terms of indicators and variables, and by means of quantitative ranges, qualitative estimates and/or an overview of diverse interpretations. Such a second round could, for example, be done by means of expert elicitation. In this step sensitivity analysis may be used to assess whether the output is sensitive to the surfaced uncertainties[45]. Implementing PRIMA in practise also implies that techniques have to be found or developed that allow explicit articulation of tacit expert knowledge on ranges and legitimate interpretations of uncertainty[46]. Last but not least, a final round is necessary to prioritise in to order to arrive at a short list of uncertainties salient to the decision-support endeavour. Because this implies a collective judgement, it seems reasonable to do this again in the form of a workshop[47].

45 See Chapter 3a.

46 One of such qualitative schemes was presented in Chapter 3a. Techniques used for expert elicitation in the context of subjective probability functions can also be useful (see also Chapter 3a).

47 As argued, see also (van der Sluijs 1997) and Chapter 3a.

The various risk dimensions as described in Chapter 5 can serve as a heuristic in assessing which uncertainties are key to the decision-support endeavour.

In view of the above lessons, the list of uncertainties as discussed in this Chapter should be considered as a first overview of uncertainties that practitioners involved in the assessment process consider important for RIVM's Environmental Outlook.

The second step in the uncertainty-in-perspective phase involved interpretation of the uncertainties from the point of view of the various perspectives. The exercise given to the working groups was to interpret the important uncertainties surfaced by the brainstorm session from the viewpoint of the assigned perspective. All working groups applied the assigned perspective to produce perspective-based chains of interpretations, and they evaluated which uncertainties impose risks to the perspective's world view and management style (referred to as "risky uncertainties"). Furthermore, in the light of the assigned perspective remarks were made with regard to the organisation of the environmental assessment process.

As discussed above, the workshop yielded an interesting set of internally consistent patterns sketching three clearly distinctive perspectives on the uncertainties important to the 5th Environmental Outlook. The assessment of the perspective-based interpretations does not yield specific statements that inherently conflict with the Cultural Theory description of that perspective. In other words, the participants seemed to have applied the perspective scheme in their interpretation endeavours in line with the original Cultural Theory descriptions. From this angle, the set of perspectives and the procedure used seem to enhance a constructive process of creative discussion in which the degrees of freedom of interpretation of uncertainty are systematically explored. All working groups involved a creative process blended with knowledge on environmental issues. The participants thought of interpretations of uncertainties out of their usual mindset while still using their expertise and knowledge. In doing so, interpretations materialised that are consistent with Cultural Theory, but which are at the same time original as well.

The reactions in the plenary presentation of the working groups indicate that the developed narratives were all considered as plausible interpretations of uncertainty with some internal logic. From the workshop experience, we conclude that the perspectives facilitated the participants in focussing and questioning consistency in terms of internal logic. The perspectives seemed to frame the creative discussions, and thereby function as a kind of common benchmark. The workshop seemed to have created more awareness concerning the fundamental nature of uncertainty, risk and pluralism, which impression is confirmed by the responses to the 2nd questionnaire[48]. A third of the participants responded that the workshop has changed their thinking about uncertainty. 50% of the respondents considered the workshop set-up used as a good way to discuss uncertainty in relation to the Environmental Outlook. Concluding this implies that the chosen design seems to be at least effective in disseminating the major principles underlying PRIMA.

The chosen format turned out to be effective in the light of the aim to arrive at perspective-based interpretations of the surfaced uncertainties. From the facilitators' observations and from the output we can conclude that in none of the working groups any problems with reasoning from the assigned perspective were observed, nor were internal inconsistencies. In the questionnaire completed after the workshop, a large majority of the respondents (about 80%) said that they were able to project oneself into the assigned perspective. The association brainstorm on the assigned perspective was just fed with four statements. Evaluation of the associations indicate that these four statements were effective in evoking conceptions that correspond quite well to the richer descriptions of perspectives found in Cultural Theory literature. The brainstorm served as a warming-up; it seemed to help the participants to affiliate with the assigned perspective and thereby facilitated the interpretation exercise.

In designing the workshop format, it was deliberately decided to have one assigned perspective per working group. This choice was motivated by the idea that such a form would make it easier for the participants to leave their own preferences behind, because it is close to role-playing. If the task had been to interpret all three perspectives, participants might have been inclined to associate themselves with one of the perspectives, which may have led to black and white interpretations and a polarised debate blocking the group process. The experience with the 'one working group – one perspective format' allows to hypothesise that such a design contributes to producing the kind of output aimed at with the "uncertainties in perspective" phase. We therefore conclude that the chosen format - each working group works with just one perspective, four statements to introduce a perspective and brainstorm before interpretation – seems to be *an* effective way to yield perspective-based interpretations in a couple of hours with participants who are not familiar with Cultural Theory. The proposed format may also be useful in perspective-interpretation exercises in which another perspective scheme than Cultural Theory is used.

48 See (van Asten and van Asselt 1999) and (van Asten 2000) for a full discussion of the questionnaire results.

The conclusion that can be drawn from the analysis of the working groups' output is that the perspective-based interpretation endeavour in PRIMA's uncertainties-in-perspective phase has to be a stepwise approach. An interpretation exercise in a workshop setting in which perspective-based interpretations are generated in a semi-structured brainstorm (like we did in the held workshop) constitutes the first step. The output has then to be structured (similar to the analysis in the previous section) to allow a systematic review. The structured chains of interpretations have then to be reviewed and enriched, either by the same the group that generated the first drafts, or by another group, or by a mixture of 'old' and 'new'[49]. In this step there should be special attention for the empty cells in tables as the ones presented above. Furthermore, in this phase the perspective-based interpretations have to be played out more systematically in terms of world view and management style. This step-wise approach would then result in resolute perspective-based chains of interpretations.

The perspective-based exercise suffered from the fact that the list of uncertainties was preliminary. This experience teaches us that either first the list of uncertainties has to be established through iteration before the perspective endeavour starts, or that the whole phase is an iterative integrated exercise, in which both mapping out the uncertainties and the perspective-based interpretations mature. The latter seems to make sense, because our experiment with the PRIMA approach in the Environmental Outlook setting suggests that the perspective-exercise may also yield insights into the salience of uncertainties. Furthermore, the obvious link with uncertainty also in the process design of applying the perspectives seems to help the participants to blend creative thinking with their scientific knowledge.

Insights with regard to the necessary step-wise approach to the uncertainties-in-perspective phase that can be derived from the experiences discussed are summarised into a flowchart (Figure 3) suggesting a procedure for implementing the uncertainties-in-perspective phase.

49 This choice depends on the context and the aim of the assessment. In the case of participatory assessment, this step-wise approach allows to involve different actors in different ways.

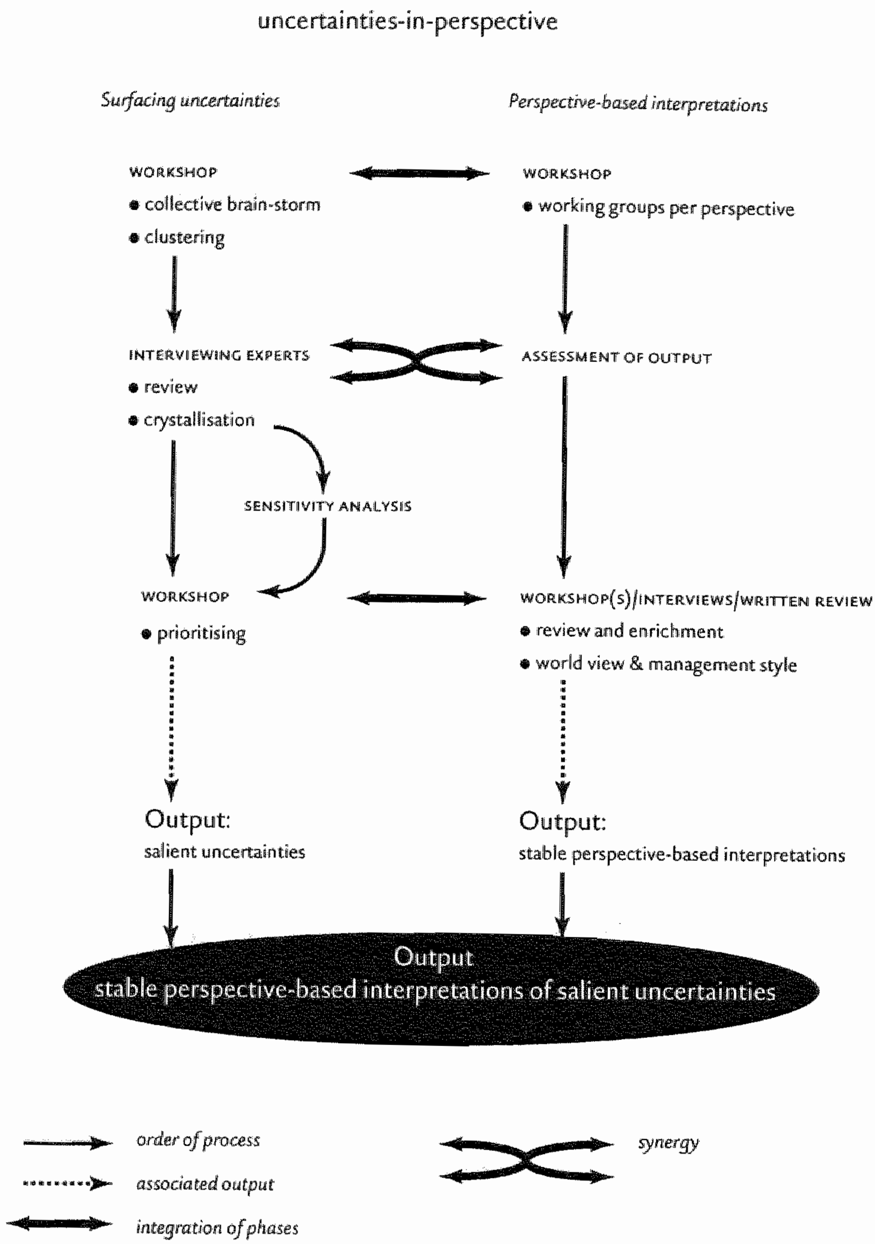


FIGURE 3 Flow chart of set-up of uncertainties-in-perspective phase derived from experiences

4.3. Use of PRIMA output in 5th Environmental Outlook

The perspective-based chains of interpretations can in principle be used for carrying out the next phases of the PRIMA approach. In the context of the 5th Environmental Outlook applying the next steps ("scenarios in perspectives" and "risk in perspective") would imply that the qualitative interpretations of uncertainty are used:

- to develop a set of perspective-based input-scenarios on exogenous variables (such as economic and demographic developments, technological innovation and lifestyles)
- to develop perspective-based model routes in the model equipment used in RIVM's environmental assessment process
- as heuristic in expert judgement about uncertainties that are not implemented in models, but for which interpretation is nevertheless needed in the assessment process.

This would enable to explore the future by systematically "thinking through" what-if questions. Doing so would yield a broad range of scenarios that covers the wide variety in legitimate and relevant interpretations of the underlying salient uncertainties. The next convergence step would then involve that insights relevant for decision making are extracted from the bunch of possible futures[50]. As discussed in Chapter 5 such an assessment would yield insights in terms of the (relative) robustness of strategies. This would then provide a basis for motivated recommendations in the form of:

- advising in favour or advising against a particular strategy
- indicating the level of societal controversy to be expected with a certain proposal
- proposing flexible strategies and the associated indicators ('signals') that are then important for decision-making in the future.

Applying PRIMA in its full form would be to develop the 5th Environmental Outlook from different perspectives in the way as described above. This implies that all uncertainties both in the pressures and in the causal chains have to be addressed, and that the choice of themes and scale levels is perspective-dependent. A less consequential, but still innovative way to use the idea of pluralistic uncertainty management in the Environmental Outlook would be to define the input-scenarios and other inputs per perspective, but the models are kept as they are and do not involve perspective-based model routes. This implies that the pressures on the environmental system are

50 See Chapter 5 for the kind of scenarios that can be developed by using perspective-based interpretations.

put into perspective. Finally, even if PRIMA and/or the perspectives are not used in the assessment itself, these concepts and notions can be useful in reflecting on the assessment product. The set of perspectives can be used ex-post to identify important uncertainties and to review critical assumptions. For example, the dilemma that resulted out of the discussed definition phase, could be used to scope the assessment in terms of the introduction and concluding chapters of the Environmental Outlook. In this way, the conclusions can be put in a broader perspective, which could improve the quality of the assessment product.

The above discussion gives an idea how the PRIMA approach could have been used in the 5th Environmental Outlook. However, apart from the fact that implementing and facilitating the full cycle was beyond the scope of our research, we here encountered also a conflict between theory and practise. The media affair[51] created a niche and momentum for experiments around uncertainty. In their report on assessment methods[52] produced as defence, RIVM explicitly referred to pluralistic uncertainty management as a promising avenue. Although RIVM's management as well as practitioners were willing to invest time and effort in participating in our research project, the PRIMA approach was not adopted as assessment methodology for the 5th Environmental Outlook. The 5th Environmental Outlook process was already fully planned and well on its way at the time our activities started. One argument not to switch to PRIMA was time-pressure. Other explicit or implicit arguments seemed to relate to the general attitude towards science-knowledge-uncertainty, the relationship between RIVM as decision-support institute and its client(s) (esp. the Minister of Environment and the professionals from the Directorate General Environment of the Ministry), and the (anticipated) expectations and ambitions of the client(s).

Our research did not involve a systematic inquiry into RIVM's decision-making with regard to uncertainty management. We therefore leave it here with concluding that RIVM primarily experimented with pluralistic uncertainty management parallel to the 5th Environmental Outlook process. The PRIMA activities described in this Chapter were not considered as an integral part of the process, but as complementary actions that were considered valuable in view of RIVM's learning process concerning uncertainty. These activities were only in second instance seen as exercises that might provide concrete input to the assessment process.

What insights do our first practical experiences with the PRIMA approach yield that could be of direct use in the 5th Environmental Outlook, irrespective of the fact

51 See Chapter 6 and (van Asten 2000)

that the PRIMA approach is not yet adopted as assessment methodology? In other words, how may the outputs and insights discussed in this Chapter be used in a sensible manner in the 5th Environmental Outlook? With addressing this question, we would like to evaluate the idea that intermediary outputs associated with a particular phase in the PRIMA approach can also serve as a valuable input to the assessment process, and ultimately the decision-making process. Assessment of the workshop output suggests that the uncertainties-in-perspective phase yields relevant insights and interesting ideas on two levels:

- the scope of the Environmental Outlook
- critical uncertainties, issues and assumptions

Such insights and ideas can in principle be of direct use to the 5th Environmental Outlook process. In the following the suggestions that can be derived from the workshop output will be discussed in more detail.

The working groups' output enables to raise interesting ideas about the Environmental Outlook and the underlying assessment process. The market optimist working group suggested that the scope should be broadened from a focus on the Netherlands to a wider Northwest European perspective. In line herewith, it is argued that the Environmental Outlooks' traditional focus on Dutch environmental policy should shift in three ways. On the one hand, an Environmental Outlook should address European environmental policy as well. On the other hand, the Environmental Outlook should not only focus on governments, but it should involve environmental measures that are taken, or can be taken by, other actors, such as multinationals and consumers. Thirdly, the Environmental Outlooks so far concentrated on accumulation of environmental and health impacts. It would be interesting to map out environmental and health profiles that enable to compare locations. Furthermore, the environmental worrywart working group brought to the fore that RIVM is not always regarded as an independent authority, but is sometimes seen as a continuation of government. If RIVM would be willing to consider the latter in the Environmental Outlook assessment process, this means that the assessment process has to be more participatory[53].

The list of surfaced uncertainties can be used as input to the design of sensitivity analysis, and the choice of model experiments. Even in case the surfaced uncertainties are not addressed in the assessment itself, the list can be used in framing the

52 (RIVM 1999)
53 See Chapters 2, 3 and 4 for discussions on participation.

scope of the assessment as well as the conclusions. Furthermore, it can be used as a checklist in writing about uncertainty in the ultimate report. It may serve as a checklist to those practitioners that have to integrate and edit the various contributions.

With the perspective exercise, specific uncertain areas are highlighted. The workshop output allows identifying which issues and assumptions are critical to societal debates (see Table 14). It was argued in the closing discussion at the workshop that if these issues are not addressed in the 5th Environmental Outlook, whether numbers are available or not, RIVM can expect critical questions from societal actors. This insight in critical issues so far not addressed in the Environmental Outlook could be used to broaden the assessment or to develop a communication strategy. The workshop output can be used to develop or to evaluate the content list for the 5th Environmental Outlook. Not all issues can be addressed quantitatively, but it may also be interesting to integrate qualitative evaluations and expert judgements in the assessment. The insight into critical assumptions may be used to reflect on the assessment and the assessment output, and can thereby help to perform some sort of ex-post evaluation of the robustness of the recommendations derived from the assessment.

critical issues
International and EU policy
Type of policy
Behaviour and consumption patterns
Environmental programmes/measures by non-governmental actors
New environmental risks
Nature

Critical assumptions
stability, continuity
100% effectiveness
Gradual technological change

TABLE 14 Critical issues and assumptions derived from workshop output

5. Practitioners's view on PRIMA experience

From the data gathered with the ex-post questionnaire[54], it became clear that the participants considered the workshop useful for assessing which issues are welcomed in the Environmental Outlook and that it enabled them to explore uncertainty in a systematic manner. Two thirds of the respondents[55] considered the workshop as a means to think (more) systematically about uncertainty. Half of the respondents furthermore argued that the workshop changed their thinking about uncertainty. In general, the workshop was considered as useful, even in case the workshop did not fully match the prior expectations. One respondent had expected a more concrete planning for the whole 5th Environmental Outlook process, another had expected a more technical workshop and another respondent had expected a broader overview of different approaches to uncertainty. Notwithstanding these reservations, the overall evaluation of the workshop as derived from the closing discussion and the questionnaire data is rather positive: it was considered a well-organised workshop that breathed an open and unforced atmosphere in which quite a lot was done in a relatively short time period. Both the participants to the focus group and the participants to the workshop valued that the prospective research offered the opportunity to have fundamental discussions about uncertainty with an interesting selection of colleagues in an open atmosphere.

The next question is how the participants to the workshop evaluated and valued the perspective approach in the light of RIVM's practise. In the questionnaire prior to the workshop, the respondents expressed a neutral attitude towards a perspective-approach. In the questionnaire completed after the workshop, a 50% of the respondents expressed an interest in a more pluralistic approach to the Environmental Outlook in the associated closed question. Furthermore, all responded positively to the open question "In your opinion, does the perspective method seem to be a desirable method for dealing with uncertainties in the Environmental Outlook?".

54 See (van Asten and van Asselt 1999) for a detailed report of the questionnaire results.
55 Of the 18 participants.

The ex-post questionnaire data show an ambiguous picture with regard to the perspective-dimension of the workshop. With regard to the perspectives used the following remarks were found in the 2nd questionnaire's response:

- more background for the choice of perspective is needed.
- whether all perspectives that play a role for RIVM have been put forward, or if more must be added in order to lay down a complete representation of society.
- how the mix of perspectives is in society.

Addressing the latter two issues would involve empirical research that is clearly beyond the scope of this thesis. It has been argued earlier in this thesis, that the perspectives used can be considered as generic stereotypes that are useful in a first fleshing out of perspectives. Nevertheless, these responses underline the importance of PRIMA's definition-phase and implicitly criticise the pragmatic approach adopted in the current case.

The majority of the respondents (65%) stated that they would be able to apply the perspective approach, with only a 10% doubting whether they could. The majority of the respondents considered the perspective approach an interesting alternative to uncertainty management that can complement existing approaches. On the other hand, the answers to the open questions indicate that the perspective approach is evaluated by some of them as being not concrete enough to be applied as is illustrated by the following quotes:

- "The perspective method" does not (yet) have enough body, in my opinion.
- It remained unclear in what aspect the perspective approach provides a better view of uncertainty.

Nevertheless, only one respondent did explicitly state that the perspective approach is not a desirable method for the Environmental Outlook. Another argued that it is not a panacea:

> *In my opinion, one of the causes of all the unrest surrounding 'De Kwaadsteniet' is the large amount of distrust from the public towards science (..). This combined with the inability to read figures by the public and media. This distrust will not be removed by only mapping uncertainties. I think that the perspective method is only half the answer to how to deal with uncertainties in scientific decision-support.*

To evaluate the PRIMA approach through the eyes of practitioners it is useful to compare the experience so far with the articulated need as discussed in Chapter 7. The prospective research yields that RIVM practitioners evaluate PRIMA primarily as a systematic and creative method for scenario development and evaluation: the combination of uncertainty and perspectives is primarily associated with 'societal uncertainties', or pressures, and much less with the causal chains. Although the PRIMA approach is explicitly meant as a way to address uncertainty pertaining to data and model quality and adequacy, the practitioners involved in our testing did not perceive it like that. From their responses, it is also clear that the participants to the process did not view the PRIMA approach as an assessment methodology that could frame the assessment. It was perceived as a potential complementary method, not as framework in which current techniques and procedures could be integrated. As discussed in Chapters 1-5 the PRIMA approach actually involves a fundamental change in thinking about uncertainty and risk. From that perspective, the above reactions also underlines that such a transformation costs time, probably years.

6. Conclusions

The prospective research discussed in this Chapter served to evaluate the first two phases of the PRIMA approach in an actual decision-support practise. The 5th Environmental Outlook functioned as a testing environment. By means of this case we aimed to evaluate the PRIMA approach as proposed in this thesis in the following terms:

- whether the PRIMA framework as proposed in Chapter 5 can serve as a heuristic for designing sensible assessment processes?
- and if so, which concrete activities are needed to realise the ambitions associated with the first two phases of PRIMA in practise?

In doing so, we evaluate the practical feasibility of the PRIMA approach. In the previous Chapters we have convincingly argued that RIVM's current practise is problematic, both from a science-philosophical and from a decision-support point of view. We therefore would like to assess whether PRIMA might address the observed need for another approach. This question provides a second angle to evaluate the potential practical value of the PRIMA approach as methodology for integrated uncertainty management and risk analysis in Integrated Assessment endeavours.

If we compare the output discussed in this Chapter with the ambitions of the PRIMA approach outlined in Chapter 5, how close is the practise to the theoretical ideal? The definition phase involves making crucial design choices that structure the whole assessment endeavour. The course of the case shows that the practitioners consider these choices as critical and that support for those choices is needed to create the necessary commitment. From the empirical testing we can thus conclude that the definition phase is not just a start of the process, but that it is an inherent essential part. In the Environmental Outlook case, we have chosen a pragmatic approach to avoid that the whole testing would get stuck in endless discussions about the problem definition and approach. In other words, we did test the relevance of that PRIMA phase, but we have not developed through the case a sensible procedure for how this phase can be carried out adequately in practise. The adopted approach worked in the sense that it enabled us to explore the science-in-perspective approach to PRIMA and the perspectives associated with Cultural Theory as perspective-scheme in practise. As a consequence of the set-up, it did not work in terms of the practitioners' necessary support for those choices.

The uncertainty-in-perspective phase aims at identifying the salient uncertainties and interpreting them from different perspectives. Salient is here described as cases in which the degree of uncertainty is significant and the policy relevance is high. The process so far has lead to a first articulation of important uncertainties; however, systematic estimation and selection have not yet been performed. So far, the risk dimensions have not explicitly been used in qualifying the uncertainties, although the working groups have signalled which uncertainties are considered to be risky to a particular perspective[57]. However, the risk concept is not addressed systematically and risk factors are not specified.

From the above analysis of the output and the evaluations, we can conclude that we did not fully succeed in producing some of the outputs associated with these first phases of PRIMA outlined in Chapter 5. However, we did succeed in producing a first set of distinctive qualitative perspective-based interpretations that are internally consistent without being straightforward. Where the scenario approach in the previous Environmental Outlook has degraded to evaluating impacts of extrapolations of the current situation[58], the produced interpretation patterns provide a basis for a relevant broader assessment of the future. Instead of concentrating on what economists consider plausible futures, proceeding with a pluralistic approach would enable to incorporate equally possible futures that are relevant to consider in evaluating the robustness of recommended environmental policy.

The core of our prospective research endeavour has been devoted to the "uncertainties in perspective" phase. The experiences discussed in the current Chapter indicate that it seems possible to design a process and to carry it out along the lines

57 See Tables 9-12.
58 As argued in Chapter 7.

of the PRIMA-framework. The framework as described in Chapter 5 turned out to be concrete enough to serve as guideline for practice, and flexible enough to be adapted to the specific features of the case. The experiences discussed in this Chapter suggest that the PRIMA framework as has been developed from theoretical, philosophical research could serve as a heuristic and benchmark for designing actual activities in a decision-support practise. Exploring the PRIMA approach in practise furthermore yields further suggestions how the uncertainties-in-perspective phase can be translated into concrete activities. It became clear that it is impossible to carry out this whole phase through one workshop. The experience taught us that a step-wise approach is needed. In Figure 3 the lessons in terms of process were summarised.

In sum, we conclude that it is in principle possible to carry out the first two phases of PRIMA in practise, although not in the full richness proposed in Chapter 5. Building upon the practical experience gained with the Environmental Outlook case, we are able to further concretise the first two phases of the PRIMA approach in terms of processes, activities and (intermediary) output and we have gained insight which methodological improvements have to be made. With regard to the latter, it has never been the intention to develop a rigid framework of procedures in which each step is outlined in details. However, from the experience it is clear that the PRIMA framework should ultimately encompass at least the following hints with regard to the first two phases:

- how to organise and facilitate the definition process among practitioners?
- methods and techniques for characterisation and mapping of uncertainty
- how to eventually involve stakeholders in the uncertainties-in-perspective phase?

A secondary aim of the prospective research was to evaluate whether PRIMA could satisfy the observed need for another approach to uncertainty management in RIVM's Environmental Outlook process. The experiences with the PRIMA approach in the practise of the Environmental Outlook indicate that this approach seemed to evoke reflection and that it seemed to contribute to learning among practitioners. Furthermore, the output of the activities as discussed in this Chapter provide material and insights that in principle can contribute to the 5th Environmental Outlook process. Next to that, no practical criterion has been encountered that would disqualify the PRIMA approach as assessment methodology for RIVM. Our experiences seem to suggest that the PRIMA approach has something to offer to RIVM's assessment practise, both in view of theoretical considerations as well as in terms of practical needs and relevance.

With regard to the practical feasibility of the PRIMA approach, we conclude that the PRIMA framework as proposed in Chapter 5 can be used as heuristic to design concrete activities in the assessment process that allow to perform a (more) pluralistic assessment. However, the experiences with the 5th Environmental Outlook process also indicate that it does not lend itself easily to be implemented in practise. The empirical experiences gained resulted in improvement of the uncertainties-in-perspective phase, both in terms of process and in terms of output(s) that can be produced with such process. If RIVM might be considered as representative for the current culture in decision-support, the experiences yield that the PRIMA approach is in the first place considered as a way to raise awareness and consciousness, and to evoke learning processes about uncertainty, risk and pluralism among decision-support practitioners. It was only in second instance, and just by some RIVM practitioners, considered as an assessment methodology. The first experiences indicate that application of the PRIMA-approach as assessment methodology in the practise of decision-support anyhow requires a change in the way of thinking, that is fundamental and time-consuming. From Chapters 3 – 8 we conclude that such a process seems to involve the following steps: i) consciousness raising about uncertainty, risk and pluralism among practitioners, ii) recognition of the importance of adequate integrated uncertainty management and risk analysis in their actual decision-support practise, iii) understanding the essence of integrated uncertainty management and risk analysis as well as understanding which and how methods and techniques can be used, iv) designing a context-dependent procedure, v) implementation in pilot-cases, and vi) incorporation in standard practise.

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Perspectives on uncertainty and risk

conclusions and discussion

Society is more and more confronted with complex issues. Decision-makers are ever more struggling with complexity. As argued in this thesis the features of today's complexity are that:

- there is not one problem, but a tangled web of related problems (*multi-problem*).
- it lies across, or at the intersection of, many disciplines (*multi-dimensional*).
- the underlying processes interact on various geographical and temporal scales (*multi-scale*).

In this thesis, we have argued that uncertainty and risk are fundamental, problematic but challenging issues in decision-support on complex issues. We have provided both theoretical arguments and empirical evidence for this claim, the latter by means of a case study on actual decision-support.

Taking the above features of current complexity into account, it is clear that an integrative approach is needed. Integrated Assessment (IA) involves an interdisciplinary process of synthesising pieces of knowledge gathered from various scientific disciplines and societal actors, with the explicit purpose to better inform policy and to support decision-making (Chapter 2). Integrated Assessment attempts to shed light on complex issues by illuminating different aspects: from causes to impacts, and from options to strategies. It is only recently that Integrated Assessment is increasingly recognised as a specific branch of science. The current state can be considered as the culmination of a process of decades that involved both the changing nature of the issues on the societal agenda as well as the evolution from mono-disciplinary to multi-disciplinary and interdisciplinary research.

It is an explicit goal of Integrated Assessment to address complexity through highlighting uncertainty and different risk perceptions. However, methods and procedures for doing this in a legitimate and systematic manner are not yet part of the Integrated Assessment tool-kit. The ultimate objective of this thesis was to develop approaches that allow to manage uncertainty and to analyse risk adequately in order to improve Integrated Assessment as approach to scientific decision-support. In the current concluding Chapter, we will summarise the findings, reflect on the conclusions and discuss some challenges for the future.

1. Summary of findings

The first steps in the reported research involved study of the sources of uncertainty and risk. We tried to understand why uncertainty and risk occur in societal debates. Analogous to investigating a physical phenomenon, such as climate change, we have attempted to study the causes underlying uncertainty and risk. This part of the research yielded a typology of sources of uncertainty (Figure 1) that can improve our understanding of, and communication on, these abstract notions (Chapter 3A).

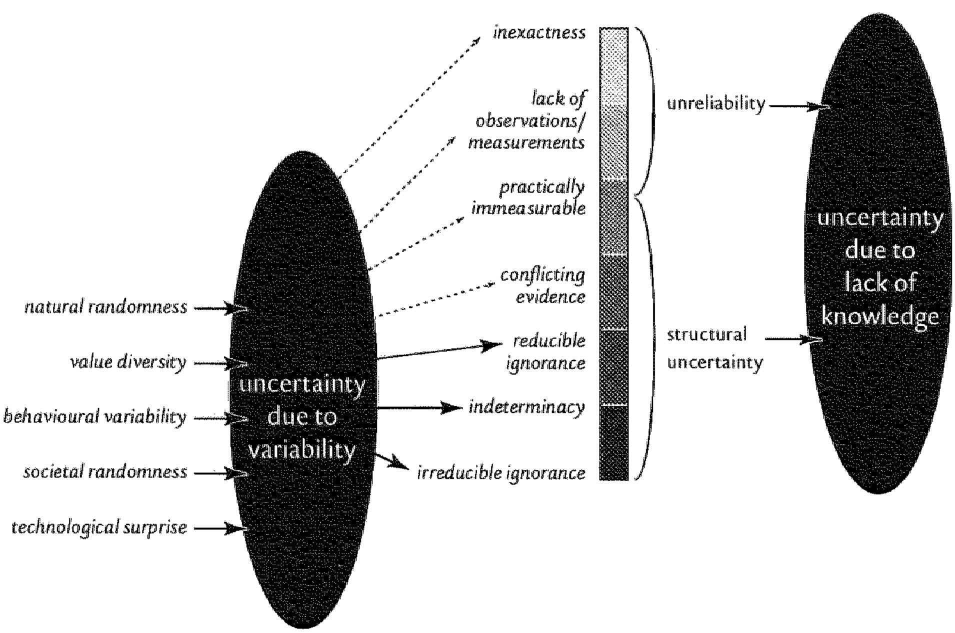

FIGURE 1 Typology of sources of uncertainty

Building upon our review of scholarly literature from various scientific disciplines on uncertainty and risk, we concluded that complexity means facing inherent, radical uncertainty, strategic risks and multiple risk perceptions. Radical uncertainty involves uncertainties that can at best be roughly assessed. Strategic risks are risks that cannot be controlled by individuals, nor can they be exactly located, and the time horizon usually transcends the short-term. We have argued in this thesis that uncertainty and risk are related concepts and that they can be considered two sides of the same coin, i.e. the limited predictability associated with complex issues. 'Uncertainty' is generally associated with the rationality of science (Chapter 3A), while 'risk' is a notion that seems to correspond most with the rationality of decision-making (Chapter 3B). Figure 2 indicates how the degree of uncertainty and the level of risk are related.

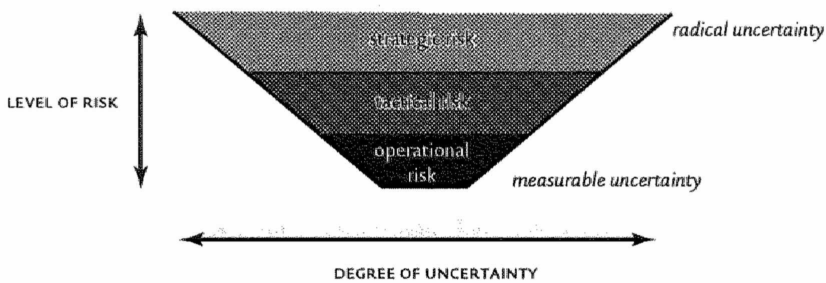

FIGURE 2 Level of uncertainty and type of risk

Complexity thus involves both uncertain risks and risky uncertainties. In other words, uncertainty and risk are symptoms of complexity (Chapter 4). This means that uncertainty cannot be adequately studied without considering risk, and vice versa. Traditionally, two separate research communities address uncertainty and risk. Notwithstanding this schism, the classical approach treating uncertainty and risk as mathematical and statistical artefacts has dominated both scientific communities for a long time, notwithstanding the increased recognition that:

- science is a creative, innovative process in which intellect, intuition and values interfere with facts and figures
- knowledge is not equivalent to truth and certainty
- experts perceive risk differently from lay people
- cultural factors affect the way people assess risk

The consequence of the above is that different perspectives on uncertainty and risk are legitimate and viable.

Our research yields that the traditional approaches to uncertainty and risk are especially inadequate in the case of radical uncertainty and strategic risks (i.e. the upper part of Figure 1), exactly those types of uncertainty pertaining to complex issues. The theoretical research led us to conclude that the challenge is to develop a decision-support heuristic that uses the two concepts in a synergetic way. Furthermore, our review of existing methods for uncertainty and risk analysis indicated that even in case an optimal combination of existing methods would be possible, the current tools and methods are by definition not sufficient. *New* integrated uncertainty and risk methodology is needed for decision-support on complex issues.

The aim of the present PhD research was to address the issue of analysis and management of uncertainty and risk in decision-support in an integrative way corresponding to the aims of Integrated Assessment. The ambition of our methodological endeavour was to develop an approach to uncertainty and risk that is theoretically sound and practically feasible. In this thesis, we have shown that such a method has to be pluralistic, in order to account for legitimate plural interpretations of uncertainty and multiple risk perceptions (Chapter 4). Our study of the concept of pluralism suggested that there is not one legitimate pluralistic starting point, but several. This means that there is not one unique approach that can satisfy the observed need, but that there is in principle a range of methods and tools that can contribute to adequate and effective pluralistic uncertainty management and risk analysis in decision-support endeavours. This means that the Pluralistic fRamework for Integrated uncertainty Management and risk Analysis (PRIMA) proposed in this thesis (Chapter 5) is but one possible approach to deal with uncertainty and risk in decision-support in a theoretically sound manner.

Building upon our theoretical study on uncertainty, risk and pluralism, we have attempted to develop an approach that can serve as a heuristic in designing pluralistic assessment processes centred around uncertainty and risk. The PRIMA framework proposed in this thesis is not meant as a blueprint or a rigid methodology. We have designed PRIMA as a flexible framework that comprises steps and stages that are theoretically sound and that appear to be useful to decision-support practice.

Central to the PRIMA heuristic is to disentangle controversies on complex issues in terms of radical uncertainties and strategic risks. The pluralistic approach adopted involves that the uncertainties and risks associated with the issue under concern are interpreted according to different perspectives. These different interpretations and risk judgements are compared and confronted in order to draw a richer image of the issue under concern. The essence of the PRIMA approach is that the uncertainties, identified in a participatory process as salient, are 'coloured' according to various perspectives, in which we used perspectives associated with Cultural Theory, i.e. controllist, market-optimist and environmental worrywart. Starting from these perspective-based interpretations, various legitimate and consistent narratives are developed as to assess what might happen in order to explore what are the key challenges for current decision-making. Integrated analysis (either qualitatively or by means of models) of the set of perspective-based chains of interpretation allows evaluation of autonomous and policy-driven developments in terms of risk. Informed by these integrated assessments, the ultimate aim is to assess the level of robustness of strategies in a systematic manner. The different stages associated with the PRIMA-approach are summarised in Figure 3.

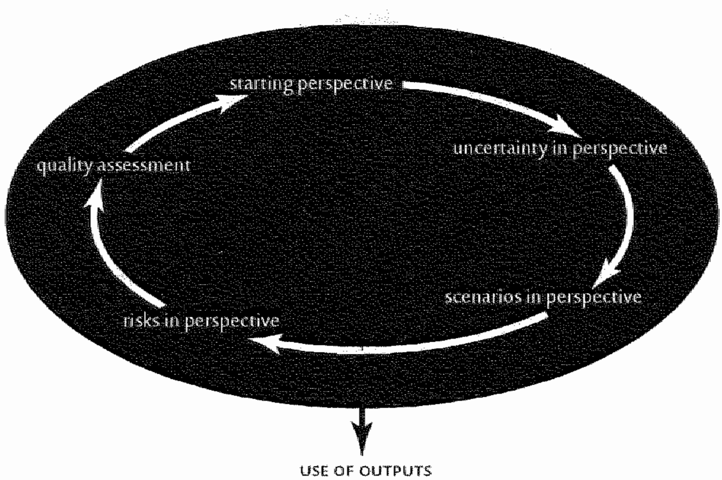

FIGURE 3 Multi-stage approach to pluralistic integrated uncertainty management and risk analysis

The next question is whether the framework is practically feasible. To that end, we have first performed a case-study on decision-support practice, in case the Environmental Outlooks produced by RIVM (the Dutch Institute for public health and the environment) (Chapter 6). Our retrospective analysis of how uncertainty was dealt with in the four Environmental Outlooks indicated that the current practice is problematic and deficient, both from a theoretical and from an empirical perspective. The retrospective case study showed that RIVM lacked a strategy and a framework for dealing with uncertainty in their assessment endeavours, which had serious consequences for the firmness and robustness of the conclusions. We concluded that RIVM is vulnerable to criticism: the assessment reports do not permit informed judgement of the robustness and quality of the conclusions and recommendations (Chapter 7). A recent media affair, known as the De Kwaadsteniet affair, underlined this conclusion in a dubious, but forceful way.

RIVM, however, seems not unique in quarrelling with the issues of uncertainty and risk in their decision-support. Our case study suggested that other decision-support institutes, so-called planning offices, are struggling with similar problems. The case-study research involved reports produced by other Dutch decision-support institutes, such as the CPB, and similar problems in terms of weak argumentation were encountered. Furthermore, in the media affair it was explicitly argued and recognised by various opponents that the criticism towards RIVM seemed to be valid for other decision-support institutes as well. There seem to be no reasons for which RIVM cannot be considered as an example case of decision-support practice: the conclusions about RIVM's practice seem to be generalisable to decision-support practice in general. Based on our research, we hypothesise that in view of increasing complexity of societal issues there is a general need for systematic approaches to uncertainty management and risk analysis. Our case study indicates that this need is more and more explicitly recognised by practitioners in decision-support themselves.

The next question is whether the PRIMA approach can serve as a heuristic in designing and implementing integrated uncertainty management and risk analysis in the practice of decision-support? To that end, we have explored the first two phases of the PRIMA approach (definition phase and "uncertainties-in-perspective" phase) in the practice of RIVM's environmental assessment process underlying the 5^{th} Environmental Outlook (Chapter 8). We did prove the relevance of the definition phase, but we have not yet developed a procedure for carrying out this phase adequately. The core of our prospective research endeavour has been devoted to the uncertainties-in-perspective phase. We did not fully succeed in producing the outputs associated with the first phases of PRIMA, although we did produce a first set of distinctive qualitative perspective-based interpretations that are internally consistent without being straightforward. The experiences discussed in this thesis indicate that it seems possible to design a procedure that enables to run the uncertainties-in-perspective phase along the lines of the PRIMA-framework.

In sum, this thesis provides insights into the sources of uncertainty and risk, it discusses a pluralistic approach for systematically addressing uncertainty and risk in decision-support endeavours, and it gives a first evaluation of the potential practical value by discussing RIVM's previous Environmental Outlooks as well as preliminary experiences with elements of the PRIMA approach in the context of the 5th Environmental Outlook.

2. Reflection

The first two phases of the PRIMA approach have been explored in a real life decision-support context. Although we did not come as far as we would have liked, it was by no means clear from the start that we would get as far as we did. Notwithstanding scepticism and careful enthusiasm, all practitioners who participated were very clear in concluding that we contributed to the learning process within RIVM, both on the individual and the collective level. The empirical data also indicate that a transition has been set in motion. It is unclear yet what this cultural change will imply for RIVM's practice in the broad sense and its ultimate decision-support products. It was clear that the potential progress in this transition is dependent on how the actual policy-analysts and decision-makers (i.e. RIVM clients) will act and react, on what they expect and desire, and on how far they do (not) want to go with innovating decision-support. We purposively decided to demarcate the ambitions of this PhD research in such a way that this complex interplay between science, societal actors and decision-makers was not a research topic. Nevertheless, the awareness that this interplay is ultimately crucial for the whole endeavour has always been clearly in the back of our mind.

The experience with RIVM taught us that a step-wise, iterative approach to integrated uncertainty management and risk analysis is needed. The framework turned out to be a heuristic at least concrete enough to serve as guideline for practice, and flexible enough to be adapted to the specific features of the case. The experiences yield that application of the PRIMA-approach as assessment methodology in the practice of decision-support anyhow requires a change in the way of thinking, that is fundamental and time-consuming. From Chapters 3 - 8 we concluded that such a process seems to involve the following steps: i) consciousness raising about uncertainty, risk and pluralism among practitioners, ii) recognition of the importance of adequate integrated uncertainty management and risk analysis in their actual decision-support practice, iii) understanding the essence of integrated uncertainty management and risk analysis as well as understanding which and how methods and techniques can be used, iv) designing a context-dependent procedure, v) implementation in pilot-cases, and vi) incorporation in standard practice.

The overall ambition underlying this thesis was to contribute to the further development of Integrated Assessment and IA methodology. In discussing the state of the art of this relatively young branch of decision-support, we have shown that the treatment of uncertainty and the incorporation of multiple perspectives are vital issues to the quality of IA, but that it is yet unclear how this can be done. Besides, it could be concluded that IA lacks frameworks to use analytical and participatory methods in a sensible and credible complementary way. Finally, it was argued that the IA community wants to explore how IA could benefit from risk approaches. What did this thesis deliver in view of these challenges? The PRIMA approach proposed in this thesis involves a process structure in which it is highlighted when, why and how analytical methods, participatory processes or a particular combination of both are valuable means to the targeted end(s). The PRIMA approach can thus be considered as proposing one possible methodological framework for IA. Because the proposed phases are discussed step by step and because concrete examples are provided, this thesis can be considered as a heuristic guide for those that would like to deal systematically with uncertainty and pluralism in IA endeavours. This thesis can be viewed as a first exploration of how IA may employ the risk concept and risk approaches. With regard to the latter, we hope that this thesis can serve as a scoping document for the IA community.

With the example of the perspective-based model routes implemented in the IA model TARGETS and with re-doing the classical example provided by Fischhoff and colleagues, we have tried to convincingly illustrate that the risk concept is essential to the PRIMA approach. Especially in terms of evaluating the policy relevance of the issues to be addressed in the assessment, in terms of fleshing out plural perspectives and in interpreting and communicating the assessment insights in a sensible and meaningful manner, the risk concept is crucial. Although the PRIMA approach is meant as integrated framework to address uncertainty and risk in decision-support endeavour, so far it has been mainly considered and used as an alternative approach to uncertainty management.

3. A look ahead

Although we have tried to be comprehensive and to fasten loose ends, a PhD thesis is always both an end and a new beginning. The following two research challenges pertaining to the proposed PRIMA approach can be easily derived from the current material and insights:

- to test the whole PRIMA-framework in varying contexts through ex-ante case studies.
- to improve the current PRIMA methodology, which involves among others: to further develop theoretically sound sets of perspectives that can be used in the various pluralistic modes of PRIMA, to explore procedures and tools to highlight different legitimate and relevant perspectives through social processes in a practically feasible manner, to strengthen the risk dimension, which among others means developing and designing tools and procedures that allow to put risk more on the table in the assessment process

Integrated Assessment aims to facilitate a process in which insights on complexity are co-produced by scientists, stakeholders and decision-makers. This means that methodology should not only be valid in scientific terms, but it should also be an acceptable approach in view of the social and political context. This means that follow-up research should involve extensive literature review on policy sciences and ideally also empirical research in order to conceptualise the decision-making contexts. These insights can then be used as another evaluation scheme for the PRIMA methodology.

Partly due to the complexity of the decision-making issues, the role of "knowledge transfer" changes: from "speaking-truth-to-power" to "mutual construction", and from given answers to highlighting uncertainty and risk, and evaluating robustness. This has consequences for institutes and organisations that have an intermediary role between science and decision-making. In the Netherlands, the planning offices, such as RIVM, CPB, RPD, SCP and CBS, are such intermediary institutions. In this thesis, we have focused on RIVM's assessment practice. For follow-up research, it would be interesting to involve other planning offices in the Netherlands, or similar intermediary institutions abroad. For such case-studies, the design developed through this thesis can be used, i.e. i) a retrospective analysis on previous assessment reports involving argumentation analysis, analysis of the argumentation in terms of uncertainty and risk perception, diachrone analysis, interviews and a focus group, and ii) an ex-ante study in which the PRIMA-framework serves as benchmark for the design. With regard to the latter, the challenge is to translate the proposed steps into procedures that fit into the context of practice, while still in line with the methodological principles. We learned from the research reported in this thesis that in order to do so a thorough analysis of the history and institutionalisation of the institute under concern, and an analysis of the organisational culture are needed to be able to put the ex-ante research in a broader context.

Apart from PRIMA-related challenges, the current research yields that the ultimate challenge is to develop variants of IA procedures that integrate different methods and approaches into a coherent assessment strategy. Such a 'toolkit' can help practitioners to design and implement concrete assessment activities. Uncertainty and risk have been the explicit starting point in this thesis. If we look back, it is clear that we have touched upon other methodological branches. To further develop methodology for Integrated Assessment the following ideas for future research can be derived from this thesis:

- systematic survey and review of relevant fields of methodology, such as participatory methods, scenario methodology, modelling approaches, evaluation methods, policy analysis, technology assessment, etc.
- development of frameworks involving a sensible and useful mix and phasing of methods
- testing the practical feasibility of these methodological frameworks in view of goals and contexts via ex-ante case-studies
- development of an IA toolkit comprising heuristic frameworks that involve goal/context - mix-of-methods combinations

In sum, an agenda for a follow-up research programme on IA methodology addressing uncertainty, risk and pluralism would comprise the following issues:

- the *methodological quality* of integrated uncertainty management and risk analysis, through further use of advances in related methodological fields.
- the *rationality of decision-making*, through use of insights from policy analysis, policy sciences and empirical research.
- the *practical feasibility and usefulness* of proposed heuristics, through empirical testing in ex-ante cases

4. Epilogue

In outlining our research perspective in the beginning of this PhD thesis, we admitted that our ideal was to act as a change agent in the practice of decision-support. With the current PhD research we have focused our efforts towards practitioners and analysts in actual decision-support practice. The next challenge is to interest actors in the decision-making realm in learning about alternative perspectives on uncertainty and risk, in addition to continuing the interactive mutual learning process with practitioners, as those from RIVM. This thesis at least provides enough basis and food for thought to continue with improving decision-support from a scientific angle.

We are well aware that this thesis may be evaluated as controversial. We realised that we played a risky game with an interdisciplinary thesis into issues fundamental to science and scientific advise. It is meant to encourage scientists, practitioners in decision-support, decision-makers and societal actors to put uncertainty and risk in another than their usual perspective and we hope to facilitate constructive communication among them about uncertainty, risk, robustness, participation and pluralism. With this thesis, we hope to sketch some more attractive perspectives to dealing with complexity than muddling along, which inadequate tools and methods.

Letter to the editor

by Rotmans and van Asselt (in Dutch)

Meten baadt niet bij RIVM-onderzoek

Onzeker zijn over de uitkomsten is inherent aan wetenschappelijk onderzoek, ook dat van het RIVM. Onzekerheid is niet aan synoniem aan slechte wetenschap. Samenwerking tussen onderzoeksinstituten kan een deel van de onzekerheid wegnemen en maken dat de politiek toch tijdig op antwoorden kan rekenen.

Milieu-onderzoek

Jan Rotmans en Marjolein van Asselt

Het RIVM is in opspraak: de betrouwbaarheid van het rijksinstituut werd de afgelopen week openlijk in twijfel getrokken, sinds Trouw een interview publiceerde met RIVM-werknemer De Kwaadsteniet (20 januari).

De Kwaadsteniet beticht het RIVM ervan gegevens met een geringe betrouwbaarheid te presenteren met name in de jaarlijks verschijnende Milieubalans. De onderzoeksresultaten zouden onvoldoende gevalideerd zijn en significant afwijken van de werkelijkheid.

Een van de problemen rondom dit soort onderzoek is de toenemende druk vanuit de politiek op instituten als het RIVM, om 'oplossingen' aan te dragen. De politiek geeft instituten als het RIVM als het ware de opdracht een onmogelijk moeilijke rekensom in een vloek en een zucht op te lossen. Dit leidt tot niet genoeg onderbouwde adviezen met een sterk ad hoc karakter, die continu worden bijgesteld in de tijd.

Op dit moment holt de politiek van rapport naar rapport zonder zichzelf en de adviserende onderzoeksinstituten de tijd te gunnen voor een grondige analyse. Slechts een dergelijk grondige werkwijze kan uitmonden in een structureel advies waar het beleid op langere termijn mee uit de voeten kan. Dit is geen pleidooi voor eindeloze onderzoekingen. Het karakter van de politiek vraagt nu eenmaal om tijdige informatie.

Maar zo'n grondige analyse door samenwerkende onderzoeksinstituten kan juist ook de basis bieden voor het snel en adequaat beantwoorden van ad hoc verzoeken om informatie.

Verder geldt dat onzekerheid omtrent milieu-gegevens er ook gewoon bij hoort: inherent aan wetenschappelijke kennis is dat deze onvolkomen is. Een significant deel van die onzekerheid kan niet worden weggenomen door het verrichten van meer metingen, zoals De Kwaadsteniet voorstaat. Het is illusoir om te veronderstellen dat het de fundamentele lacunes in onze kennis zou opvullen. Dus 'meten is weten' (Willem Breedveld, Podium, 27 januari) is achterhaald.

Politiek zet RIVM onder druk door een snel antwoord te vragen

Het werkelijke probleem dat schuilt achter de cijfers van het RIVM is dus niet zo zeer het gebrek aan metingen. De cijfers zijn beperkt betrouwbaar, omdat er grenzen zijn aan wat we kunnen weten. Om dit te onderbouwen moeten we de verschillende bronnen van onzekerheid nader analyseren.

Een belangrijk onderscheid is dat tussen 'onzekerheid door gebrek aan kennis' en 'onzekerheid door variabiliteit'.

Er zijn verschillende gradaties van gebrek aan kennis, te weten meetfouten, gebrek aan metingen en waarnemingen. Daarbij zijn er ook cijfers die in theorie te verzamelen zijn, maar in de praktijk niet.

Het is bijvoorbeeld onmogelijk te observeren hoeveel afval elke Nederlander iedere dag produceert, of om op iedere vierkante meter de concentraties fosfaat en ammoniak te meten. Daarnaast kunnen er verschillende cijferreeksen beschikbaar zijn die ruimte openlaten voor tegenstrijdige interpretaties.

Fundamenteler is het gebrek aan kennis doordat er zogenoemde variabiliteit optreedt. Variabiliteit betekent dat het systeem zich onvoorspelbaar kan gedragen en zich niet aan wetten houdt. Belangrijke redenen waarom die variabiliteit een rol speelt in milieu-onderzoek is de natuurlijke willekeur (denk aan het weer), de onvoorspelbaarheid van menselijk gedrag, en maatschappelijke en technologische verrassingen. Met andere woorden, al zou het RIVM alles meten wat er meten valt, dan nog zou de onzekerheid niet verdwijnen. Opeenstapeling in het onderzoek van verschillende van dergelijke onvoorspelbaarheden is een fundamenteel probleem, dat helaas niet opgelost kan worden door het opnemen van betrouwbaarheidsintervallen en waarschijnlijkheidsverdelingen, zoals de Kwaadsteniet suggereert. Zo'n interval is ondanks alle geavanceerde statistische methoden slechts een schatting van de mate van onzekerheid.

Daarnaast tonen sociaal-wetenschappers, vooral op het gebied van risico-communicatie, keer op keer aan dat niet-wetenschappers niet weten hoe waarschijnlijkheidsverdelingen en betrouwbaarheidsintervallen te interpreteren. Onze stelling is dat een dergelijke 'statistische' communicatie over onzekerheid de verwarring groter zou maken.

Het werkelijke probleem van onzekerheid is dus aanzienlijk complexer, en is ook geen typisch RIVM probleem. Ander beleidsonderbouwende instituten zoals het CPB, het SCP en het CBS worstelen met dezelfde problemen en produceren studies waarvan de resultaten zijn omgeven met de nodige onzekerheid, maar deze vormen anderzijds een onmisbaar hulpmiddel in het proces van de beleidsvoorbereiding. Dit ontslaat de voornoemde instituten uiteraard niet van de plicht om de nodige zorgvuldigheid te betrachten bij de presentatie van hun onderzoeksresultaten en beleidsadviezen.

De enige oplossing lijkt ons te zijn om een nieuwe modus te vinden voor het omgaan met onzekerheid in onze maatschappij. Dus niet langer onzekerheid in onze maatschappij. Dus niet langer onzekerheid louter als een probleem beschouwen of als synoniem van slechte wetenschap, maar ermee leren omgaan. Wie niet wil inzien dat onzekerheid onvermijdelijk is en schijnzekerheid gevaarlijk, zal tot in lengte van dagen steeds opnieuw geschokt zijn over de beperkte betrouwbaarheid van de cijfers in de rapporten van gerenommeerde onderzoeksinstituten.

Prof.dr.ir. Jan Rotmans en ir. Marjolein van Asselt, oud-werknemers van het RIVM, zijn directeur resp. onderzoeker bij het ICIS (International Centre for Integrative Studies) van de Universiteit Maastricht

Track record of media facts of DeKwaadsteniet affair

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in chronological order

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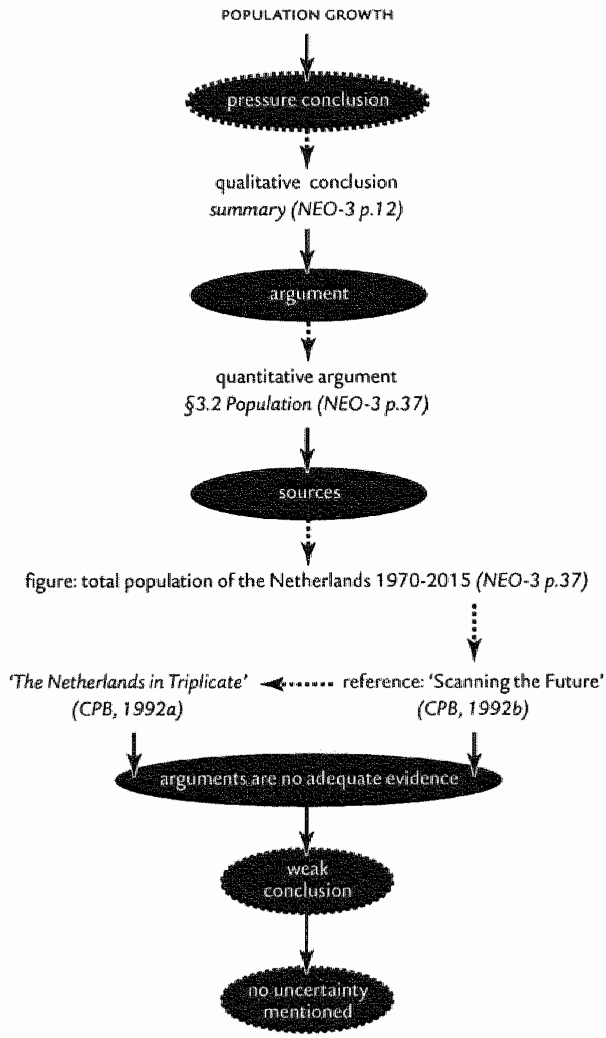
Argumentation analysis schemes

ISSUES NATIONAL ENVIRONMENTAL OUTLOOK-3 (1 of 4)



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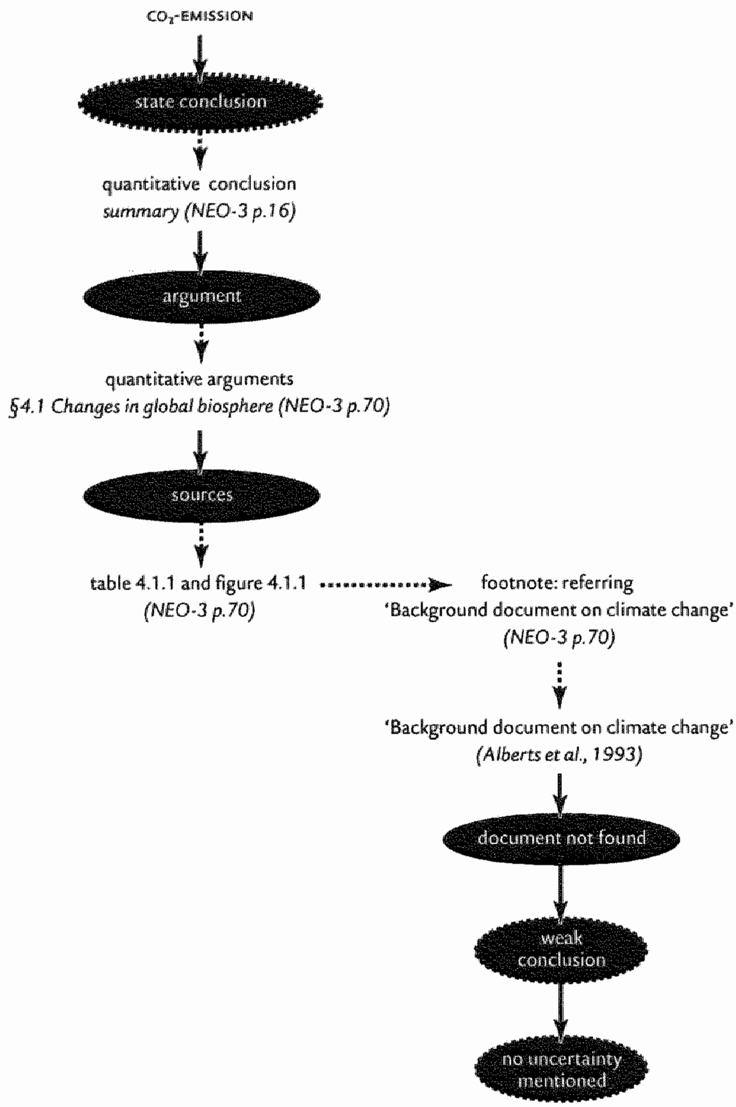

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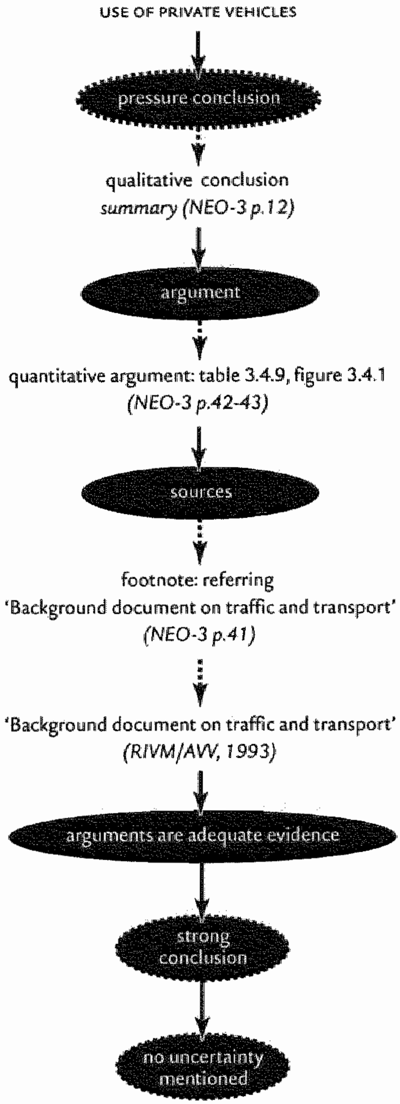

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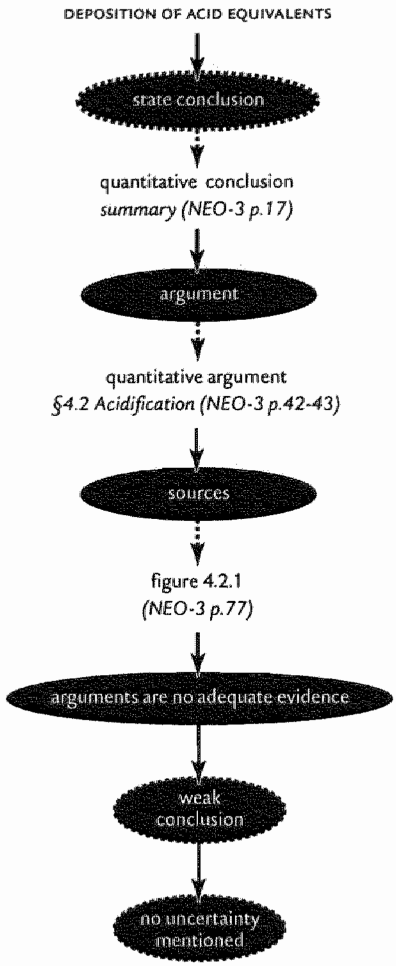

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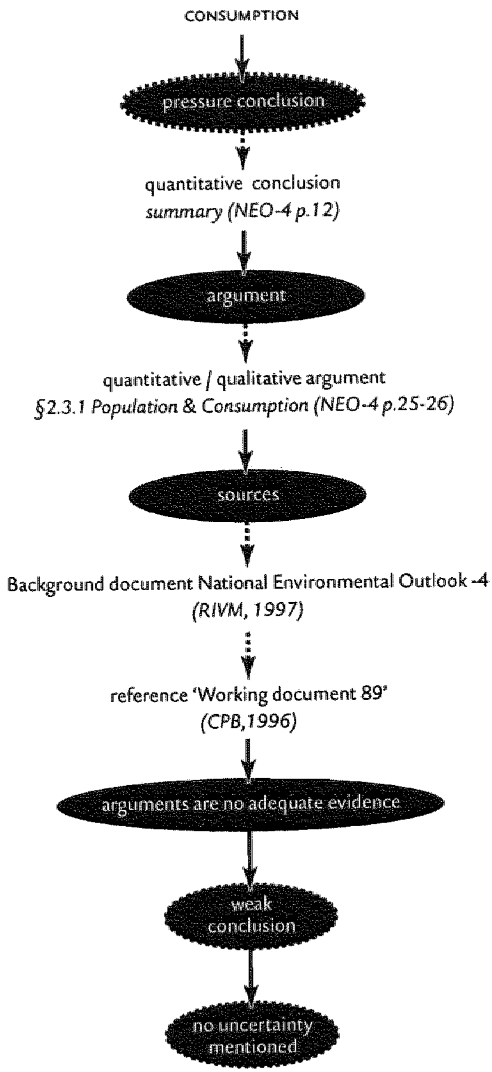

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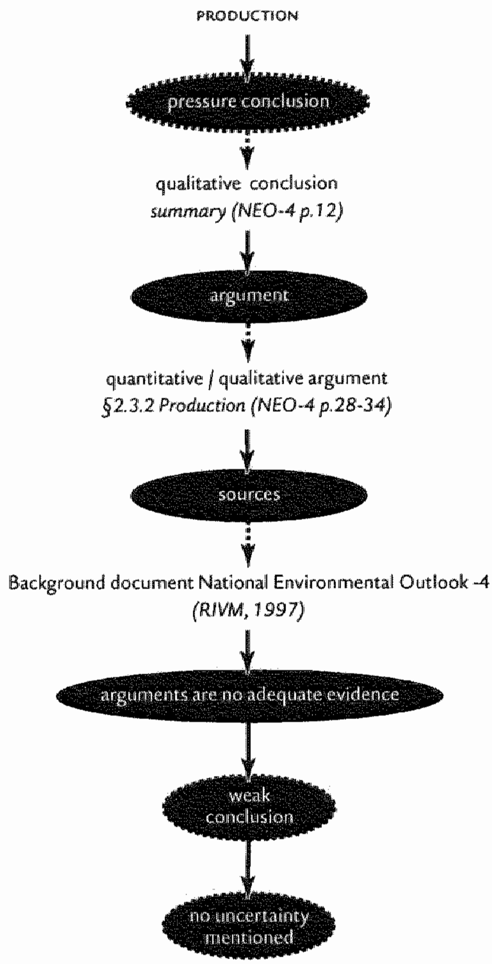

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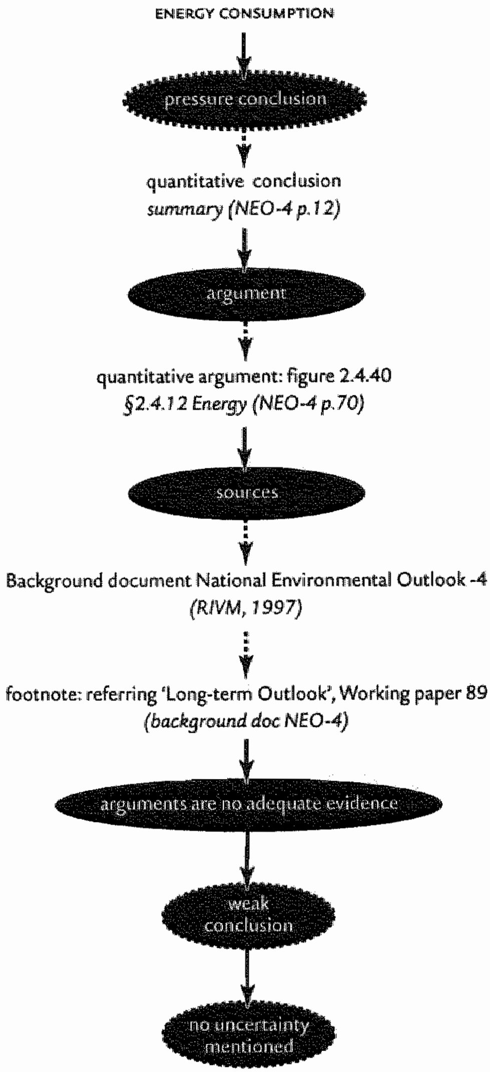

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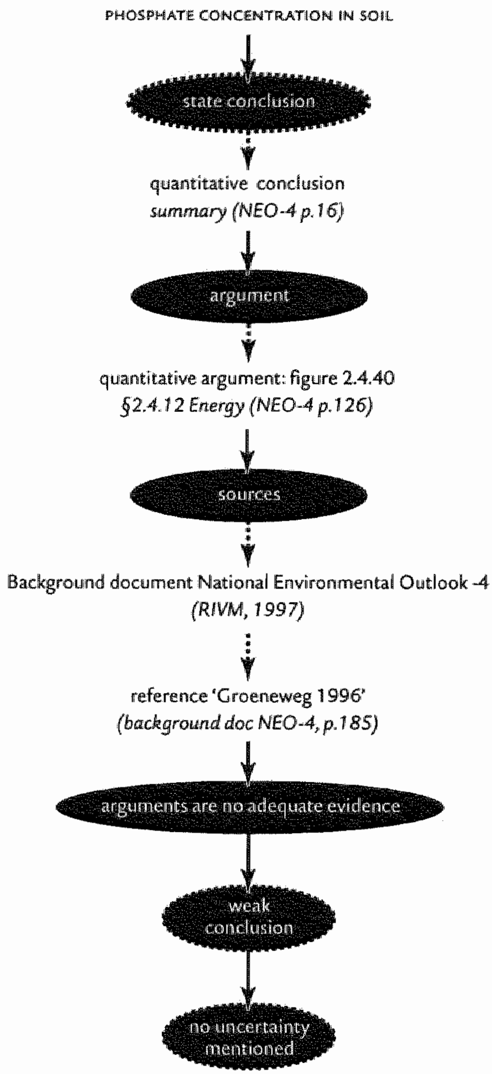

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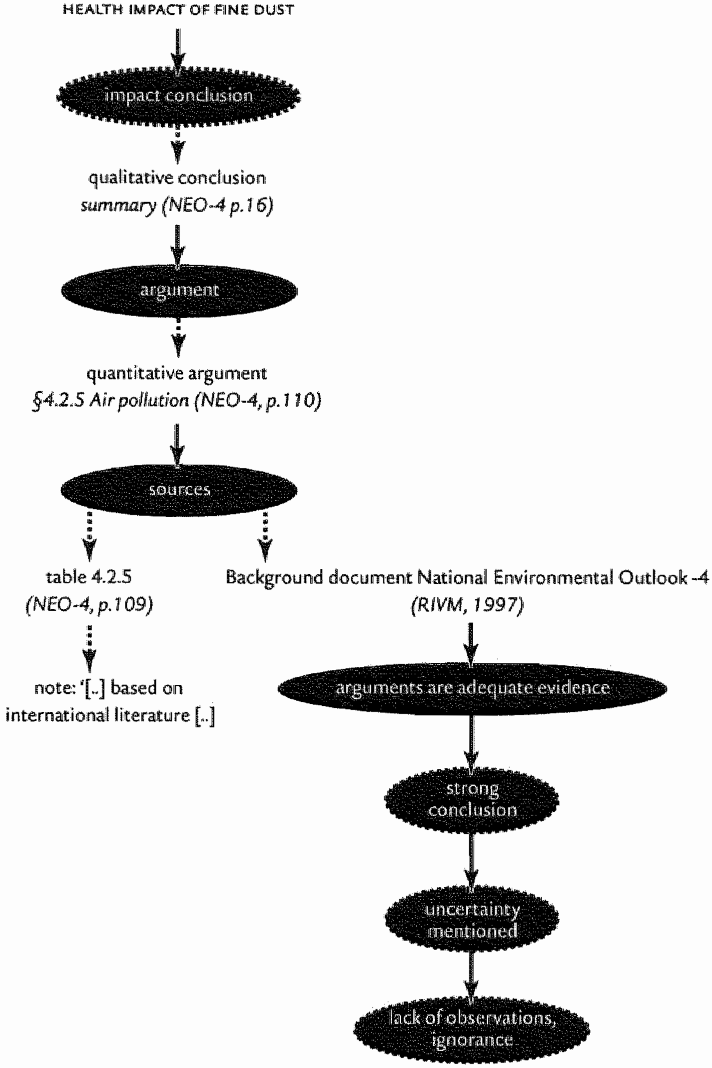
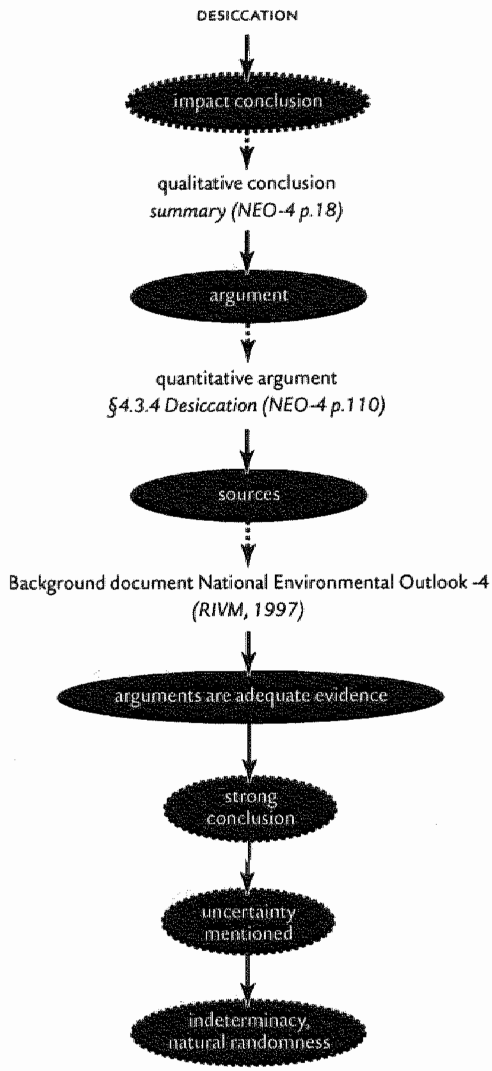


ISSUES NATIONAL ENVIRONMENTAL OUTLOOK-4 (6 of 6)



Perspectives on uncertainty and risk

The PRIMA approach to decision-support

Marjolein B.A. van Asselt

Perspectives on uncertainty and risk

The PRIMA approach to decision-support

proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Maastricht
op gezag van de Rector Magnificus, Prof. dr. A.C. Nieuwenhuijzen Kruseman
volgens het besluit van het College van Decanen,
in het openbaar te verdedigen
op donderdag 12 oktober 2000 om 16.00 uur

DOOR

ir. Marjolein B.A. van Asselt

PROMOTORES

Prof. dr. ir. J. Rotmans

Prof. dr. R. Hoppe Universiteit Twente

BEOORDELINGSCOMMISSIE

Prof. dr. ir. W.E. Bijker voorzitter

Prof. dr. C.C. Jaeger Potsdam Institute for Climate Impact Research, Germany

Prof. dr. P. Kirschner

Prof. dr. T. O'Riordan University of East Anglia, United Kingdom

Prof. dr. W.F. Passchier

Prof. dr. S. Rayner Columbia University, USA

Stellingen

1. Onzekerheid en risico zijn met elkaar samenhangende symptomen van complexiteit. Een complexe maatschappij als de onze, waarin ongelijksoortige processen steeds meer verstrengeld raken, wordt dus in toenemende mate gekenmerkt door inherente onzekerheid en daaraan gekoppelde risico's.

2. De analysemethoden die momenteel gebruikt worden in wetenschappelijk beleidsondersteunend onderzoek zijn ontoereikend om de meest cruciale onzekerheden en risico's adequaat te adresseren, omdat ze geen inzicht geven in de verschillende bronnen en typen van onzekerheid.

3. Het interpreteren van onzekerheid en risico vanuit één perspectief is misleidend en fundamenteel onjuist. Het zichtbaar maken van pluralisme door het gebruik van verschillende perspectieven vormt de grote uitdaging voor beleidsondersteunend onderzoek.

4. De in dit proefschrift voorgestelde benadering (PRIMA) om onzekerheid vanuit verschillende perspectieven te interpreteren, teneinde strategische risico's zo grondig mogelijk te verkennen met het doel robuuste strategieën te ontwikkelen, is theoretisch juist, en lijkt hanteerbaar en nuttig voor de praktijk van beleidsondersteuning.

5. Door het fenomeen onzekerheid lange tijd niet echt serieus te nemen, hebben de planbureaus, waaronder het RIVM, zich onnodig kwetsbaar gemaakt voor kritiek. De Kwaadsteniet legde alleen maar deze kwetsbaarheid bloot, zonder te begrijpen waar de klepel hing: meer meten is geen oplossing.

6. Het is heden ten dage eenvoudiger een torenhoog salaris en een lease-auto te regelen dan een echt interessante baan.

7. Het is onbegrijpelijk dat de universiteiten disciplinaire bastions blijven (waarvan de onneembaarheid in stand wordt gehouden door het NWO-mechanisme van disciplinaire 'peer-review'), terwijl de maatschappij schreeuwt om een interdisciplinaire aanpak van complexe problemen. Op deze manier zijn de universiteiten tot leegloop en maatschappelijke irrelevantie gedoemd.

8. Ouders van nu betalen liever een oppas dan dat ze (kinderloze) vrienden inschakelen. Daarmee onthouden ze hun kinderen en hun vrienden onbetaalbare momenten.

9. Als een kosmopoliet iemand is voor wie geen bestemming te ver is, dan zijn de meeste Randstedelingen gezien hun perceptie van de afstand Amsterdam-Maastricht eersteklas provincialen.

10. Wetenschap bedrijven is bewust nadenken. De liefde bedrijven is bewuste sex.

Perspectieven op onzekerheid en risico

de PRIMA-benadering voor beleidsondersteuning

Nederlandse samenvatting

De maatschappij wordt in toenemende mate geconfronteerd met complexe problemen. De kenmerken van de hedendaagse complexiteit zijn:

- er is sprake van een web van met elkaar samenhangende problemen (multi-problem)
- de problematiek ligt op het snijvlak van verschillende disciplines en domeinen (multi-dimensional)
- de onderliggende processen spelen zich op verschillende schaalniveaus in ruimte en tijd af (multi-scale)

De huidige beleidsondersteunende praktijk is niet toegesneden op dergelijke complexe vraagstukken. In dit proefschrift wordt een poging gedaan een constructieve bijdrage te leveren aan de noodzakelijke innovatie in beleidsondersteuning door een nieuwe benadering voor het systematisch analyseren van onzekerheid en risico (PRIMA) te ontwikkelen. Met theoretische en empirische argumenten wordt aangetoond dat onzekerheid en risico fundamentele onderwerpen zijn waaraan in beleidsondersteunende onderzoek tot nu toe nauwelijks serieuze aandacht wordt besteed. Het gevolg daarvan is dat de kwaliteit van beleidsondersteuning momenteel onder druk staat.

Tegen de achtergrond van het bovenstaande, staat in dit proefschrift de volgende vraag centraal (hoofdstuk 1):

> **Wat zijn theoretisch juiste en praktisch bruikbare wetenschappelijke methoden die beleidsondersteunende onderzoekers in staat stellen om onzekerheid en risico op een adequate en effectieve manier te adresseren in beleidsondersteunende studies?**

Met andere woorden:

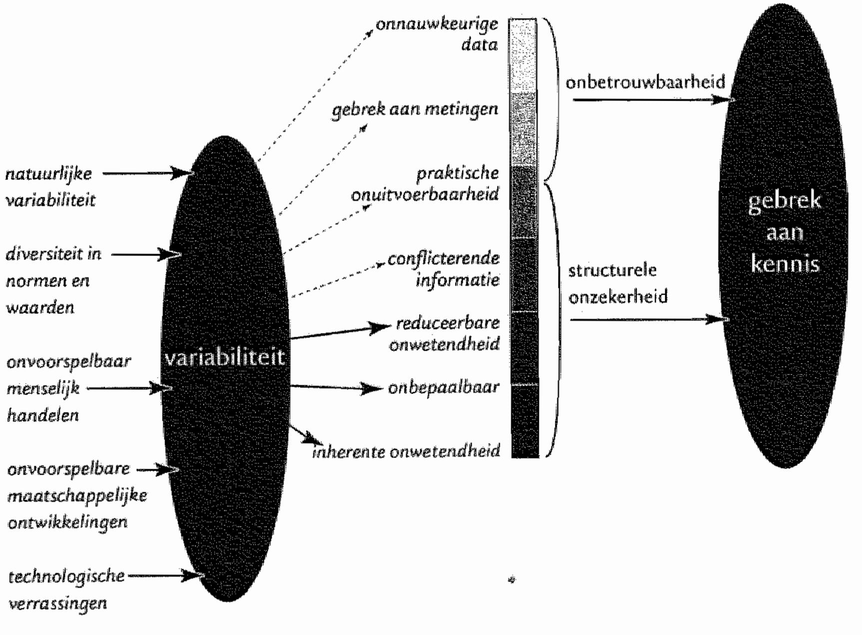
> **Hoe kan de kloof tussen het theoretische ideaal en de beleidsondersteunende praktijk overbrugd worden?**

De onderliggende onderzoekshypothese is dat het daartoe nodig is nieuwe methoden te ontwikkelen. In dit proefschrift wordt onderbouwd dat dergelijke methoden pluralistisch moeten zijn; daarmee wordt bedoeld dat de methoden rekening houden met, en gebruik maken van, het voorkomen van verschillende zienswijzen, normen- en waardenpatronen, percepties, paradigma's, culturen, wereldbeelden, etc.

Rekening houdend met de kenmerken van complexiteit, spreekt het voor zich dat een integrale benadering noodzakelijk is. Integrated Assessment (*in het Nederlands*: geïntegreerd denken en handelen) is een interdisciplinaire aanpak die zich in toenemende belangstelling mag verheugen. Integrated Assessment (IA) kan het best omschreven worden als een interdisciplinair en participatief proces waarin relevante kenniselementen worden gecombineerd met als doel besluitvormingsprocessen beter te ondersteunen. Het doel van Integrated Assessment is om inzicht te verkrijgen in complexe problemen door oorzaken, effecten en mogelijke strategieën te verkennen. Het is expliciet de bedoeling dat in geïntegreerde studies onzekerheden en verschillende risico-inschattingen expliciet gemaakt worden. Methoden en procedures om dit op een legitieme en adequate manier te doen ontbreken echter momenteel in de IA-gereedschapskist (hoofdstuk 2). Het is de ambitie van dit proefschrift om deze methodologische uitdaging op te pakken door methoden te verkennen die het mogelijk maken om op een geïntegreerde manier onzekerheid te 'managen' en risico te analyseren. De bedoeling is om daarmee een bijdrage te leveren aan de verdere ontwikkeling van Integrated Assessment als aanpak voor wetenschappelijk beleidsondersteunend onderzoek.

PRIMA

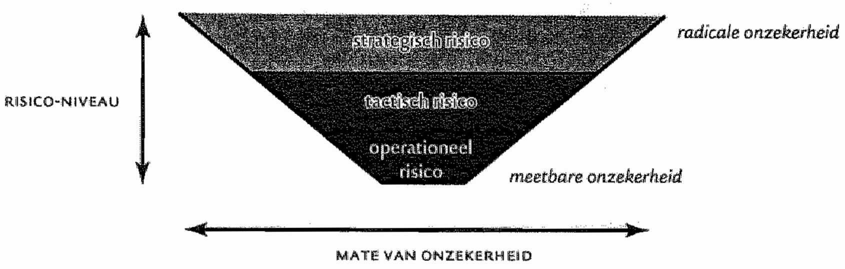
Het eerste onderdeel van het promotie-onderzoek behelst een studie naar de bronnen van onzekerheid en risico. Analoog aan het onderzoeken van een fysisch fenomeen, zoals klimaatverandering, hebben we geprobeerd de oorzaken die aan het voorkomen van onzekerheid en risico in maatschappelijke debatten ten grondslag liggen, te identificeren. Dit deelonderzoek mondt uit in een taxonomie van bronnen van onzekerheid (figuur 1), die gebruikt kan worden om het begrip te verhelderen en de discussie te verbeteren. Deze taxonomie is generiek, in de zin dat hij algemeen bruikbaar is voor het iden-



FIGUUR 1 Taxonomie van bronnen van onzekerheid

tificeren en verkennen van bronnen van onzekerheid in studies naar complexe maatschappelijke problemen.

Op basis van de analyse van de wetenschappelijke literatuur uit verschillende disciplines (uiteenlopend van wiskunde en economie tot filosofie en wetenschapsstudies) over onzekerheid en risico, concluderen we dat radicale onzekerheid, strategische risico's en meerdere perspectieven inherent zijn aan complexiteit. Radicale onzekerheid betreft onzekerheden die op zijn best grof geschat kunnen worden. Strategische risico's zijn risico's die niet gecontroleerd kunnen worden door individuen, die niet exact gelokaliseerd kunnen worden, en het zijn risico's die spelen op de lange termijn (zowel wat oorzaken als effecten betreft). In dit proefschrift wordt beargumenteerd dat onzekerheid en risico aan elkaar gerelateerde concepten zijn, die beschouwd kunnen worden als twee zijden van dezelfde medaille: de beperkte voorspelbaarheid van complexiteit. Onzekerheid en risico zijn dus symptomen van complexiteit. 'Onzekerheid' (hoofdstuk 3A) wordt veelal geassocieerd met de wetenschappelijke rationaliteit, terwijl 'risico' een concept is dat in de eerste plaats geassocieerd wordt met de rationaliteit van beleidsmakers en besluitvormers (hoofdstuk 3B). In figuur II wordt weergegeven hoe de mate van onzekerheid en het type risico gerelateerd zijn.



FIGUUR II Mate van onzekerheid en type risico

Complexiteit impliceert dus zowel onzekere risico's als riskante onzekerheden. Dit betekent dat onzekerheid niet adequaat bestudeerd kan worden zonder risico daarbij te betrekken en vice versa. Tot nu toe houden veelal gescheiden onderzoeksgemeenschappen zich of bezig met risico of met onzekerheid. In deze onderzoeksvelden domineerde tot voor kort de klassieke benadering waarin onzekerheid en risico behandeld worden als mathematische en statistische artefacten. In deze onderzoeksgemeenschappen groeit het inzicht dat:

- wetenschap een creatief en innovatief proces is waarin intellect, intuïtie, normen en waarden interfereren met feiten en cijfers
- kennis niet equivalent is met zekerheid en waarheid
- experts risico's anders percipiëren dan 'leken'
- culturele factoren de manier waarop mensen risico's inschatten beïnvloeden

De logische consequentie van deze gedeelde inzichten is dat verschillende perspectieven op onzekerheid en risico legitiem en valide zijn.

In dit proefschrift wordt aangetoond dat de huidige methoden voor onzekerheidsanalyse en risico-assessment vooral te kort schieten in geval van radicale onzekerheden en strategische risico's, precies die soorten onzekerheden en risico's die zo'n grote rol spelen bij complexe maatschappelijke problemen. Op grond daarvan concluderen we dat er behoefte is aan nieuwe methoden, die gebruik maken van verschillende perspectieven teneinde pluralisme zichtbaar te maken en constructief te benutten. Een pluralistische aanpak impliceert dat verschillende legitieme interpretaties van de onzekerheden en divergerende risico-percepties worden meegenomen in de analyse. Onze analyse van het concept 'pluralisme' (hoofdstuk 4) mondt uit in de constatering dat er niet slechts één pluralistisch uitgangspunt mogelijk is, maar meerdere. Dit betekent dat er niet één unieke methode is waarmee de geobserveerde behoefte vervuld kan worden, maar dat er in principe een variëteit aan methoden denkbaar is waarmee een bijdrage geleverd kan worden aan effectief pluralistisch onzekerheidsmanagement en risico-analyse. Dat betekent dat het Pluralistic fRamework for Integrated uncertainty Management and risk Analysis (PRIMA), dat in het voorliggende promotieonderzoek wordt ontwikkeld, maar één manier is om onzekerheid en risico theoretisch adequaat te adresseren in beleidsondersteunende studies. De PRIMA-benadering is überhaupt niet bedoeld als blauwdruk. Het doel van de PRIMA benadering is om een heuristiek - een manier om een zoekproces te structureren- te bieden, die bestaat uit een aantal stappen en stadia, die theoretisch consistent zijn en praktisch bruikbaar lijken voor de beleidsondersteunende praktijk.

Centraal in de PRIMA-benadering (hoofdstuk 5) staat de ambitie om controverses over complexe maatschappelijke problemen te ontrafelen in termen van radicale onzekerheden en strategische risico's. De pluralistische aanpak impliceert dat de geïdentificeerde onzekerheden en risico's systematisch geïnterpreteerd worden aan de hand van verschillende perspectieven. Deze verschillende interpretaties en inschattingen worden met elkaar geconfronteerd met het doel om een rijker beeld te schetsen van de betreffende complexe problematiek.

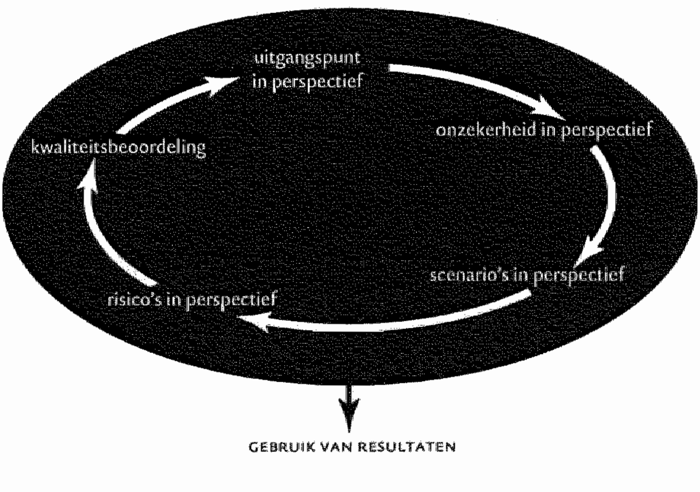
De essentie van de PRIMA aanpak is dat onzekerheden die in een participatief proces als cruciaal met het oog op strategie-ontwikkeling worden aangeduid, volgens verschillende perspectieven worden 'ingekleurd'. In het

marktoptimist	**milieu-doemdenker**	**controlist**
Vrij marktmechanisme en antiregulering; economische groei en technische ontwikkeling is vooruitgang.	Natuur is kwetsbaar, dus geen milieurisico's nemen; voorkomen is beter dan genezen.	Stabiliteit door regelgeving, hiërarchie en normstelling. Regulering van natuur en milieu. Verschillen accepteren.
Individuele ontplooiing en materieel eigenbelang zijn motieven voor handelen. Succes is een persoonlijke verantwoordelijkheid.	Gelijkheid	Risicomijdend en anti-verandering; zoetjes aan dan breekt het lijntje niet.
Natuur is niet kwetsbaar, kan wel tegen een stootje.	Economie als middel, niet als doel; bewust consumeren.	Autoriteit door expertise en ervaring.
Problemen zijn oplosbaar; Risico's bieden mogelijkheden, uitdagingen.	Mensen zijn solidair en gedragen zich ook zo; collectief belang.	Macht en aanzien zijn de motieven voor actie.

TABEL 1 Eigenschappen van de drie gebruikte perspectieven

proefschrift maken we daartoe gebruik van drie perspectieven (de markt-optimist, de milieu-doemdenker en de controlist; zie tabel I) ontleend aan de Culturele Theorie.

De perspectivische interpretaties van onzekerheden worden vervolgens gebruikt om op een systematische manier verschillende scenario's te ontwikkelen. Geïntegreerde analyse (hetzij kwalitatief, hetzij gebruik makend van modellen) van deze fundamenteel verschillende scenario's biedt vervolgens de basis om autonome ontwikkelingen en beleidsstrategieën te evalueren in termen van risico. Scenario's worden in dit proefschrift gedefinieerd als coherente beschrijvingen van verschillende mogelijke toekomsten, dat wil zeggen dat een scenario een sequentie is van elkaar opvolgende gebeurtenissen en processen over een bepaalde tijdsperiode. Een dergelijke geïntegreerde evaluatie stelt analisten in staat de mate van robuustheid van de aanbevelingen systematisch te verkennen, te onderbouwen en te communiceren. Deze verschillende fasen van de PRIMA-benadering zijn samengevat in figuur III.



FIGUUR III Samenvatting van PRIMA-aanpak

Onzekerheid en RIVM's Milieuverkenningen

De volgende vraag is of de voorgestelde PRIMA-benadering ook potentiële waarde heeft voor de beleidspraktijk. Is het mogelijk de geformuleerde PRIMA-stappen uit te voeren? Zo ja, hoe en wat levert dat op? Met het oog op deze vragen hebben we een case-studie uitgevoerd betreffende de Milieuverkenningen van het Rijksinstituut voor Volksgezondheid en Milieu (RIVM). Het eerste onderdeel van deze case-studie behelst een retrospectieve analyse van de vier Milieuverkenningen die het RIVM sinds 1988 heeft geproduceerd. In dit deelonderzoek is nagegaan hoe de belangrijkste conclusies onderbouwd worden en op welke manier in deze redenering wordt omgegaan met onzekerheden. Op basis van deze analyse kan geconcludeerd worden dat het RIVM een strategie en een kader ontbeert om in hun activiteiten op een systematische manier met onzekerheid om te gaan, wat consequenties heeft voor de robuustheid en de kwaliteit van de conclusies en beleidsaanbevelingen. De huidige manier van werken is met het oog op het fundamentele karakter van onzekerheid dus problematisch te noemen. Het RIVM is daardoor kwetsbaar voor kritiek, zoals de De Kwaadsteniet-affaire op een dubieuze, maar krachtige manier illustreerde. Het RIVM is niet het enige planbureau dat worstelt met het vraagstuk van onzekerheid. Uit het case-studie materiaal blijkt dat het aannemelijk is dat dit evenzeer geldt voor de andere planbureaus en beleidsondersteunende instituten. De conclusies aangaande de Milieuverkenningen lijken dan ook te gelden voor soortgelijke verkenningsactiviteiten. Op grond van onze case-studie concluderen we dus dat er in de wetenschappelijke beleidsondersteuning een latente behoefte is aan nieuwe methoden voor onzekerheidsmanagement. Uit onze data blijkt dat die behoefte ook meer en meer expliciet door de praktijk zelf wordt onderkend.

De volgende vraag is in hoeverre de PRIMA-aanpak de potentie heeft om in deze behoefte te voorzien. In dit proefschrift hebben we ons beperkt tot de vraag of en hoe het mogelijk zou zijn de eerste twee PRIMA-stappen uitvoeren. Deze vraag is verkend in de context van het Milieuverkenningen 5 proces, waarbij we ons vooral toegespitst hebben op de 'onzekerheid-in-perspectief' fase. Vervolgens hebben we gekeken hoe de output van de PRIMA-activiteiten (focusgroep, workshop, enquêtes en integrale analyse daarvan) bruikbaar zou kunnen zijn voor de Milieuverkenningen 5, om op die manier het praktisch nut van de gezette stappen te verkennen. Dit empirische onderzoek mondt uit in een werkbare procedure voor de fase 'onzekerheid-in-perspectief'. Daarnaast wordt door het empirische onderzoek de relevantie voor de praktijk van de fase 'uitgangspunt-in-perspectief' aangetoond.

De ervaringen opgedaan in deze prospectieve fase van het onderzoek suggereren dat het mogelijk en zinvol is om de PRIMA-benadering in de praktijk van beleidsondersteunend onderzoek in te zetten. Duidelijk is wel dat implementatie van de PRIMA-aanpak in de praktijk een fundamentele omslag in de manier van denken en handelen vergt en dat een dergelijke omslag ook de nodige tijd en moeite kost. De bij het prospectieve onderzoek betrokken RIVM-ers waren eensgezind in hun evaluatie dat de PRIMA-activiteiten tenminste een bijdrage geleverd hadden aan het individuele en collectieve leerproces binnen het RIVM.

Conclusies

Het promotie-onderzoek heeft tot doel inzicht te geven in de vraag of er theoretisch juiste en praktisch bruikbare alternatieve wetenschappelijke methoden denkbaar zijn die beleidsondersteunende onderzoekers in staat stellen om onzekerheid en risico op een adequate en effectieve manier te adresseren in beleidsondersteunende studies. In dit proefschrift wordt beargumenteerd dat er zowel een theoretische behoefte als een behoefte vanuit de beleidsondersteunende praktijk is aan pluralistische methoden waarin onzekerheid en risico in hun onderlinge samenhang worden beschouwd. De voorgestane PRIMA-benadering is ontwikkeld conform deze eisen. De eerste ervaringen beschreven in dit proefschrift geven aan dat het mogelijk en zinvol lijkt de PRIMA-benadering in de praktijk te gebruiken. Daarmee zou de kloof tussen het theoretische ideaal en de praktijk zeker niet gedicht zijn, maar er zouden met het verder ontwikkelen en toepassen van de PRIMA-benadering wel belangrijke stappen op weg naar een theoretisch onderbouwde innovatie in beleidsondersteuning gezet kunnen worden.

De ambitie die ten grondslag ligt aan dit proefschrift is om een methodologische bijdrage te leveren aan de ontwikkeling van Integrated Assessment als aanpak voor wetenschappelijk beleidsondersteunend onderzoek. Wat heeft PRIMA Integrated Assessment te bieden? De PRIMA aanpak geeft een proces-structuur waarin zowel analytische als participatieve methoden gebruikt worden. De PRIMA-benadering kan dus beschouwd worden als een methodologisch kader voor geïntegreerde studies. Daarnaast kan het als heuristiek gebruikt worden om in Integrated Assessment meer systematisch met onzekerheid, risico en pluralisme om te gaan.

Een proefschrift is altijd zowel een eindpunt als een nieuw begin. Uit het voorliggende materiaal en de gegenereerde inzichten kunnen de volgende uitdagingen voor vervolgonderzoek worden afgeleid:

- verdere methodologische ontwikkeling van prima door kennis en inzicht met betrekking tot participatieve methoden en scenario-ontwikkeling, en inzichten ontleend aan aanverwante velden zoals beleidsanalyse en technology assessment (nog) beter te benutten
- het erbij betrekken van de rationaliteit van beleid en beleidsprocessen, door gebruik te maken van beleidsanalyse, beleidswetenschappen en politicologie en middels empirisch onderzoek
- het toetsen van het praktische nut van prima door empirische toetsing in een serie van ex-ante case-studies ten aanzien van beleidsondersteunende activiteiten

Een interdisciplinair proefschrift is nog steeds een curiositeit. Daarnaast stelt dit proefschrift fundamentele vragen over de interactie tussen wetenschap en beleid. Het is duidelijk dat dit proefschrift daarom door deze en gene als controversieel beschouwd zal worden. Het is vooral de bedoeling dat dit proefschrift wetenschappers, beleidsondersteuners, beleidsmakers, maatschappelijke actoren en geïnteresseerde individuen uitdaagt om onzekerheid en risico eens in een ander perspectief te plaatsen om op die manier een noodzakelijke discussie over de toekomst van wetenschappelijk beleidsondersteuning aan te jagen.

Curriculum vitae

Marjolein B.A. van Asselt

Marjolein van Asselt (1969) has an evident interest in ***interdisciplinary research***. She is interested in the fundamental question how theories and knowledge from natural sciences and social sciences can be brought together in such a way that it is both scientifically valid and useful to society. In that sense the young research area of Integrated Assessment fits perfectly with her research interests. Marjolein can be characterised as someone ***building bridges*** in various ways: between disciplines, between process and product, and between science and society.

Marjolein van Asselt did her undergraduate in Computer Science at Twente University in the Netherlands. She finished the master course Philosophy in Science, Technology and Society (Twente University) in 1994. In 1993, she was awarded with the Stork UT prize: an annual award for a student who combines good study results with an active, recognisable role in student and university life. She was the first female prize winner ever and the first laureate from a non-technical department.

In 1993, she entered the Global Dynamics and Sustainable Development group of prof. Jan Rotmans at RIVM (Bilthoven, the Netherlands) as intern studying the gap between Integrated Assessment modellers and their targeted users (i.e. decision-makers). After her graduation, she stayed with this team till June 1996. Together with Jan Rotmans she developed the concept of perspective-based model routes as an approach to highlight inherent uncertainty and subjectivity in Integrated Assessment Models. Through team-work, the concept was implemented in the IA model TARGETS.

Since the beginning of her research carreer, Marjolein has tried to use insights from philosophy and sociology of science to improve methodology for interdisciplinary decision-support. Although she acqainted a fair level of knowledge on a variety of issues related to global change and sustainable development through working in Integrated Assessment projects, her main interest is still methodological.

From July 1996 to June 1997, Marjolein van Asselt worked in Switzerland, in the Human Ecology Group at the Swiss Institute for Environmental Science and Technology (EAWAG). Supervised by prof. Carlo Jaeger, she particpated in two large IA projects, i.e. the ULYSSES project and the CLEAR project. Both projects aimed to find ways to use models and participatory methods in a complementary manner in the assessment effort. In this way, Marjolein gained experience with participatory assessment processes.

In July 1997, she returned to the Netherlands. She was invited by Jan Rotmans to assist him in establishing a new research team at Maastricht University. In January 1998, the International Centre for Integrative Studies (ICIS) opened her doors. Marjolein van Asselt is currently deputy director of ICIS and team leader of the ICIS' research programme IA methodology. Next to that, she is co-director of ICIS-BV, a consultancy firm that has been developed as a spin-off from the ICIS' research activities.

Next to her PhD research, Marjolein has been involved in a number of innovative research projects, such as the VISIONS project in which integrated multi-level scanerios for Europe are developed, and a NOP/IRMA project in which perspective-based scenarios are used to develop integrated water-management strategies for the Rhine and Meuse. She furthermore plays a leading role in the IA consultancy projects, for clients such as the Province of Limburg, the city of Maastricht, RIVM and Dutch Ministries.

Marjolein van Asselt has initiated and organised the first international advanced study course in Integrated Assessment (August - September 1999): a 3-week course featuring leading scientists in the field of Integrated Assessment, in which 25 post-graduates from 17 nationalities and from a wide range of disciplines participated. This course "Tools and methods for Integrated Assessment" was organised under the auspices of the European Commission-DG Research and the European Forum on Integrated Environmental Assessment (EFIEA). She is furthermore co-organisor and host of the EFIEA workshop on scaling issues in Integrated Assessment (July 2000) as well as of the workshop "Dealing with uncertainty in environmental decision-making" (November 2000) within the European Science Foundation TERM II programme.

Marjolein is an active member of the European Forum on Integrated Environmental Assessment (EFIEA). She is furthermore member of the editorial board of the international journal Integrated Assessment and associate of the International Journal of Risk Assessment and Management (IJRAM).

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the road ahead is empty

paved with miles of the unknown

whatever seems to be your destination

take uncertainty as your guide