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Uncertainty & RIVM's Environmental Outlooks
Documenting a learning process

M.B.A. van Asselt, R. Langendonck, F. van Asten,
A. van der Giessen, P.H.M. Janssen,
P.S.C. Heuberger and I. Geuskens

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RIVM, PO Box 1, 3720 BA Bilthoven, telephone: +31 30 274 91 11; fax: +31 30 274 29 71

Cover design: Esther Mosselman, Zwaar Water

National Institute of Public Health and the Environment (RIVM)
P.O. Box 1
3720 BA Bilthoven, The Netherlands
Tel. +31 30 2749111
Fax. +31 30 274297

CONTENTS

Figures

Tables

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EXECUTIVE SUMMARY

Uncertainty is an important topic within RIVM. How to deal with uncertainty has been an explicit and often asked question in the course of the 5th Environmental Outlook (MV-5) assessment process. The current report synthesises the research on uncertainty and the Environmental Outlooks that has been carried out since November 1997.

The topic of uncertainty is introduced by tracking the thinking about uncertainty over time and providing a taxonomy of sources of uncertainty. Existing quantitative and qualitative approaches for addressing uncertainty in assessment endeavours are discussed and reviewed in view of the various sources of uncertainty. The major conclusion from this review is that uncertainty management lacks a toolkit that enables us to identify and address salient uncertainties in an adequate manner as a key activity in policy analysis (Chapter 2).

Chapter 3 reports the analysis of the series of Environmental Outlooks, from 'Concern for Tomorrow' (RIVM first Environmental Outlook) to the 4th Environmental Outlook. Using the MV (Environmental Outlook) reports as starting point, it was analysed how uncertainty was managed. Although a variety of quantitative as well as qualitative methods have been used for dealing with uncertainty, it was concluded that uncertainty was not managed in a systematic way in the first four Environmental Outlooks. It is furthermore argued that this lack of explicit and systematic uncertainty management has resulted in a vulnerable position, illustrated by the so-called 'DeKwaadsteniet affair'.

Chapter 4 summarises the PRIMA (Pluralistic fRamework for Integrated uncertainty Management and Risk Analysis) approach, which provides a structure for the process of uncertainty management. The basic ideas and the various steps in this approach are discussed as a background to the subsequent Chapters. The guiding principle in the PRIMA approach is that uncertainty legitimates different perspectives and, that - as a consequence - uncertainty management should consider different perspectives. Central to the PRIMA approach is the issue of disentangling controversies on complex issues in terms of salient uncertainties. The salient uncertainties are then 'coloured' according to various perspectives. Starting from these perspective-based interpretations, various legitimate and consistent narratives are developed to serve as basis for integrated analysis of autonomous and policy-driven developments in terms of risk. In this way, the level of uncertainty of the underlying knowledge can be made explicit and robust insights relevant for decision-making can be distilled.

In the course of time, a growing interest evolved on exploring how the PRIMA approach could be used in the assessment process for the 5th Environmental Outlook. As a consequence, a sequence of activities was carried out between February 1999 and March 2000: a focus-group meeting with the RIVM management, a workshop with analysts, an open lecture for those directly and indirectly involved in the 5th Environmental Outlook process and a review workshop with the 5th Environmental Outlook project team. These activities enhanced awareness of uncertainty and provided the practitioners with ideas on considering uncertainty in their contribution to the Environmental Outlook. Furthermore, ideas and concepts from the PRIMA approach were used to communicate on uncertainty in the 5th Environmental Outlook report. All this is reported in chapter 5.

In order to evaluate how uncertainty had been treated in the 5th Environmental Outlook process, a number of group interviews was set-up with analysts who played a leading role in this process (Chapter 6). In general uncertainty was considered to be inherent to science (i.e. a constructivist attitude). A shared ambition to explicitly address uncertainty in the MV-5 assessment process was observed. A number of uncertainties were collectively judged as being critical to the MV-5: human and ecological effects, effectiveness of policy/measures, developments abroad, behaviour, climate variability, emissions, technology and economy. The interview data seem to suggest that, in the MV-5 assessment process, uncertainty was mainly dealt with in an informal intuitive way - by means of expert judgement and peer review - that was neither completely transparent nor fully documented. This inadequate uncertainty treatment was argued as being not only a question of time and priority, but also of the need for more learning. The empirical evidence reported in chapter 3-6 of this document indicates that a growing conviction exist that systematic uncertainty management is definitely needed. To facilitate the required learning it will be essential that a substantial amount of time, effort and expertise is invested. The argument was put forward that uncertainty management should be a strategic priority for RIVM as a whole.

In the interviews a number of suggestions can be derived for future assessment activities. First, there is a clear and broadly shared need for *scenarios* that offer a broader perspective than the CPB scenarios. Secondly, since uncertainty information is not really transmitted over the course of the *model chain*, an increased focus is needed on interdisciplinary uncertainty communication in integrated assessment studies. Finally, since neither the final report nor the background documents fully address the integrated assessment ('the bridge' between the background reports and the main report), it was suggested to produce two equally assessed documents, i.e. a comprehensive integrated assessment report, in which uncertainty is consistently addressed (*scientific compendium*) and a brief policy summary with relevant points for governmental consideration. Background reports, which discuss particular topics in detail, form the ingredients for the integrated assessment that is reflected in the scientific compendium. It is also important that such basic documents are produced on a continuous basis so that they can actually be used in the assessment process, and not later or too late in the process as is current common practice. (See chapter 7).

In sum, it can be generally concluded that RIVM needs a *protocol* or at least a guideline that describes which uncertainty management steps need to be taken in which phase of the assessment process. Our analysis indicates that RIVM scientists are more than willing to embark on the endeavour towards uncertainty management. It has to be realised that this will be a lengthy common query of apparently small steps forward. Unrealistic expectations should be avoided, since this may even frustrate the learning process. It is important that RIVM dares to be consistent in its uncertainty management ambition. Attention should be given to adequate communication on uncertainty, its nature, role and implications, towards policy-makers, the public and other stakeholders. Most respondents shared the opinion that RIVM should start *today* with the 6th Environmental Outlook. It is argued that in all relevant project plans uncertainty management should be explicitly indicated, also in terms of time, effort and expertise needed.

1 INTRODUCTION

Uncertainty is an important topic within the Dutch National Institute of Public Health and the Environment, RIVM. How to deal with uncertainty was an explicit and often posed question in the course of the 5th Environmental Outlook assessment process. Certainly, no new topic to the RIVM, uncertainty was the subject of a workshop organised by RIVM in the late 1980s. Since then, there have always been several experts working on this subject at the Institute. Early examples of such RIVM activities in the field of uncertainty analysis are e.g. the report 'Uncertainty Analysis and Sensitivity Analysis: An Inventory of Ideas, Methods and Techniques from the Literature' written by Janssen, Slob and Rotmans in 1990 and the development of the UNCSAM software for Monte Carlo uncertainty analysis in the early 1990s. Notwithstanding these and several other efforts (see e.g. reference list in RIVM (1999b)), uncertainty has not been the main focus in RIVM's research and assessment activities. RIVM was no exception here: other policy analysis offices and decision-support agencies tended to underestimate the importance of addressing uncertainty in their assessment activities. Decision-makers on the other hand expected answers to their questions, and were not looking for uncertainty estimates. However, RIVM considered 'uncertainty' an issue worthy of further study. In this context, it was decided in 1997 to finance a research project at Maastricht University (International Centre for Integrative Studies - ICIS) on uncertainty management. Part of the project was a case study on uncertainty and the Environmental Outlooks. This project has culminated in the report you have before you, which represents a summary of the research project, 'Perspectives on uncertainty and risk'. It is meant to provide insight into a collective learning process[1]. In the course of time, the endeavour developed into a kind of background project on uncertainty management in the 5th Environmental Outlook.

The so-called De Kwaadsteniet affair early in 1999 illustrated the societal and political importance of uncertainty, which created the momentum both at RIVM and other policy analysis agencies to confront the issue. This affair started on January 20, 1999 with a reader's letter from, and an interview with, Hans de Kwaadsteniet, an RIVM employee, which had been published in a national newspaper (*Trouw*). De Kwaadsteniet made the headlines with his argument under the title, 'Environmental institute lies and cheats' that RIVM was unjustifiably suggesting a level of certainty in their environmental reports[2]. A media affair then broke loose and was kept alive for the rest of the year. All Dutch newspapers, both national or regional, and news bulletins, current affairs programmes and documentaries on radio and television reported on the topic[3]. A wide variety of scientists and policy analysts expressed their views via the so- can be roughly divided into two camps: those supporting De Kwaadsteniet's argument called 'opinion pages' in the national press or as opponents in media debates. The surge of reactions that measuring is knowing, versus those acknowledging inherent uncertainty in decision-support related to complex issues. The first group advocated more measurements and statistical methods as the dominant way to improvement. The second group of respondents argued that uncertainty is not exclusively an RIVM problem, but is also found in other institutes for decision support where scientists are struggling with the same issue. In line with this vision, an argument was presented to

[1] This report builds on Van Asselt (2000) and previous project documents, especially Langendonck (1999), Van Asten and Van Asselt (1999) and Van Asten (2000).
[2] De Kwaadsteniet initially directed his criticism to the Environmental Balance ('Milieubalans') reports.
[3] See Appendix 1 for an overview of the media facts associated with the De Kwaasteniet affair.

have science, decision-support institutes and politicians work out a new way/new ways to deal with uncertainty[4]. In response to all the criticism, RIVM published a report and an addendum referred to as 'Measurements, calculations and uncertainty: RIVM's environmental research methodology'[5].

The affair had a multitude of effects with regard to uncertainty management in relation to the 5th Environmental Outlook. It illustrated the societal and the political importance of uncertainty. It also created momentum. Everyone working at RIVM was forced to express his/her opinion about uncertainty in scientific decision-support. The interviews that were carried out as part of the project 'Perspectives on uncertainty and risk' seemed to offer an opportunity to channel thoughts, opinions and ideas of RIVM employees (see Chapter 3). The affair popped up in all the interviews. The workshop on uncertainty and the 5th Environmental Outlook, organised as part of the project 'Perspectives on uncertainty and risk', was fully booked. The open lecture on uncertainty in the Environmental Outlooks was well visited (see Chapter 5). In this way, the project 'Perspectives on uncertainty and risk' became much more integrated in RIVM's assessment activities. Since early 2000, the project has been carried out by a project team including both researchers from the RIVM (Anton van der Giessen, Peter Janssen en Peter Heuberger) and researchers from ICIS (Maastricht University).

Concretely, the report synthesises the research on uncertainty and the Environmental Outlooks carried out since November 1997. A complete list of the research reports can be found in Appendix 2. In Chapter 2 the concept of uncertainty is analysed historically; an analysis of the sources of uncertainty is also made. Current approaches to uncertainty analysis are discussed and evaluated in the light of these theoretical insights on uncertainty. Chapter 3 summarises the retrospective case-study, addressing the question of how uncertainty was managed in the previous Environmental Outlooks (from Concern for Tomorrow to the 4th Environmental Outlook). In Chapter 4 a new approach to uncertainty in decision-support is presented, i.e. the **P**luralistic f**R**amework for **I**ntegrated uncertainty **M**anagement and risk **A**nalysis (abbreviated to **PRIMA**)[6]. The PRIMA approach served as a heuristic guideline for exploring in practice how uncertainty management could be improved in the 5th Environmental Outlook (abbreviated to MV-5). Chapter 5 summarises the collective learning process involving a focus group consisting of RIVM's environmental management team, a workshop on uncertainty with MV-5 practitioners, an open lecture on uncertainty in the Environmental Outlooks, and a workshop with the MV-5 project team to review a pre-draft of the Environmental Outlook from the uncertainty perspective. Chapter 6 evaluates how uncertainty was dealt with in the MV-5 according to leading figures in the assessment process. To this end, interviews were held during the final stage of the 5th Environmental Outlook. In Chapter 7 conclusions on the learning process are drawn. The report concludes with recommendations directed to the RIVM concerning the way forward to a 6th Environmental Outlook and other integrated assessments. To facilitate fast reading of the report, all Chapters are preceded by a short abstract.

[4] See, for example, Rotmans and van Asselt (1999a)
[5] RIVM (1999a; RIVM (1999b)
[6] Van Asselt (2000)

2 UNCERTAINTY IN PERSPECTIVE

This Chapter provides an introduction to the topic of uncertainty by tracking the thinking on uncertainty over time and providing a taxonomy of uncertainty sources. It also discusses existing quantitative and qualitative approaches for addressing uncertainty in assessment endeavours. The Chapter concludes with a review of the existing approaches considering the various sources of uncertainty. The major conclusion is that uncertainty management lacks a toolkit which would enable us to identify and address salient uncertainties in an adequate manner as a key activity in policy analysis.

2.1 Uncertainty in historical perspective

What can science do about uncertainty? This issue has bothered thinkers and academics ever since intellectual activities were taken up by society. In a nutshell our activities are restricted to describing milestones in the development in thinking about uncertainty. Let us take a look at the historical developments around uncertainty.

The Enlightenment

The role ascribed to science as the 'provider of certainty' has been deeply influenced by the epistemology[7] of what is known as the Enlightenment or the Age of Reason. The notion 'Enlightenment' came into use at the end of the 18th century[8]. Enlightenment thinking goes back to 17th and 18th century thinkers in Europe (such as Voltaire, Rousseau, Kant and Hegel). In a certain sense, Enlightenment-thinking built on 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. 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 on reality. Science 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 paradigm that defines science as the search for, and prediction of, empirical regularities to make universal, true statements. In the positivist epistemology, uncertainty is considered as something unscientific[10]. These positivist absolutisms dominated science far into the 20th century.

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

[7] Epistemology refers to the human capacity to know. An attitude towards science is therefore rooted in a particular epistemological stand.
[8] e.g. Kant (1783)
[9] Bartels (1993)
[10] See Klir (1996)

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 foundation level of mathematics were revealed. 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 increasingly criticised. The hegemony of the natural science method was questioned both from the philosophy and the social science sides. 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 and economics in particular are thoroughly discussed. What can be called 'the sceptical crisis'[12] was initiated in the turbulent 1960s. The most extreme antagonists of positivist epistemology hold that scientific 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.

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 the work of Nietzsche (1844-1900) and Heidegger (1889-1976). Post-modernism denies the possibility of any certain, objective knowledge. 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. Post-modernism challenges all endeavours to explain processes and events, and, in doing so, it undermines the traditional claims in both natural and social sciences. If post-modern claims are taken to the extreme, there are no grounds for systematic investigation, analysis and interpretation.

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

[11] Knight (1921)
[12] Funtowicz and Ravetz (1993)
[13] See for an overview Rosenau (1992)
[14] See for an overview Jasanoff and Wynne (1998); Knorr-Cetina and Mulkay (1983; Pickering (1992). The journal associated with this school of thought is *Social Studies of Science*.
[15] E.g. Barnes and Shapin (1979)
[16] E.g. Latour and Woolgar (1979)

scientific community, and is thereby socio-cultural. Social constructivist epistemology can be deduced into 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 research takes, 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.

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 that:

- 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 are currently widely shared in social sciences, and are getting increasingly accepted in the natural sciences as well. From discussions in the context of the European Forum on Integrated Environmental Assessment[19], it is clear that the majority of the scholars involved in integrated assessment activities also subscribe to the above attitude towards science and uncertainty. In this viewpoint, uncertainty is not simply the absence of knowledge. Uncertainty can still prevail in situations where a lot of information is available. Besides, 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 used to be thought. In other words, more knowledge does not imply less uncertainty and vice versa. Or as Shackle phrased it in his theory of 'unknowledge'[20]: '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[21].

[17] Compare Hess (1995)
[18] Hess (1995)
[19] See e.g. Rotmans and Vellinga (1998), Jäger (1999)
[20] Shackle (1955)
[21] Funtowicz and Ravetz (1993)

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 knowledge[22]. Controversy involves arguments that articulate uncertainties and express risk attitudes[23]. It is generally shared that experts perceive risks differently from lay people and cultural factors affect the way people assess risks. The acknowledgement of inherent uncertainty implies that science has to accept the differences in perspectives and utilise them consciously as resource. This theoretical consequence has two fundamental implications for the practice of science, i.e. it requires:

- the willingness to open the scientific black boxes and to consider their internal construction[24].
- that uncertainties are considered from different legitimate perspectives in order to articulate multiple manifestations of a problem[25]. In case of 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[26].

In sum, the adopted attitude towards science and uncertainty implies that science has to be pluralistic, i.e. incorporating various perspectives[27].

2.2 Taxonomy of sources of uncertainty

It is difficult to define uncertainty. Uncertainty is usually defined through classification. One way to classify uncertainty is by investigating different sources of uncertainty. Analogous to investigating a physical phenomenon like climate change, we have attempted to study the cause underlying uncertainty and risk[28]. In this way, we have developed a taxonomy of sources of uncertainty (Figure 1) that enables practitioners to differentiate between uncertainties and to communicate about uncertainties in a more constructive manner. The taxonomy is meant to be generic, i.e. applicable to all contexts. This implies that it should be possible to trace revealed uncertainties back to one or more sources of the taxonomy[29].

Sources of uncertainty

Building on extensive literature analysis, synthesis of proposed classes of uncertainty and discussions with experts, we concluded that the following two sources of uncertainty can be distinguished at the highest level of aggregation[30]:

- **variability**,
  The system/process under consideration can behave in different ways or is valued differently. Variability is an attribute of reality.

[22] See, for example, Keynes (1937), Lave and Dowlatabadi (1993))
[23] Von Schomberg (1993)
[24] Wynne (1992)
[25] Wording is inspired by Khalid Saeed from the Symposium on Environment, Energy and Economy: A Sustainable Future, Rome, 12-13 October 1998.
[26] For a further discussion on this pluralistic approach to uncertainty, see Van Asselt (2000).
[27] See Van Asselt (2000) for an in-depth discussion of the notion of pluralism.
[28] Van Asselt (2000)
[29] To test this hypothesis, case-studies are needed. One of the case-studies carried out within ICIS involved analysis of the debate on genetically modified food (compare Eike (2000)). Also, the project on uncertainties pertaining to water management in which ICIS is involved (Van Asselt et al. (2000)) can serve as such a test case. These case-studies did not yield specific uncertainties of which the sources could not be described in terms of the taxonomy of sources of uncertainty presented in the current report.
[30] Compare Hoffman and Hammonds (1994)

also referred to as 'objective uncertainty'[31], 'stochastic uncertainty'[32], 'primary uncertainty'[33], 'external uncertainty'[34] or 'random uncertainty'[35]:

- **limited knowledge**,
  Limited knowledge is a property of the analysts performing the study and/or of our state of knowledge.
  also referred to as 'subjective uncertainty'[36], 'incompleteness of the information'[37], 'informative uncertainty'[38], 'secondary uncertainty'[39] or 'internal uncertainty'[40].

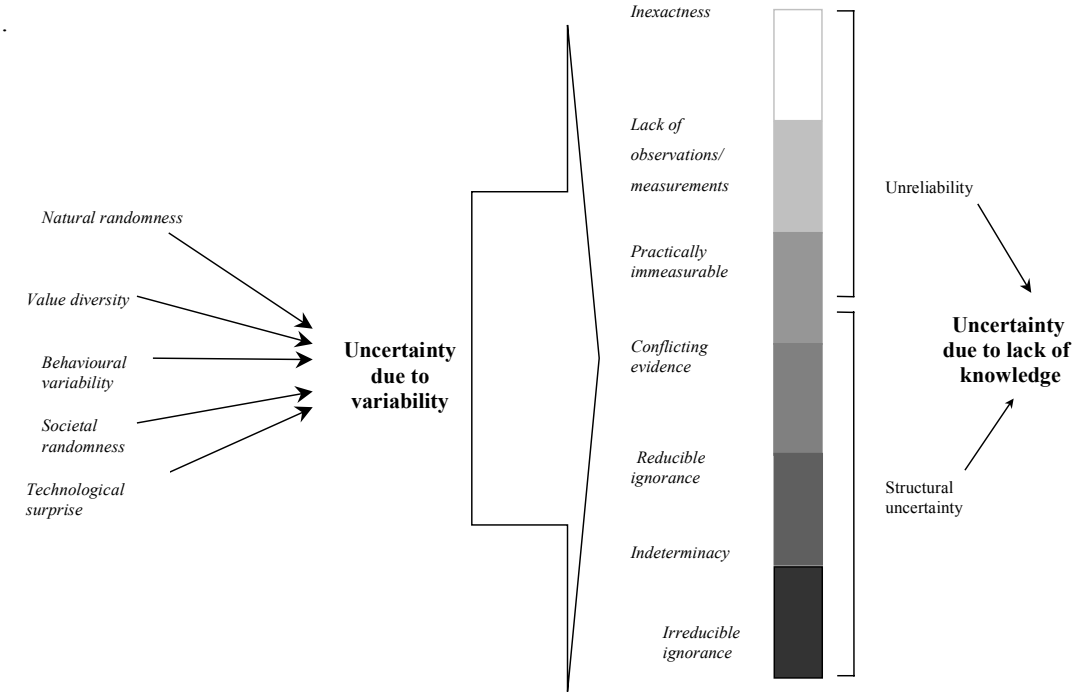


Figure 1 – Typology of sources of uncertainty

Different sources of variability can be distinguished, i.e.[41]:

- inherent randomness of nature[42]: the non-linear, chaotic and unpredictable nature of natural processes
- value diversity[43]: differences in people's mental maps, world views and norms and values due to which problem perceptions and definitions differ

[31] Natke and Ben-Haim (1996)
[32] Helton (1994)
[33] Koopmans (1957)
[34] Kahneman and Tversky (1982)
[35] Henrion and Fischhoff (1986)
[36] Helton (1994); Natke and Ben-Haim (1996)
[37] Von Schomberg (1993)
[38] Klir (1996); Natke and Ben-Haim (1996); Van Witteloostuijn (1987)
[39] Koopmans (1957)
[40] Kahneman and Tversky (1982)
[41] Compare Rowe (1994) We owe the concretisation of each of the sources to Eike (2000).
[42] See also Morgan and Henrion (1990), also referred to as (unobserved) seasonalities: Van Vlimmeren et al. (1991)
[43] Also referred to as subjective judgement and disagreement: Morgan and Henrion (1990) or moral uncertainties: De Marchi (1995).

- human behaviour: 'non-rational' behaviour, discrepancies between what people say and what they actually do, or deviations of 'standard' behavioural patterns (micro-level behaviour)
- social, economic and cultural dynamics[44] (societal randomness): the non-linear, chaotic and unpredictable nature of societal processes (macro-level behaviour)
- technological surprises: unexpected developments or breakthroughs in technology or unexpected consequences of technologies.

Variability as defined by the above sources goes beyond established seasonal variations. Due to variability in combination with limited resources to measure and obtain empirical information, reality inhibits inherent uncertainty and unpredictability. As such, it contributes to lack of knowledge.

Limited knowledge results partly out of variability, but knowledge with regard to deterministic processes can also be incomplete and uncertain. A continuum can be described that ranges from inexactness to irreducible ignorance:

- *inexactness*[45], also referred to as lack of precision, inaccuracy, metrical uncertainty[46], measurement errors[47], or precise uncertainties[48]. 'We roughly know'.
- *lack of observations/measurements*: lacking data that could have been collected, but haven't been. 'We could have known'.
- *practically immeasurable*: lacking data that in principle can be measured, but not in practice (too expensive, too lengthy, not feasible experiments). 'We know what we do not know'.
- *conflicting evidence*[49]: different data sets/observations are available, but allow room for competing interpretations. 'We don't know what we know'.
- *reducible ignorance*[50]: processes that we do not observe, or theoretically imagine at this point in time, but probably in the future. 'We don't know what we do not know'.
- *indeterminacy*[51]: processes of which we understand the principles and laws, but which can never be fully predicted or determined. 'We will never know'.
- *irreducible ignorance*[52]: there may be processes and interactions between processes that cannot, or not unambiguously, be determined by human capacities and capabilities. 'We cannot know'.

The continuum thus ranges from unreliability to more fundamental uncertainty, also referred to as radical[53], structural[54] or systematic uncertainty[55]. Uncertainties in the category

[44] 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).
[45] Funtowicz and Ravetz (1990); Zimmermann (1996). The classical theory of measuring errors postulated by Gauss (1777-1855) states that *every* measurement of a physical quantity is affected by measuring errors of a random character, which are unknown.
[46] e.g. Rowe (1994)
[47] e.g. Beck (1987); Van Vlimmeren et al. (1991)
[48] e.g. Wallsten (1990)
[49] Zimmermann (1996)
[50] Funtowicz and Ravetz (1990; Wynne (1992)
[51] For example, Wynne (1992)
[52] I owe the distinction between reducible and irreducible ignorance to fascinating discussions with such persons as Steve Manson, Brian Norton and Jan Rotmans.
[53] Funtowicz and Ravetz (1993)
[54] For example, Rowe (1994)

of unreliability are usually measurable, or can be calculated, in the sense that they stem from well-understood systems or processes[56]. This implies that, in principle, either margins or patterns can be established, so that the uncertainty can be described quantitatively (either in terms of a domain or as a stochastic equation). On the other hand, the other end of the continuum involves uncertainties that are difficult or impracticable to estimate. Such radical uncertainties can at best be roughly estimated. Radical uncertainties generally arise due to conflicting evidence, ignorance, indeterminacy and uncertainty due to variability. It is even likely that the most salient uncertainties in the assessment of complex issues are radical.

In sum, uncertainty as defined by these sources is the entire set of beliefs or doubts that stem from our limited knowledge of the past and present (especially lack of knowledge) and our inability to predict future events, outcomes and consequences (especially variability).

2.3 Approaches to uncertainty analysis

We can distinguish between quantitative and qualitative approaches for dealing with uncertainty in scientific decision support. Quantitative approaches to uncertainty analysis are used in combination with mathematical models. O'Neill[57] appears to have been the first to call for uncertainty analysis in the context of environmental modelling[58]. Since then more and more attention has been paid to dealing with uncertainty in environmental management.

The aim of current quantitative methods for uncertainty analysis is to evaluate to what extent particular uncertainties impact on the conclusions. The standard practice is that uncertainty analysis is performed as a final step in the model cycle. The following quantitative approaches are currently used for uncertainty analysis in environmental assessment[59]:

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

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

Sensitivity analysis
Sensitivity analysis is the study of the influence of variations in model parameters and initial values on model outcomes[60]. 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

[55] For example, Henrion and Fischhoff (1986; Morgan and Henrion (1990)
[56] Such measurable processes are also referred to as 'ergodic processes' (see, for example, Davidson, (1983)).
[57] O'Neill (1971); O'Neill and Gardner (1979)
[58] Hettelingh (1989)
[59] Compare Kann (1998)
[60] Janssen et al. (1990; Rohen (1988).

method[61] and meta-modelling[62]. 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 does nothing more, and nothing less, than providing insights in the role of uncertain parameters and initial values in model runs.

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 environmental modelling is the Bayesian approach[63], in which probabilities are interpreted as subjective 'degrees of beliefs'. The information required to apply probability calculus are distributions for uncertain inputs/parameter; this expresses how likely the analyst or group of experts[64] 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[65] or statistical measures as the 95-percentile. Usually 'intelligent' sampling techniques, generally Monte Carlo techniques[66], are applied to reduce the computing requirements.

The different outcomes of a large set of model runs performed with probability-based techniques are collected and aggregated in terms of 95-percentiles. This range has just statistical meaning; i.e. it indicates the range that comprises the trajectories of 95% of the outcomes. The remaining 2.5% beyond both the upper and lower boundaries are considered to be outliers that should not be taken into account. Apart from this statistical meaning the upper and lower boundaries, and the range in between do not explain the adopted interpretation of the underlying uncertainties.

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 the case of lack of knowledge beyond the level of inexactness, it is questionable whether probability distributions can cover the range of possibilities. In practice, modellers apply uniform distributions, because probability distributions are unknown. Furthermore, the method requires a complete covariance matrix, but in many

[61] See Iman et al. (1981); Janssen et al. (1990) for a comprehensive discussion on various methods for sensitivity analysis.
[62] See Braddock et al. (1994) for an example.
[63] The fundamentals of the Bayesian approach are explained in, for example, Bayes (1763; Marshak (1955; Savage (1962).
[64] Examples of a modelling project in the field of environmental management in which probability distributions were derived from elicitation processes within a group of experts are found in: Morgan and Keith (1995; Nordhaus (1994).
[65] See Dowlatabadi and Morgan (1993) for an example of such a probability-based uncertainty analysis in Integrated Assessment modelling.
[66] See Fedra (1983) for an elaboration of the use of Monte Carlo methods as uncertainty analysis in environmental modelling.

cases the correlations between the uncertainties are unknown[67]. This implies that the outputs do not tell so much about the probability of a certain development or event in reality, but merely indicate how the model propagates probability distributions.

The attention in probability-based methods was usually focused on parametric uncertainties and their propagation. Recently, uncertainty in model-structure has also been addressed more explicitly[68]. Saltelli et al. (2000) give a good overview of recent developments in uncertainty and sensitivity analysis in a probabilistic context.

Approaches such as the use of Bayesian belief networks for addressing uncertainty currently receive attention in the environmental area too[69]. An alternative approach to probabilistic oriented uncertainty analysis is the use of fuzzy sets in a possibilistic paradigm[70].

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; in this way it has a considerable advantage over random sampling methods in terms of uncertainty analysis. Table 1 gives an example of the kind of scenario-variables currently used in integrated modelling efforts. These variables are central to the scenario analysis involving the use of different IA models[71] in the context of the IPCC Third Assessment process.

Table 1 – Scenario-variables as proposed by the scenario-working group in the IPCC Third Assessment Report process.[72]

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

As the IPCC example illustrates, scenario input merely sets comprise socio-economic variables. Used in this way, scenario analysis merely addresses uncertainties in model inputs. In terms of the above distinction, this implies that scenarios created in this way assess the consequences of socio-economic uncertainties on projections for the environmental system but neglect the scientific uncertainties in the environmental system itself.

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

[67] Rohen (1988).
[68] Draper (1995)
[69] Varis (1995; Varis and Kuikka (1999)
[70] Zadeh (1978); Dubois and Prade (1982)
[71] Namely Aim, Maria, Image 2, IIASA Message, ASF, MiniCam
[72] IPCC Open process website: http:// sres.ciesin.org/sres/

Hedging-oriented methods

This class of method is one of the newer approaches for dealing with uncertainty. Hedging can be viewed as building contingency plans and responding to opportunities and risks as they become apparent[73]. Hedging-oriented methods aim to identify strategies, which balance the risks of waiting with premature action[74]. In this type of modelling, the value of decision-variables in the model is determined on the basis of a joint distribution of 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 have the advantage that they do not only address uncertainty in the model, but through incorporating action and yield uncertainties, they 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[75].

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. A more pragmatic approach to validation involves the analysis of the model fitness for use. In terms of our typology of uncertainty, validation is the analysis of uncertainty on model suitability, the type of uncertainty usually mainly caused by ignorance, indeterminacy and variability. In this broader perspective, it is therefore legitimate to consider validation as uncertainty analysis.

Validation may be a quantitative, semi-quantitative, participatory or hybrid exercise. 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[76]. 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[77]. That a model is 'validated' does not necessarily imply that it is complete enough or that it is an adequate representation of reality. Models can only be evaluated in relative terms. A good validation means that the model is not conflicting with current empirical and theoretical insights. Validation exercises, which in principle address the epistemological dimension, are not systematically used to assess and discuss radical

[73] Kann (1998)
[74] Manne and Richels (1995)
[75] Bressers and Hoppe (1998)
[76] Root and Schneider (1995)
[77] Oreskes et al. (1994)

uncertainties. The results of validation are in general primarily used to 'sell' the model as being scientifically credible.

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 the 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 assessment. Van der Sluijs[78] proposed a procedure for applying NUSAP in Integrated Assessment modelling, but no applications have been 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 the 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 views of the future are possible in 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 after the seminal publication of Kahn and Wiener in 1967[79]. Although many definitions of scenarios circulate, they share the following features[80]:

- 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 are expert-based. In this way, scenarios address in principle uncertainty due to variability and lack of knowledge. However, actual scenario studies[81] are often developed from a narrow, disciplinary-based perspective. Such studies employ a limited set of standard assumptions, which are implicitly or explicitly treated as certainties[82]. Many narrative scenarios do have a 'business-as-usual' character, assuming that 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 which salient uncertainties formed 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 the heading: the strategic

[78] Van der Sluijs (1997)
[79] Kahn and Wiener (1967)
[80] Rotmans (1998); Van Asselt (2000)
[81] See, for example, our evaluation of the last decade of European scenario studies: Van Asselt et al. (1998).
[82] The famous economist, Keynes (1937), was one of the first scholars to explicitly state that scientists tend to substitute certain conventions for the knowledge that is unattainable.

choice approach[83] and robustness analysis[84]. 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[85]. The strategic choice 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. So-called 'robustness analysis'[86] 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 a range of options open for the future. The participatory process of robustness analysis involves characterising the decision-making 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[87] 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 the characterising of estimates 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 1 for an application of the NUSAP scheme as a way to characterise uncertainties.

Box 1 – Application of NUSAP

The NUSAP method can be illustrated by means of an example[88], i.e. the economic value of shrimps in the wetlands in Louisiana[89]. 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 with high peer acceptance. Pedigree was determined by using Table 2.

Table 2 – Pedigree matrix

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

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: $ per acre per 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 on work done by Costanza and colleagues, [90] gave the following estimates:

[83] This description is based on the overview paper of Friend (1989). See also Friend and Hickling (1987).
[84] This description is based on the overview papers of Rosenhead (1989a) and Rosenhead (1989b)
[85] Environmental Resources (1987); Hickling (1989); Van de Graaf (1985) describe examples of the strategic choice approach to high-level national policy-making.
[86] Examples of applications of this approach: breweries: Gupta and Rosenhead (1968), chemical plants: Caplin and Kornbluth (1975) and health systems: Best et al. (1986).
[87] Funtowicz and Ravetz (1990)
[88] Funtowicz and Ravetz (1990) pp. 195-197
[89] Building on research by Farber and Costanza (1987) and Costanza et al. (1989).
[90] Ibid.

Table 3 – NUSAP representation of fishery categories in the wetlands of Louisiana

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)

Funtowicz and Ravetz used these grades to determine the NUSAP score for the total commercial value of fishery for 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:

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

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 the 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 characterisation of the quantitative, the qualitative and the subjective aspects of uncertainty in a formal way, and strives to explicitly reveal the underpinnings of this information. It has been developed in the context of post-normal science that argues that uncertainty is inherent in Integrated Assessment and should be at the heart of the analysis (see also Van der Sluijs[91]).

Application of the NUSAP methodology in this area will be an interesting challenge which poses many relevant questions yet to be solved, e.g. how to assess the pedigree in target-outcomes of modelling chains on the basis of the uncertainty and quality of the various constituent parts (e.g. data; (sub)models; expert reasoning and interpretations); how to apply the methodology in situations where time and resources are limited; what role can NUSAP play in communicating information on uncertainties, their characteristics and causes, to public and policy etc? Answering these questions satisfactorily will definitely make NUSAP a promising and valuable contribution towards improved uncertainty management.

[91] Van der Sluijs (1977).

2.4 Tool-kit for uncertainty management?

Because uncertainty is multi-dimensional, it is unlikely that a single approach will suffice to capture all the salient sources of uncertainty[92]. Different approaches address different sources of uncertainty in different ways. Table 4 summarises what uncertainties in models are analysed by the methods discussed.
Table 5 lists the sources of uncertainty for which the approaches discussed are used.
NUSAP is not mentioned explicitly here. In principle - being a general methodology - it can be applied irrespective of the nature of the uncertainty sources.
A complementary use of various methods is needed to be able to provide comprehensive insight into the extent and the scope of uncertainty. Such combinations of uncertainty analysis methods are applied in model-based assessments. For example, it follows from the description above that hedging-oriented methods are combined with probability-based methods. Sensitivity analysis is quite often used to filter out the uncertain parameters that will be subjected to probability-based uncertainty analysis. Exploratory modelling[93] is an example of an approach that explicitly aims to incorporate a combination of the above methods 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.

Table 4 – Methods of uncertainty analysis in terms of types of uncertainty

Uncertainty		**Method**	**Output**
Uncertainty in model quantities	Uncertainties in input data	- sensitivity analysis - probability-based methods - formal scenario analysis - hedging-oriented methods - NUSAP	- role of uncertainties in input data in model runs - 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 quali- and quantitative nature of (input) uncertainty
	Parameter uncertainties	- sensitivity analysis - probability-based method - hedging oriented methods - NUSAP	- role of uncertainties in parameters in model runs - propagation of probabilities in parameters to outcomes - assessing effects: uncertainty reduction in parameters - insight quali- and quantitative nature of parameter uncertainty.
Uncertainty about modelform	Uncertain equations	- sensitivity analysis in form of meta-modelling	- insights into crucial equations
	Modelstructure uncertainties	- *no methods*	- *no methods*
Uncertainty on Model completenes	Uncertain levels of confidence	- NUSAP	- insight in the level of confidence in terms of the quality of the underlying sources
	Uncertainty about model validity	- validation	- insights in model performance

[92] Boritz (1990)
[93] Bankes (1994; Lempert and Bonomo (1998)

Table 5 – Potential of discussed methods in addressing different sources of uncertainty

Source	Methods
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
Value diversity	*No methods*
Behavioural variability	Scenario-approaches
Societal randomness	Scenario-approaches
Technological surprise	*No methods*

However, even if the available methods for uncertainty analysis are combined in a systematic manner, crucial sources are ignored as apparent in Tables 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[95]. Current uncertainty analysis techniques thus merely address uncertainties categorised under unreliability. Furthermore, sources of variability are difficult to address with the current methods. In principle, scenario approaches allow inclusion of behavioural variability and societal randomness, however, in practice, this is seldom the case. As can be concluded from Table 5, there are no methods available yet to deal with value of diversity and technological surprise.

2.5 State-of-the-art

At the moment, uncertainty is not at the heart of scientific assessment. In the case that uncertainty is explicitly addressed, uncertainty is treated as a marginal issue that can, unfortunately, not yet be resolved. Uncertainty is treated as if it were an additional physical variable[96], 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, current uncertainty analysis is in a sense hiding inherent uncertainty.

[94] Bankes (1994); Lempert and Bonomo (1998)
[95] Wynne (1992)
[96] Funtowicz and Ravetz (1993)

The above analysis implies a switch in focus from analysing the impact of uncertainty on the conclusions to treating uncertainty as an intrinsic and key facet of the issue under concern. Uncertainty should no longer be treated as a marginal issue or closing entry in the analysis, but should be at the heart of the assessment[97]. In this perspective, science is no longer understood as a steadily advancing certainty of objective knowledge. Science for decision-making is conceived as a pluralistic and participatory search process that aims to provide insights facilitating conscious acting in an uncertain world. This implies a switch from the technical discourse of objectivity, problem-solving and definite answers, to pluralism, puzzling and insights. The notion 'uncertainty-management' is introduced[98] to mark this shift in orientation and used throughout this report. Uncertainty management can then be defined as an approach to decision support that reasons from inherent uncertainty, providing 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 strategies and measures. Robust implies the identified strategy as 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[99].

To date, there is no alternative crystallised portfolio of methods to enable conscious practitioners in environmental management to deal adequately with inherent uncertainty in daily practice. There are 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[100]. We conclude that:

> *Uncertainty management lacks a tool-kit to enable us to identify and address salient uncertainties in an adequate manner as a key activity in policy analysis*[101].

Developing methods and procedures to enable uncertainty management is thus a major challenge to the decision-support community.

[97] Funtowicz and Ravetz (1993)
[98] Funtowicz and Ravetz (1990) use the notion of uncertainty management to mark this switch; however, they do not explicitly define it.
[99] Compare Collingridge (1980) Colglazier (1991) and Lempert and Bonomo (1998).
[100] Compare Rowe (1994)
[101] 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 deal with the uncertainties involved'.

3 UNRAVELLING UNCERTAINTY

FROM 'CONCERN FOR TOMORROW' TO THE 4TH ENVIRONMENTAL OUTLOOK

This Chapter reports the analysis of the Environmental Outlook series, from 'Concern for Tomorrow' (RIVM's first environmental outlook) to the 4th Environmental Outlook. Using the reports as starting point, we have derived or interpreted how uncertainty was managed. Although quantitative methods, qualitative approaches and presentation approaches have been used, a framework or systematic strategy for uncertainty management was clearly lacking. Quantitative methods ranged from different model runs to sensitivity analysis on individual models, while qualitative approaches involved expert judgements, consensus formation, contra-expertise and review; presentation approaches referred to avoiding the word 'prediction' and using linguistic expressions to indicate uncertainty to carefulness in the smooth graphs and maps. Our overall conclusion is that the four Environmental Outlooks fail to systematically manage uncertainty. It is furthermore argued that this lack of uncertainty management led to a vulnerable position, which only came to light in the so-called 'DeKwaadsteniet affair'.

3.1 Introduction

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 long terms. The first environmental outlook, 'Concern for Tomorrow', was published in 1988 and is generally considered to be a milestone in the realisation of RIVM's environmental mission. Its main message was that: 'the environment was getting worse at all scale levels despite all the efforts'. This was a shock for Dutch politicians, but also for society as a whole. This 1st 'Environmental Outlook' served as the scientific basis for the first National Environmental Policy Plan (NMP)[102], which appeared in 1989[103]. Since 'Concern for Tomorrow', the Environmental Outlook has become one of RIVM's key decision-support products. In 1991, the second assessment, 'Environmental Outlook 2 1990-2010'[104], was produced, functioning primarily as 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 would assess the proposed environmental policies. The 3rd Environmental Outlook[105], published in 1994, indicated the effectiveness of policy plans in relation to the environmental quality objectives as formulated in the first Environmental Policy Plan. Environmental Outlook 4 1997-2020[106] appeared in 1997.

The aim of an Environmental Outlook (abbreviated to MV) is to assist long-term environmental decision-making. Future developments are assessed in order to arrive at policy recommendations. Each Environmental Outlook provides an assessment of the environmental and health impacts in the Netherlands associated with future states of the

[102] In Dutch: the *Nationaal Milieubeleidsplan*
[103] VROM et al. (1989)
[104] RIVM (1991)
[105] RIVM (1993)
[106] RIVM (1997)

environment resulting from specific developments of societal pressures in terms of economic growth, demographic developments, and consumption and production patterns. RIVM attempts to anticipate future developments so as to provide recommendations for environmental policy. An Environmental Outlook thus describes the cause–effect chains relevant to environmental change. Furthermore, it evaluates current Dutch environmental policies and policy proposals. One of its aims is to evaluate whether future environmental targets can be reached under current policy. The Environmental Outlooks are long-term assessments; generally with a time-horizon of 20-30 years. Its spatial focus is the Netherlands, but European and even global developments and trends are considered. The assessment underlying the Environmental Outlooks is a complex undertaking: problems are not addressed in isolation, but rather a tangled web of related issues is involved; multiple dimensions play a role - environmental, economic, socio-cultural and institutional factors and processes matter - and the underlying processes interact on various scale levels and different temporal scales. In view of this complex character, it is clear that uncertainty is inevitably associated with the assessment.

To explore the coming decades, possible future developments in societal pressures in terms of economic growth, demographic developments, and changes in consumption and production patterns will have to be estimated. One of the key relevant exogenous uncertainties for 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 Netherlands Bureau for Economic Policy Analysis (CPB)[107] 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 derived from the CPB's 'Scanning the Future' exercise[108] were used, 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 anticipated 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: Divided Europe (DE), European Co-ordination (EC) and Global Competition (GC), which were derived from the new CPB scenario exercises[109] and further fortified with the 'Water System Outlook'[110] and the long-term assessment of the National Spatial Planning Agency[111].

The assessment process underlying the Environmental Outlooks is supplied information through monitoring and measuring. RIVM manages national monitoring networks on air, soil, groundwater, manure and radiation. Data related to surface water are obtained from the Ministry of Transport, Public Works and Water Management and the Water Boards. RIVM furthermore participates in the Dutch ecological monitoring network[112]. 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

[107] In Dutch: *Centraal Plan Bureau (CPB)*
[108] CPB (1992b)
[109] CPB (1996)
[110] Rijkswaterstaat (1996)
[111] In Dutch: *Rijksplanologische Dienst (RPD)*
[112] RIVM (1999a)

and demographic data are obtained from the Netherlands Bureau for Economic Policy Analysis (CPB), Statistics Netherlands (CBS) and the Social and Cultural Planning Office (SCP). These data and measurements are analysed in the Environmental Outlook process.

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[113], 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 effect models. These assess effects, like the SMART/MOVE model to assess the impacts associated with environmental change on terrestrial ecosystems, the PC-Lake and PC-Ditch models for effects on aquatic ecosystems and the LBV model that calculates noise nuisance. These models are calibrated and validated, as far as possible, against available monitoring data. RIVM is not in possession of one fully integrated model, but uses the available models in cascades to assess the relevant environmental cause–effect chains.

In this Chapter, we will evaluate the Environmental Outlooks from the perspective of uncertainty[114], taking the reports as the starting point of the analysis. How was uncertainty managed in RIVM's four Environmental Outlooks (vertical analysis) and has the approach to uncertainty changed over time (horizontal analysis), and if so, how and why? To this end, a document analysis was performed, in which argumentation analyses per Environmental Outlook were carried out, i.e. reported evidence for selected concluding statements were traced (see Figure 2). The argumentation analysis of the main conclusions selected provided insight into how arguments were built up and if uncertainties were involved, how these were interpreted. Using this as a basis, we attempted to get some initial insight on how uncertainty seemed to have been managed in each Environmental Outlook. As will become clear from the analysis, this was not a straightforward task. We then compared the insights per Environmental Outlook in order to address whether and, if so, how the way uncertainty was managed might have changed later. 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[115]. The cascade of research methods (i.e. document analyses, interviews, focus group and questionnaires) guaranteed a more complete and probably more realistic, picture of how uncertainty was managed in the four Environmental Outlooks.

[113] RIVM (1999a)
[114] This section builds on Langendonck (1999; Van Asselt (2000)
[115] For a more detailed description of the research approach, see Langendonck (1999); Van Asselt (2000)

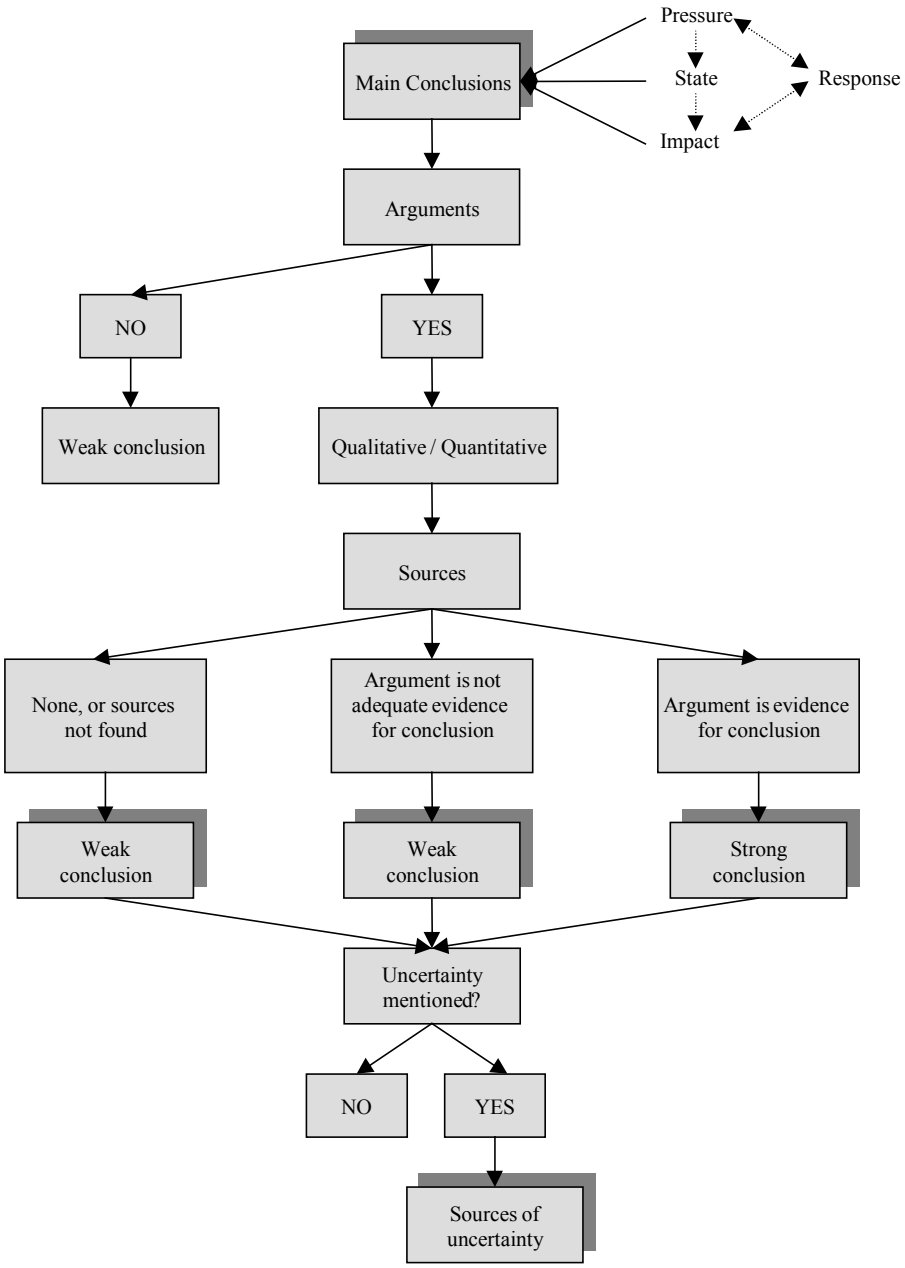


Figure 2 - Analysis scheme for the argumentation analysis.

3.2 Argumentation analyses

The aim of the argumentation analysis was 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 arguments given were not solid, logical or did not match with the conclusions. 'Weak' is, in the first place, a judgement on the quality of argumentation, and as such is not an indicator referring to uncertainty. 'Strong' implies that solid, in principle, verifiable evidence underpins the conclusion. In this way, we wanted to analyse if uncertainty pertained to the selected conclusions: in this analysis we focused on

the 3rd and the 4th Environmental Outlooks. Box 2 outlines the concluding statements extracted from the Summary Chapters of the 3rd and 4th Environmental Outlooks for further analysis[116].

Box 2 - Concluding statements selected for the argumentation analysis

To cover some of the relevant cause–effect chains, our selection comprised conclusions on both pressures, and states and impacts. The following quotation from the **3rd Environmental Outlook** indicates the salient driving forces:

> '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 policy in a broad sense is primarily oriented: energy consumption, mobility, manure production and water consumption' (MV-3, p.36).

After screening the texts in the Summary Chapter for the issues underlined, we selected the following conclusions on 'pressure' for further analysis:

- *Population growth*
  'The Dutch population is expected to grow more than is assumed in the NEPP[117]. The level forecasted for 2000 was already reached in 1992. The population figures for 2010 in the ER and GS[118] scenarios are about 10% higher than in the NEPP' (MV-3, p. 12).
- *Economic development*
  'In the ER scenario GNP[119] 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.' (MV-3, p. 12).
- *Mobility*
  'The policy that has now been formulated is expected to curb growth and thereby enables one to reach the target for the year 2000. After 2000 car use will further increase' (MV-3, p.12).

The following conclusions pertaining to 'state' or 'impact' issues were 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' (MV-3, p.16).
- *Deposition of acid equivalents*
  'The deposition target of 1400 acid equivalents per hectare (average on woodland) for 2010 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' (MV-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 be easily achieved. However, the target for 2010 (a negligible level of serious nuisance) will not be achieved' (MV-3, p.22).

Three conclusions pertaining to 'pressures' were selected and extracted from the Summary Chapter of the 4th Environmental Outlook*:*

- *Consumption*
  'It is expected that the consumption per capita will increase by 45%-100% between 1995 and 2020' (MV-4, p.12).
- *Production*
  'According to the economic long-term scenarios on which this Environmental Outlook is based, the production will increase by 50%-125% in the next 25 years' (MV-4, p.12).

[116] See Langendonck (1999) and Van Asselt (2000) for a more comprehensive description of this selection and the analysis.
[117] VROM et al. (1989)
[118] Van Asselt (2000)
[119] Gross National Product

- *Energy consumption*
  'Between 1995 en 2020 the energy consumption will grow by 8%-45%' (MV-4, p.12).

In the 4th Environmental Outlook, the theme 'environmental quality' is divided into three categories: urban, green and blue areas. Environmental state and impact issues are evaluated for each category. From the Summary Chapter we chose one conclusion pertaining to state or impact issues from each category:

- *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' (MV-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 in preventing health damage (breathing problems)' (MV-4, p.16).
- *Desiccation*
  'Assuming an advisable rise of the ground water level of 25 cm and where desiccation is adequately prioritised in land structure projects, the target for desiccation (a decrease in the naturally desiccated area by 40% in 2010 in relation to 1985) will be almost reached in 2010-2020' (MV-4, p.18).

It is beyond the scope of this report to present the full analysis. To keep the analysis brief we will limit ourselves here to the full description of the argumentation analysis for two illustrative conclusions, one characterised as weak and another as strong (see the following subsections), in order to illustrate if and how uncertainty was accommodated in MV3. The other evaluation results are summarised in Box 3.

Box 3 - Main findings per selected concluding statement

Population
The 3rd Environmental Outlook, along with the CPB reports 'Scanning the Future' and 'The Netherlands in Triplicate', all utilise the same population trends without explicit references and without explaining how these trends are generated. A thorough report analysis leads us to conclude that certain projections of the United Nations (without any proper reference) are used as starting point for the assessment in 'Scanning the Future', followed by an unmotivated downscaling to 'The Netherlands in Triplicate', in 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[120]. 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 section 4.1, 'Changes in global biosphere' (MV-3, p.67) refers to a background document on climate change. This report, 'Background document to 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, during our analysis (1999) this particular report could not be found, which led us first to conclude that it had never been finished. While finishing our research, we found out that the report had eventually been published, but that the title and the authors had changed to 'Greenhouse gas emissions in the Netherlands 1990, 1991, 1992 and projections for 1990-2010'[121] and Van Amstel. This report mentions the trend in energy prices as the most important uncertainty with regard to CO_2 emissions. However, although the concluding statement seems to suggest that experiments had been carried out using the ER and GS 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

[120] Van Wee et al. (1993)
[121] Van Amstel (1993)

concluding statement). The background report indicates other experiments with additional policy; these experiments result in a decrease in CO_2 emissions of 1.1% in the ER scenario and 2.7% in the GS scenario. We therefore find the conclusion on CO_2 emissions weak.

Deposition of acid equivalents
The scarce information on the deposition of acid equivalents involves a repetition of the conclusions, with some, very limited, information on underlying causes. A potential source of information is Figure 4.2.1 (MV-3, p.77) in Chapter 4, 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.

Consumption, Production and Energy consumption
The statements on 'consumption', 'production' and 'energy consumption' in the 4th Environmental Outlook are all assessed as weak for reasons similar to the above. 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 explains 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, not even in the section (MV-4, section 4.3.3) devoted to this issue. The only argumentation is a more extensive version of the conclusion. The background document neither underpins nor justifies 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 therefore assessed as weak.

Health impacts of fine dust
Despite the acknowledgement that little is known about the relation of health impact to 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 quotation indicates that the uncertainties associated with the issue under concern can be categorised as a 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 primarily responsible for the health effects, and which mechanisms play a role' (background document MV-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 assumptions discussed, 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. The following quotation is important when it comes to uncertainty matters:

> 'It is unclear to what extent a rise in groundwater level by 25 cm would be sufficient to prevent desiccation effects' (MV-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).

Example of a weak conclusion

The analysis of the statement on economic development extracted from the 3rd 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' (MV-3, p.12).

It is argued in the MV3 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' (MV-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 one to assess whether so-called 'de-coupling'[122] of economic growth and pressure on the environment may be considered a realistic future outlook. In this discussion, we limit ourselves to the analysis of the concluding statements on GNP[123], which implies that only the left part of Figure 3 is discussed in detail.

The first place in the 3rd Environmental Outlook where we expected more specific information regarding the development of GNP is section 3.3, '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)' (MV-3, p.39).

[122] See Molendijk and Rotmans (1999)

[123] A detailed description of the argumentation analysis for physical economic growth can be found in Langendonck (1999) and Van Asselt (2000)

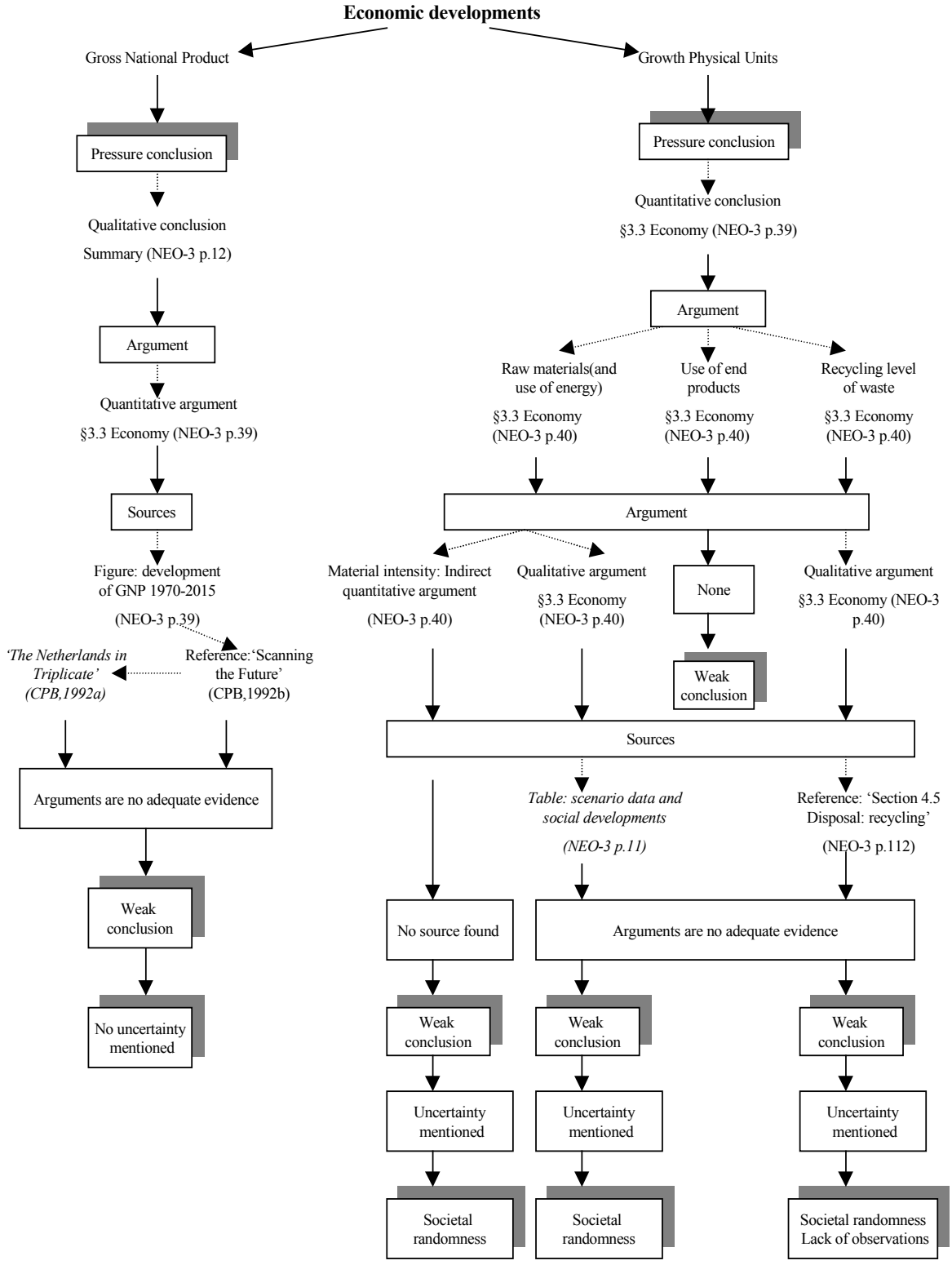


Figure 3 – Analysis scheme of the argumentation analysis of the statement 'economic development'

Section 3.3 further consists of graph 3.3.1 (MV-3, p.39) (see Figure 4) indicating the development in GNP over the 1970-2015 period for the Middle scenario[124], 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)[125]. 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, dynamic 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 using the WorldScan model[126], however, this cannot be deduced from the report.

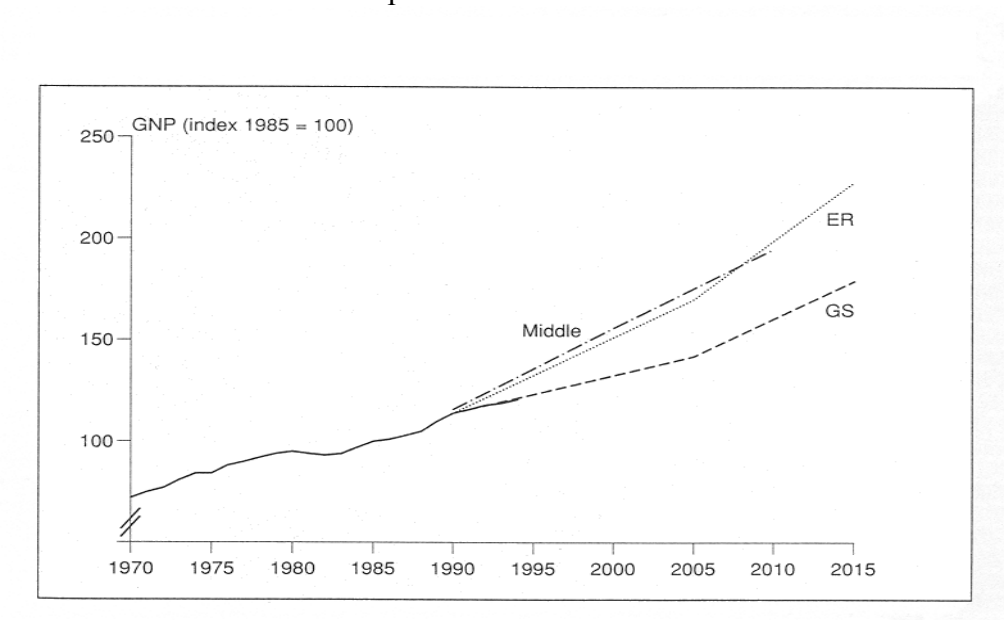


Figure 4 – GNP trends in the 1970-2015 period, both actual and according to the Middle, ER and GS scenarios (CBS; CPB) (Source: National Environmental Outlook 3, Figure 3.3.1)

The CPB has produced a follow-up scenario document, 'The Netherlands in Triplicate'[127]. Based on the European scenarios outlined in 'Scanning the Future', this CPB 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, how these GNP trends are generated is not made transparent. After a thorough comparison between

[124] The scenario used in the 1st and 2nd Environmental Outlooks. Added to this graph for comparison.
[125] CPB (1992b).
[126] See, for example, Timmer (1998), Geurts et al. (1995) and www.cpb.nl/eng/
[127] CPB (1992a)

'Scanning the Future' and 'The Netherlands in Triplicate', we conclude that the (unmotivated) quantitative trends for GNP development in Western Europe were most likely 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.

It can be argued that because RIVM took the trends from a report published by the authoritative CPB, underpinning is firm. However, there are two counter-arguments for this reasoning. First, RIVM provided the wrong reference: they referred to 'Scanning the Future' instead of the 'Netherlands in Triplicate', where the trends seemed to have been taken from. Second, our analysis of the CPB reports indicates that no solid information or logical justification for the trends used in the Environmental Outlooks could be found in the two major documents. 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[128]. We therefore conclude the statement on GNP development in the 3rd Environmental Outlook to be weak, although the underpinning itself lies beyond RIVM's mandate.

The full argumentation analysis[129] on economic development is summarised in Figure 3, in which 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 undermines, in principle, the quality of the full assessment.

In the present case, either the observed weakness resulted from lack of underpinning information and justification or the information presented 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 about the quality of the argumentation, and as such 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 this end, it would be relevant to investigate whether any uncertainties pertaining to GNP development are mentioned in the 3rd Environmental Outlook.

[128] It should be noted here that the institutional relationship between CPB and RIVM is fairly hierarchical. The CPB models and scenarios are usually not questioned by other decision-support institutes or ministries before use. With regard to weakness of the selected conclusion the above observation may therefore be seen as an example of how institutional arrangements (implicitly) influence the quality of the assessment.

[129] As previously mentioned, 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 the physical growth was more important than GNP for environmental assessment, GNP growth was used as an indicator throughout the 3rd Environmental Outlook. The full description of the analysis summarised in the righthand side of Figure 2 can be found in Langendonck (1999) and Van Asselt (2000).

Section 3.3, 'Economy', of the 3rd Environmental Outlook refers to uncertainty in general terms. The following quotation 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 (MV-3, p.34).

The underlined 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 uncertainties mentioned in connection with future GNP as uncertainty due to variability, and more specifically, societal randomness. In this case, the lack of knowledge resulting from this particular source of variability can be considered structural. These observations 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.

Example of a strong conclusion

The number of people experiencing noise nuisance due to road traffic is an example of an effect on one's well being, and can thereby be considered as one of the key outputs of RIVM's assessment. The 3rd Environmental Outlook offers the following conclusion on noise nuisance:

> '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 to 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' (MV-3, p.22).

The conclusion in the specific section on 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%, respectively and in the GS scenario to 51% and 12%, respectively (see Figure 4.6.2a)' (MV-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 5 (Figure 4.6.2) further illustrates the described trend. However, neither the figure, nor the above quote, indicates how these numbers were generated and the uncertainties associated with these numbers. Chapter 4 does not provide further justification or further references. Nevertheless, we decided to screen the background documents, the one on traffic and transport[130] seemingly the most relevant.

[130] Van Wee et al. (1993)

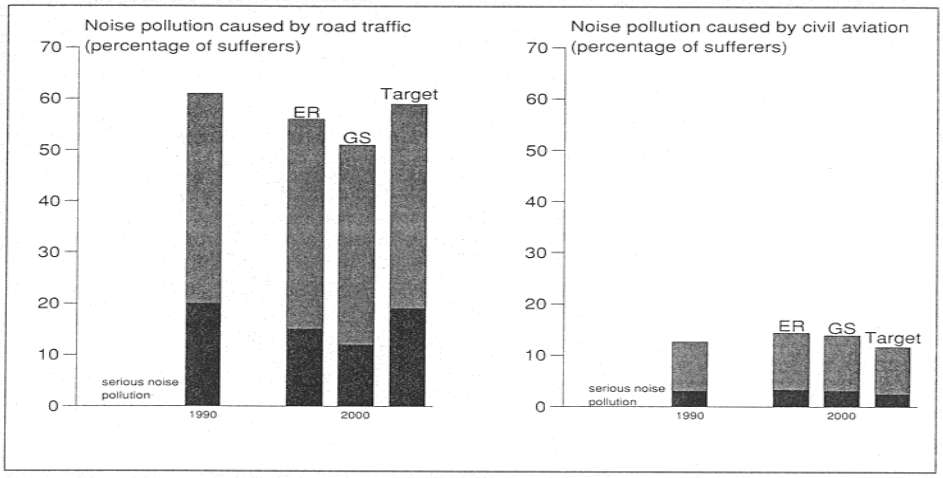


Figure 5 – (a) Noise pollution caused by road traffic showing number of people suffering noise nuissance and serious nois pollution in 1990 and 2000, and (b) noise pollution caused by civil aviation: number of people suffering noise nuisance and serious noise pollution in 1990 and 2000,ER and GS
(Source: 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 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 consistent and transparent where referring to the scientific origins 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 desirable, we can classify the conclusion in the Summary Chapter on noise nuisance due to road traffic as strong (see also Figure 6).

A 'strong' classification implies a conclusion 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 quality judgement in our search for uncertainty? In principle, 'strong' implies that it should be possible to recognise which uncertainties play a role and how they are considered in the underlying assessment. However, argumentation that is judged as being strong can be said to hide uncertainty; it may be that only experts in the field[131] 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 if uncertainties are mentioned in the case of strong conclusions and, if so, 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, the analysis would have required expert knowledge and understanding of this particular topic, which was not available in the research team. We have limited ourselves to sources of uncertainty traced directly from the

[131] As opposed to the kind of generalists who performed the reported argumentation analyses.

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 on the basis of volume developments. In the first place, the volume of heavy goods transport in rural areas will be less than expected; the intensities in this transport category in the future are assumed to 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 judge the conclusion.

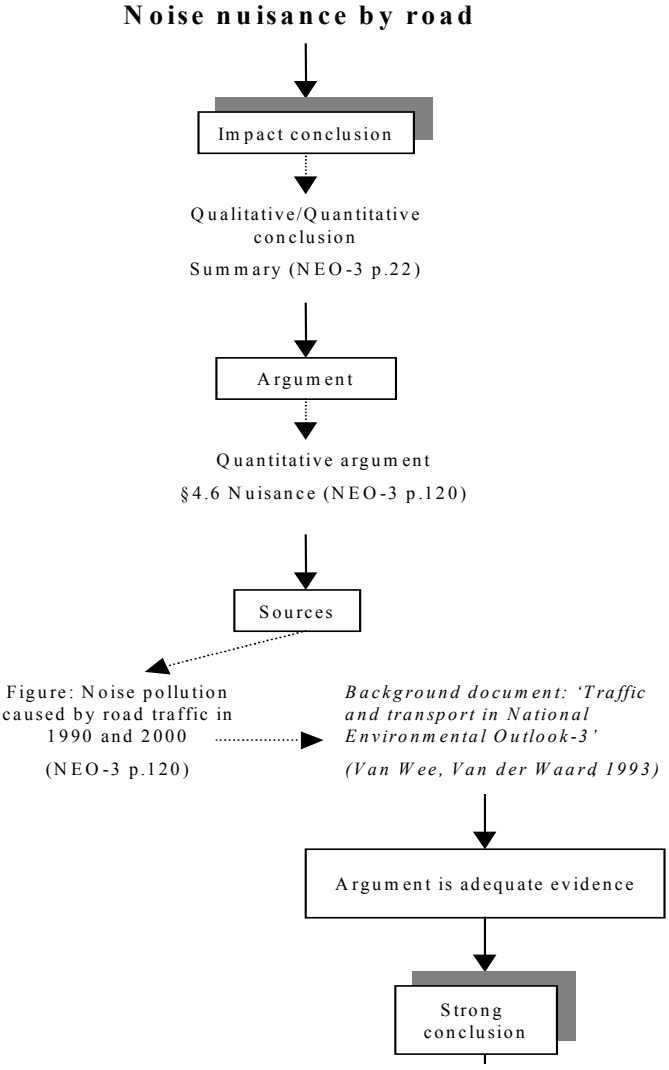


Figure 6 – Scheme with argumentation analysis for 'noise nuisance by road traffic'.

3.3 Assessment of argumentation analyses

Table 6 provides a summarising overview, indicating the quality of the argumentation, and whether uncertainties are mentioned, and if so, which sources were identified.

Table 6 – Overview of the results of the argumentation analysis.

	Analysed issues	**Argumentation**		**Uncertainties mentioned?**	
MV-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	
	CO2 emission	X			-societal randomness
	Deposition of acid equivalents	X		X	
	Total	**4/6**	**2/6**	**5/6**	**1/6**
MV-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**

Our argumentation analysis of the concluding statements extracted from the 3rd and 4th Environmental Outlook in a somewhat aselect way, indicates that 8 out of 12 can be characterised as weak, and that only 4 were classified as strong (see Table 6). If we compare the classifications of the selected statements between the two Environmental Outlooks, we can conclude that the picture remains the same for both. If the selected conclusions can be considered as representative for the whole Environmental Outlook, this observation would suggest that the quality of argumentation has not substantially improved over time. However, the rather random selection of statements, the number of statements selected, the limited scope of the performed vertical analysis in view of the available text and our self-imposed limitations to the two recent Environmental Outlooks, do not allow us to address this hypothesis in an acceptable manner.

From the above overview, it can be concluded that in the case of strong conclusions, uncertainty can, in some cases, be clearly identified in the text, while in 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. The consequence is that it is probably 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 or mentioned, with two exceptions: in the argumentation associated with the statement on economic development and in the case of 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 other weak

argumentation. However, our analysis of the weak conclusion on economic development and our analyses of the strong conclusions indicate that it would be sensible to propose a systematic treatment of uncertainty as basis for improvement in transparency and quality of the argumentation.

3.4 Searching for sources of uncertainty

Consequential to the design of the argumentation analysis is that we only accidentally traced particular sources of uncertainty. To supplement this analysis, we decided to scrutinise the Environmental Outlooks again, but this time to find concrete examples for each source of uncertainty[132]. In this way we can roughly assess if, in principle, all sources of uncertainty played a role in the series of Environmental Outlooks. Box 4 reports the concrete examples for the various sources of uncertainty.

Box 4

- **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' (MV-2, p.23).
- 'It can therefore not be determined with sufficient certainty what those two trends (i.e. the decrease of NOx emissions in the cities and the decrease of hydrocarbon and the NOx level on regional and European scales) imply for the number of days with summer smog in 2020' (MV-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' (MV-3, p.61)
- 'There is still little understanding of the degree to which provincial and local authorities (…) implement the adopted environmental policy (…)' (MV-3, p.34).

Value diversity
- All estimates of future costs in the Environmental Outlooks involve a degree 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' (MV-3, p.122).
- 'Future social developments are, of course, extremely uncertain, particularly when they concern a period of more than a decade' (MV-3, p. 33)

Technological surprise
- 'For trucks and buses 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' (MV-4, p.42).

- **Uncertainty due to Lack of Knowledge**

Inexactness
- 'Using current measures, a reduction of approximately 20% will therefore be possible' (MV-2, p.231).
- 'Agricultural products, foods and fertiliser hold a 40 to 45% share in domestic road haulage' (MV-3, p.44).

[132] See Chapter 2.

- 'The emission of phosphate increases in all scenarios over the 1995-2000 period by circa 20%' (MV-4, p.86).

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 clean-up operation' (MV-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 emission levels. Information on both issues is limited at the present time' (MV-3, p.47).
- 'lengthy series of measurements of UV radiation are not available' (MV-4, p.162).

Practically immeasurable
- 'The health impacts of fine dust will decrease by 25% between 1995 and 2020 assuming that all components of fine dust are equally responsible for health impacts'[133] (MV-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 (…)' (MV-2, p.108).
- 'It has been estimated that there may be 110,000 seriously polluted locations, for which the total clean-up costs would be NLG 50 billion. However, recent data point to even higher costs' (MV-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 MV-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' (MV-3, p.34).

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[134]. The examples found for each source nevertheless seem to suggest that all sources of uncertainty matter, at least to some degree, in the environmental assessment. They may thus have an impact, to a smaller or larger extent, on the policy conclusions. Furthermore, we did not find specific examples of recognised uncertainty in any Environmental Outlook that could not be straightforwardly classified according to our typology. This finding suggests that the taxonomy of sources of uncertainty has something to offer to the practice of decision-support.

[133] Informed by Rob Maas that this quote could be characterised as referring to uncertainty due to practical immeasurability.

[134] 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, it was beyond the scope of the present study to comprehensively list all uncertainties in each Environmental Outlook, it was also impossible to perform such an assessment of sources of uncertainty dealt with in the Environmental Outlooks over time.

3.5 The Environmental Outlooks compared

The four Environmental Outlooks were compared in order to understand whether and, if so, how, RIVM's approach to uncertainty management has changed over time. This comparison comprised two types of analysis. First, we compared the number and type of linguistic expressions for uncertainty. Second, we investigated the scenario approach applied in the four Environmental Outlooks.

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 words such as 'roughly', 'approximately' and 'circa'. Phrases like 'a possible trend', 'it is assumed' and 'it is not clear' indicate more structural uncertainty. Box 5 provides some illustrative quotes from the 3rd and 4th Environmental Outlooks in which uncertainty is hinted at by means of linguistics.

Box 5 – Linguistic expressions indicating uncertainty

Examples from the 3rd Environmental Outlook

- 'There are also great uncertainties about the effectiveness of enforcement (…)' (MV-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' (MV-3, p.35).
- 'In ER, this growth is restricted to 35% between 1986 and 2010 and in GS to over 25% (MV-3, p.42-43).
- 'The ozone layer at the 52th Northern degree of latitude (above the Netherlands) is expected to become at least 10% thinner' (MV-3, p.67).
- 'The banning of lead shot for hunting will cause a radical drop in lead (approximately 75%)' (MV-3, p.102).

Examples from the 4th Environmental Outlook

- 'The private car use will increase between 1995 and 2020 by roughly 25 till 35% (…)'
(MV-4, p. 39).
- 'The production volume of the whole livestock will decrease by circa 10%' (MV-4, p.47).
- 'In 2010 the emissions will be 52 to 55% less than in 1980 (…)' (MV-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' (MV-4, p.109).
- 'This concentration leads to approximately 400 cases of lung cancer (…)' (MV-4, p.113).

Using 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 if the relative use of linguistic uncertainty expressions varies over the different assessments. To this 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 7).

Table 7 – Location and number of effective pages of text.

Sections on issues A and B		***Total effective pages***
MV-1	- **A**: Demographic developments p.14-17 - **B**: Air pollution inner city p.312-322	7 2/3
MV-2	- **A**: Demographic developments p.49-52 - **B**: Air pollution in towns p.390-399	7 5/6
MV-3	- **A**: Population p.37-38 - **B**: Local air pollution p.122-123	1 2/3
MV-4	- **A**: Population and consumption p.25-28 - **B**: Air pollution (urban area) p.108-110	3 1/3

- 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 8 summarises the results of the linguistic analysis for the two selected issues, while Table 9 reports the analysis of uncertainty expressions in the Summary Chapters. Furthermore, Figure 7 shows the uncertainty density deduced from the latter analysis.

If we take the Environmental Outlooks as adequate representations of the state-of-the-art knowledge, the results presented in Table 8 do not allow us to judge from the number of linguistic expressions whether either demographic developments or local air pollution involves more uncertainty. The number of uncertainty expressions in the 2nd Environmental Outlook suggest that demographic developments are more uncertain, while the outputs of the linguistic analysis in the other Environmental Outlooks would lead to the opposite conclusion.

Table 8 reveals that both in absolute and in relative terms the 4th Environmental Outlook involves significantly fewer 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 its successor's uncertainty density. It is fairly 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.

Table 8 – Results of issue-oriented linguistic analysis.

Linguistic expressions which.. …indicate uncertainties	**MV-1**		**MV-2**		**MV-3**		**MV-4**	
	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
.. cannot 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 difficult to predict		1						
Not clear is		1						
The uncertainty is		1						
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
Total expressions	8	14	19	8	9	10	2	7
Total expression (- 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 expressons per page	**2.9**		**3.4**		**11**		**2.7**	

The above picture is confirmed by the summary-oriented linguistic analysis (see Table 9 and Figure 7). 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 explicitly than any of the other environmental assessments, both absolutely and relatively speaking.

Table 9 – Results of the linguistic analysis of the summaries.

Uncertainty expressions	**MV-1** 'Summary' p.VIII-p.XXVIII	**MV-2** 'Summary' p.11-p.39	**MV-3** 'Summary' p.9-p.27	**MV-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**

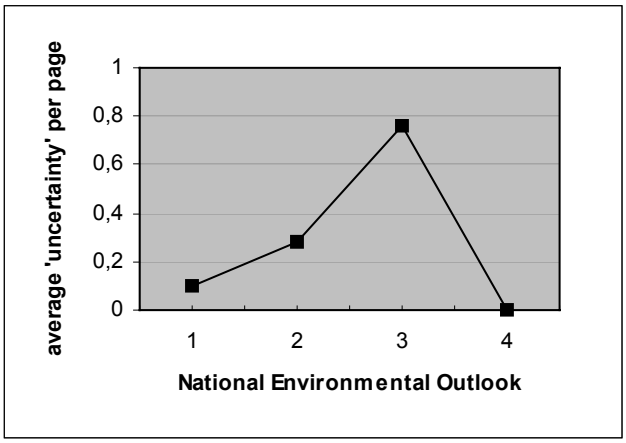


Figure 7 – Average frequency of the term 'Uncertainty' in the Summary Chapters.

The results of horizontal linguistic analysis suggest that the number in the Environmental Outlooks is not indicative of the degree of uncertainty involved in the assessment. Our analysis concludes that there has been a consistent RIVM strategy for determining, how and how often uncertainty is expressed in the literal text. The linguistic analysis seems to suggest that using uncertainty expressions is more a matter of individual style and preference. We conclude that the linguistic approach to uncertainty is not a strategy systematically employed by RIVM.

Analysis of the scenarios

So far, we have focused on argumentation and text analysis. Another way to get insight 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. Especially in the 3rd and 4th Environmental Outlook, the scenarios area argued to cover the uncertainty concerning future societal developments, as illustrated by the following quotes:

> 'The uncertainty concerning future social developments, including economic growth, is clearly shown in two contrasting future scenarios' (MV-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 (MV-3, p.34).
>
> 'To do justice to the uncertainties, three scenarios have been developed. The scenarios differ in assumptions pertaining to global economic developments, demographic and socio-cultural developments, and technology development (MV-4, p.21).

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 the introduction to this Chapter, since this overview was needed as background for the 'vertical' argumentation analysis. The essence of scenario methodology[135] is that multiple possible

[135] See also Chapter 2.

futures are developed and considered in the assessment as a reflection of uncertainty. The 1st and 2nd Environmental Outlooks 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 practice used as apparent certitudes, which is in contrast with the argument that strict prediction in view of uncertainty is principally impossible.

Against that background, the scenario approach adopted in the 3rd Environmental Outlook represented a fundamental change in RIVM's uncertainty management. In the 3rd Environmental Outlook, two scenarios, i.e. one tailored towards the European Renaissance, and one towards 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 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' (MV-3, p.33).

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 this 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) (..)' (MV-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 and some social-cultural developments.

The key question then is whether these scenarios covered 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[136] indicated

[136] Van Asselt et al. (1998)

the variety expressed by the set of scenarios to be limited. The scenarios used in the 3rd and 4th Environmental Outlook presuppose a linear relationship between economic growth and technological development[137]. 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 rate of the economy remain behind the monetary growth rate. The postulated relationship implies a lower economic growth to be associated with fewer funds for technology and so will result in less 'eco-technology'. The consequence is that a low-economic-growth future is associated with a relatively high physical economic growth.

This means that none of the CPB scenarios relate to a future in which economic growth is not a condition for technology improvement, but one in which more environmental-friendly lifestyles are adopted, and available technology innovations applied on large scales. This would result in a scenario with a low economic growth and a physical growth lower than assumed in the set of CPB scenarios. Furthermore, the set of scenarios used in the previous Environmental Outlooks 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 they increase the range of possible environmental impacts.

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 it was not possible to link the scenario approach of the 3rd and 4th Environmental Outlooks directly towards the question on which uncertainties were salient to assess the state of the environment.

3.6 Uncertainty ranges

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 margins to the extremes per Outlook:

- 'With a high economic growth, an increase in the global energy use of 2 – 2.5 % per year is expected.' (MV-1, p.21)
- 'To prevent health damage by ozone, it is necessary to achieve a drastic reduction of acidifying emissions of about 65-75%.' (MV-1, p. 22).
- 'In 2010 there will be an estimated 35%-40% less energy' (MV-2, p.12).

[137] To a certain extent it would seem legitimate to relate autonomous technological change in terms of efficiency to economic growth (pers. comm., Jan Rotmans). What we question here is that all three scenarios include the assumption that all technological development is a linear function of economic development.

- 'The consumption of energy and raw materials will increase by 10%-20%' (MV-2, p.12).
- 'The number of private vehicle kilometres could end up 10%-15% higher' (MV-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' (MV-3, p.14).
- '(…) the energy consumption of the households increases between 1995 and 2020 by 60%-140% in case of unaltered policy, the use of private cars increases by 15%-25%, aviation by 140%-300% and the total household waste by 15%-35%' (MV-4, p.12).

The ranges reported in the 1st Environmental Outlook are from 0.5 to 10% (i.e. 2.5% - 2% = 0.5% and 75% to 65% = 10%). In the 2nd Environmental Outlook the spread is somewhat more condensed, 5% to 10% (i.e. 40%-35% = 5%, and 20%-10% =10%). In the Summary Chapter of the 3rd Environmental Outlook, the smallest margin was also 5% (i.e. 15%-10%), while the largest margin had grown to 30% (i.e. 40%-10% = 30%). The 4th Environmental Outlook, however, denoted consequent larger spreads, with margins ranging from 10% (i.e. 25%-15% = 10%) to 160% (i.e. 300%-140% = 160%).

This could mean that the estimates of uncertainty had 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 in comparison to the previous Outlook, one would expect such a difference to be explicitly acknowledged and explained. This is, however, not the case[138].

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 those covered in the last two Environmental Outlooks. To this end, we compared the distance between future trends in terms of total magnitude of the margin[139]. Because the 1st and 2nd Environmental Outlooks use only one scenario, and thus report only one pathway into the future, the total margin is zero. This can also occur in the last two Outlooks if the outputs associated with the various scenarios overlap, as, for example, in the quantitative estimates in the 3rd Environmental Outlook concerning livestock volume, NH_3 emissions and CH_4 emissions. Table 10 reports the results of this comparison.

Table 10 – Results of comparing quantitative forecasts over ten selected issues.

	Total margin				**Ratio**
Issue	***MV-1***	***MV-2***	***MV-3***	***MV-4***	***MV-4 / MV-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

[138] Compare also the results of the linguistic analysis.
[139] See Van Asselt (2000) and Langendonck (1999) for a more detailed discussion of the method employed to calculate total magnitudes.

From Table 10 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% for the larger margins to four times the 3rd Environmental Outlook uncertainty range, without an explicit explanation in the Environmental Outlook report[140]. The comparison of quantitative forecasts for the ten issues reinforces the observation that the uncertainty ranges expressed in the 4th Environmental Outlook are significantly larger than in the previous Environmental Outlooks. It is interesting to note that this increase in quantitative uncertainty assessment is observed both in the Summary and consistently for selected issues.

The increase in margins over time, i.e. the sprinkler-effect, also has 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 the decision-support dimension. Uncertainty management should be more than an expression of ever-increasing margins; it should provide information on robust policy strategies.

3.7 RIVM's uncertainty management as deduced from document analyses

The document analysis yields the general picture that uncertainty is not explicitly nor consistently considered in the Environmental Outlook reports. The argumentation analysis did not allow us to recognise which uncertainties were salient to the assessment and how the uncertainty was managed in the underlying assessment process. We thus conclude that the Environmental Outlook *reports* are not transparent with regard to uncertainty. This 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.

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. This observation seems to be at odds with the results of the argumentation and linguistic analyses. The result of this tension is that RIVM's communication on uncertainty is very ambivalent, if not inconsistent. The messages on uncertainty expressed by linguistic expressions fundamentally conflict 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%, of which the range in common language says that it is more uncertain than fully uncertain.

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 an uncertainty method. It can be argued that the scenario methodology,

[140] It was beyond the scope of the present study to examine in detail possible arguments for these increases in uncertainty ranges.

after all, is not systematically applied as a method for uncertainty management, but more as a way to consider some pathways into the future that are known in the Dutch policy arena. As a matter of fact this is in conflict with the explicit claim made in the Environmental Outlooks that the scenarios are employed to do justice to uncertainty.

The conclusions with regard to RIVM's uncertainty management as deduced from the document analyses of the four Environmental Outlooks follow:

- Analyses show weak argumentation (i.e. adequate argumentation and information justifying the conclusions is lacking)[141]
- Analyses 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, or systematically, treated in the Environmental Outlooks; there does not seem to be a strategy for uncertainty management.
- Whether the set of scenarios employed is adequate in view of the decision-support ambitions associated with an Environmental Outlook can be questioned.
- 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 uncertainty is dealt with in the Environmental Outlooks in a problematic fashion. 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 the one around De Kwaadsteniet[142] 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.

3.8 Empirical research

From the extensive document analyses, we have concluded that uncertainty was not systematically treated in the four Environmental Outlook *reports*. However, this doesn't necessarily mean that it was not systematically treated in the underlying assessment process. Practitioners in the previous Environmental Outlook processes were another source of information. A number of responsible RIVM people have been interviewed[143], a focus-group session[144]carried out and questionnaires[145] distributed among analysts in the current Environmental Outlook process, the majority of whom participated in previous assessment processes. This empirical research output[146] was analysed to address the following research questions:

[141] 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 Outlooks.
[142] De Kwaadsteniet's criticism was mainly targeted at the Environmental Balance; however, in the subsequent contributions to the discussions in the media, the Environmental Outlook was also discussed.
[143] See Langendonck (1999); Van Asselt (2000)
[144] See Van Asten (2000)
[145] See Van Asten (2000) Van Asten and Van Asselt (1999)
[146] Preliminary analyses of the empirical output were presented in Van Asselt et al. (1999) and in Van Asten and Van Asselt (1999)

- How was uncertainty managed in the Environmental Outlook assessment processes?
- Has the attitude towards uncertainty and uncertainty management changed over time? If so, why and how?
- Which sources of uncertainty relevant to the assessment process are recognised by the practitioners themselves?
- Do the RIVM practitioners see a potential need for improvement and change?

Uncertainty in the Environmental Outlook practice

The interviews, the focus group and the RIVM report describing the practice (produced during our case study as RIVM's official response to the media and political pressure[147]) revealed uncertainty in the Environmental Outlooks to be addressed in the following fashion:

- ***Quantitative methods for uncertainty analysis:***
- economic-technological scenarios, sometimes complemented with specific model simulation runs (such as low and high energy prices)
- sensitivity analysis on inputs[148] for individual models[149] (reported in research reports)
- uncertainties in parameter values checked by means of standard uncertainty analysis techniques
- ***Qualitative approaches:***
- expert judgements
- consensus formation with other institutes
- contra-expertise
- 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
- care in the presentation of maps, since maps suggest certainty

The next question is concerned with how the above methods were applied. Expert judgements, discussions among internal experts 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[150], brain-work, which is not a linear stepwise process, is thus 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 would be difficult to trace.

With regard to the actual use of quantitative methods, the discussions in the focus group made it clear that two groups of uncertainties – uncertainties linked to the social system, and uncertainties linked to the environmental system - are distinguished within the RIVM. Uncertainty in the environmental causal chains is not systematically addressed, implying

[147] RIVM (1999a; RIVM (1999b)

[148] In the focus group, it was made explicit that sensitivity analyses on model parameters in the context of the Environmental Outlook assessment are rare.

[149] It was explicitly said in the focus group that a systematic sensitivity analysis for the modelling framework (i.e. cascade of models) used in the assessment had never been performed.

[150] De Bono (1968); De Bono (1969); De Bono (1970)

that accumulation of uncertainty is not analysed. The working hypothesis underlying this practice was that because societal uncertainty dominates, the major uncertainty with regard to the state-of-the-environment is already discounted 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, with some rare exceptions, 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 chains 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.

In the interviews, the question was therefore asked on whether the respondents considered the scenarios used as an adequate handling of the salient uncertainties. The adequacy of the CPB scenarios for the environmental assessment was questioned both in the interviews and in the focus group. A number of problems inherent to CPB's scenario methodology were brought to the fore. The CPB scenarios cover merely extrapolation of trends and not bifurcations and surprises, items that the CPB models could not handle. The resulting 'boring' character of the scenarios was thus questioned, as illustrated in the following quotation taken from the interviews:

> *'The past teaches us that developments are non-linear. The scenarios do not incorporate this lesson.'*

Furthermore, the CPB scenarios were 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 found in the agricultural sector. Implied here 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 of the environmental assessment. A discussion on the CPB scenarios also 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[151] implies emission scenarios that 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 a high economic growth in the Netherlands to correlate with economic growth worldwide, which would cause the economic stimulus for migration to weaken. As a consequence, the CPB forecasted either high economic growth and 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 high economic and population growth due to migration combined with limited technological development (implying a scenario featuring an increase in pressure on the environment) was ignored in the set of scenarios. The same

[151] See also discussion on the scenarios in the document analysis part of this Chapter.

holds for a future characterised by low economic and population growth combined with substantial technological improvement, especially where environmental-friendly technology is concerned.

Another crucial issue in the environmental assessment involves deposition patterns. These patterns are not only dependent on Dutch emissions, but emissions in other European countries and even other continents, in particular, from substances like ozone, 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 view of RIVM's task to assess the future state of the environment, the following disadvantages can be deduced with reference to scenarios used in the previous Environmental Outlooks:

- extrapolative, linear character of the scenarios
- consumption-driven calculation of production trends
- rigid assumptions for relationships between economic growth, population development and technological innovation
- limited discounting 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 seems far too limited to adequately cope with economic-technological uncertainties, let alone relevant socio-cultural uncertainties. Building on the focus-group discussions, it can therefore be concluded that the scenarios adopted seemed inadequate in their approach for managing societal uncertainty in RIVM's assessment. This kind of problem had at the time never been systematically considered in the collaboration between RIVM, CPB and SCP. The respondents argued that the RIVM had been rather authority-abiding, and thus uncritical in its use of the CPB scenarios in its environmental assessments[152].

The interviews, the focus-group data and the questionnaire data (see Box 6) led the practitioners to conclude that uncertainty was not ***systematically*** managed in the assessment processes underlying Environmental Outlooks 1 to 4. At the time, a framework for uncertainty management was lacking, as well as a coherent strategy towards applying the recognised approaches and techniques for uncertainty analysis. Not all approaches were used purposively, consequently and consistently. The respondents revealed that their perception was that it was an explicit choice of the management of the Environmental Outlook not to bother the readers too much with uncertainty. As a consequence, the respondents argued, uncertainty is only mentioned in the Environmental Outlook reports if RIVM judged it as being salient to the policy recommendations. There were no explicit criteria that facilitated this judgement; in the interviews the evaluation of the policy relevance of uncertainty was stated as being a fairly intuitive process. The interview data suggested that the above attitude and behaviour could be explained by their perception that

[152] 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.

policy-makers had difficulties handling uncertainty. Summing up, we can conclude that uncertainty did not get adequate attention in the series of Environmental Outlooks, neither in the process nor in the product.

Box 6 – Uncertainty in the assessment process: Interview, focus-group and questionnaire data

N.B.:
Singular quotes from the interviews(quotes reported pertain explicitly to MV-1 to MV-4):

- '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 the result. Dealing with uncertainties is not our second nature. 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.'

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 anywhere, 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 little 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 uncertainty as being 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 a 5-point scale questionnaire:
Total number of respondents: 15

0-2	3-4	5-6	7-8	9-10	11-12	13-15

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Uncertainties were dealt with adequately in the Environmental Outlooks.	1	2	8	3	0
Uncertainties were dealt with adequately during the Environmental Outlook process.	1	9	3	2	0
Uncertainties were dealt with adequately in the translation from process to product.	0	10	5	0	0

The above questionnaire data indicate that the analysts involved in the 5th Environmental Outlook process doubt that uncertainty was adequately managed in the previous Environmental Outlooks.

A lack of systematic uncertainty management seems problematic, considering RIVM's decision-support aim. Questions as to whether and how uncertainty was accounted for in the four Environmental Outlooks could be answered by means of reference to the associated Environmental Outlook reports or the process documentation. This was not a problem as long as RIVM's authority was unquestioned. However, the De Kwaadsteniet affair taught us that authority in our current society is not a solid basis (anymore). This media affair furthermore proved that uncertainty management is not only relevant from a philosophical point of view, but that it is critical to RIVM's decision-support role in the policy arena. It illustrated that vulnerability due to lack of dealing systematically with uncertainty in assessment processes poses a real risk to decision-support institutes. De Kwaadsteniet did not create the vulnerability; the media affair only brought it to the (public) fore. The evaluation of the four Environmental Outlooks has indicated that RIVM's uncertainty management can be improved and has provided some hints on how this can be done. In the following chapters we will discuss how the lessons forthcoming from the 'DeKwaadsteniet affair' and the review of the previous Environmental Outlooks (MV-1 – MV-4) were used in the assessment process underlying the 5th Environmental Outlook.

4 THE PRIMA APPROACH

This Chapter summarises the PRIMA approach, which is an attempt to provide a structure for the process of uncertainty management. The basic ideas and the various steps are discussed to serve as background material to the subsequent chapters. The guiding principle in the PRIMA approach is that uncertainty legitimates different perspectives and that as a consequence uncertainty management should consider different perspectives. Central to the PRIMA approach is the issue of disentangling controversies on complex issues in terms of salient uncertainties. The salient uncertainties are then 'coloured' according to various perspectives. Starting from these perspective-based interpretations, various legitimate and consistent narratives are developed to serve as a basis for integrated analysis of autonomous and policy-driven developments in terms of risk. In this way, the level of uncertainty of the underlying knowledge can be made explicit and robust insights relevant for decision-making can be distilled.

Building on the overview of existing approaches to uncertainty management in Chapter 2, the argument from theoretical point of view was that new methods and procedures for dealing with uncertainty in Integrated Assessment would have to be developed. In Chapter 3, it was concluded that the practice of decision support lacked strategies and frameworks for dealing with uncertainty throughout the assessment. There is an observed need for a more structured approach to manage uncertainty in assessment endeavours. The PRIMA approach[153] has been developed to address this need. In this context, uncertainty management is defined as 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. In this Chapter the main features of the PRIMA approach are summarised.

4.1 Principles

So far the mathematical, statistical approach has dominated in uncertainty analysis[154]. From the review in Chapter 2 we concluded that these approaches to uncertainty were especially inadequate in the case of radical uncertainty, i.e. uncertainties that can at best be roughly assessed. In the case of complex issues, uncertainties are usually radical. Furthermore, the traditional approaches reason from the positivist paradigm, 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 may be legitimate and viable. Taking this into account, the implication is that uncertainty management should be pluralistic. Pluralism implies cultivating a diversity of perspectives, without necessarily slipping into a relativistic tolerance of all view points. The innovative feature of the PRIMA approach is that it provides concrete ideas about how the notion of pluralism can be used in

[153] See Van Asselt (2000); PRIMA is an acronym for **P**luralistic f**R**amework for **I**ntegrated uncertainty **M**anagement and risk **A**nalysis.
[154] See Chapter 2.

a constructive and sensible manner in assessment endeavours, so as to improve uncertainty management.

4.2 General framework

The PRIMA approach consists of five stages (see Figure 8):

- definition of 'starting perspective'
- uncertainties in perspective
- scenarios in perspective
- risks in perspective
- quality assessment

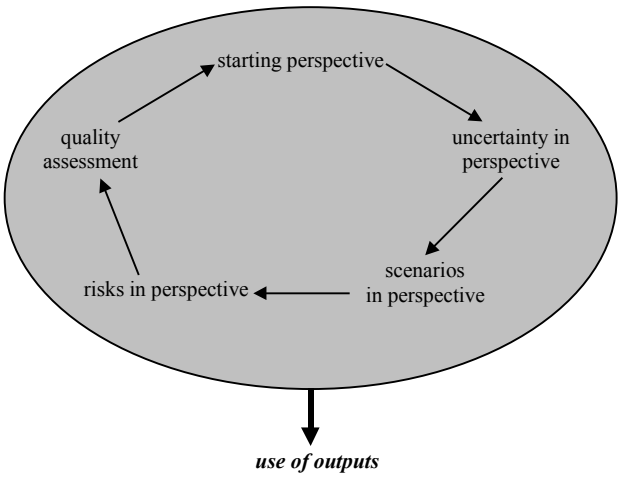


Figure 8 – *PRIMA approach.*

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 stage is characterised by 'uncertainties in perspective'. In this stage, the scanning and selection of salient uncertainties and the perspective-based interpretation of these uncertainties are the central tasks. In the following phase – 'scenarios in perspective'- scenarios that seem to be possible and plausible are assessed. This involves scanning the future from a wide variety of perspectives. This can be done both in a qualitative and quantitative manner. The next challenge is to assess risks, taking into account the variety of perspective-based assessments gathered in the previous phases. This stage is therefore characterised as 'risks in perspective'. It is very important to test the quality of the associated robust insights by reflecting on the previous steps; this means evaluating whether the uncertainties and risk factors relevant for these particular conclusions have been considered in an adequate manner. This stage of quality assessment can be considered to close the assessment cycle (see Figure 8). Building on these insights, the process can be

iterated with an adopted or new definition of the controversy or dilemma, or with another perspective on pluralism.

This above process yields outputs that can be used to improve the quality of the decision-support. Intermediate products can also be used as input for actual decision-support endeavours. For example, the overview of salient uncertainties can be useful in an assessment, also without perspective-based interpretations.

The PRIMA approach is meant to serve as a guide for uncertainty management. This implies that the above scheme should not be interpreted as a rigid procedure, but as an attempt to structure the desired ingredients. The various steps, including concepts, tools and methods that enable one to perform these steps, are summarised stage-wise in the following sections[155].

4.3 Starting perspective

Applying pluralism means taking a certain stand with regard to pluralism[156]. 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 practice and in being too time consuming, this would turn uncertainty management into a mission impossible. We would advise, as the first step, choosing the perspective on pluralism that corresponds best with the attitude of both the analysts and the clientele, and then being consistent with this perspective during the assessment process.

There are four design choices crucial for setting up the assessment; these are dependent on the choice of pluralistic stand, i.e.:

- the type of uncertainties to be included in the pluralistic analysis
- whether a demand- or a supply-driven approach is advocated; in *supply-driven* studies, a group of scientists anticipates the societal relevance of a complex theme. The scientific problem definition scopes the assessment. *Demand-driven* studies imply 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 scopes the assessment.
- 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. Van Asselt proposes a spectrum of perspectives on pluralism ranging from rather positivist ‘observation-in-perspective’ to the extreme social-constructivist ‘reality-in-perspective’). The aim of this classification is to outline the major differences in theorising on pluralism in relation to science. The features associated with this spectrum of these so-called ‘meta-perspectives’ are briefly explained below and summarised in Table 13.

[155] For a full description see Van Asselt (2000)
[156] For a more comprehensive discussion on the issue of pluralism about pluralism, see Van Asselt (2000).

The *'observation-in-perspective' pers*pective maintains that observation is shaped by what the researcher wants to falsify or verify. This means that competing hypotheses form 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 uncertainties. This perspective on pluralism implies an essentially supply-driven assessment, in which the perspective-based analysis is restricted to radical uncertainties, while the majority of the recognised uncertainties is dealt with by standard methods.

The *'theory-in-perspective' perspective* includes radical uncertainties in the perspective-based analysis, while measurable uncertainties are handled with standard methods. This perspective on pluralism advocates the supply-driven approach, although this does not exclude the possibility that some of the activities will be participatory. In this perspective it would be appropriate to use different scientific paradigms to compose a set of perspectives. Even in disciplines in which the governing 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 carried out. 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 11 is an attempt to highlight some major dichotomies.

Table 11 – Exploration of major dichotomies within science.

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)
Socio-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

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[157].

[157] In such an exercise the following references can serve as a source of inspiration: Nordhaus (1994), Morgan and Keith (1995).

In the *'science-in-perspective' perspective* a typology of socio-cultural perspectives is welcomed, since this perspective maintains that pluralism in science arises from pluralism in society. Such a typology can be found in Cultural Theory[158]. We advocate a pragmatic approach through renaming and summarising the 'cultural theory'-perspectives in terms of heuristic rules[159]. The complicated naming of the perspectives is one of the recognised obstacles, also for people neutral or positive to Cultural Theory. Van Asselt (2000) proposes the following terms[160], i.e.:

- the market optimist (instead of individualist)
- the environmental worrywart (instead of egalitarian)
- the controllist[161] (instead of hierarchist)

Besides this, we proposed summaries (see Table 12) comprising the heuristic rules that turned out to be critical in interpreting uncertainties in our applications of Cultural Theory so far[162]. Furthermore, we have tried to prioritise these critical features. In doing so, the characterisations summarised can be used as heuristic schemes in quickly applying the above perspectives to assessment practitioners and stakeholders not familiar with Cultural Theory.

Table 12 – Features of socio-cultural perspectives.

	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 motives for action. Success is personal responsibility.	Equity	Risk-aversive; Anti-abrupt change; Easy going, 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	Reliance on expertise and experience of authoritative institutes/experts
Heuristic rule 4	Problems are solvable; Risks are challenges and opportunities.	Human beings essentially show solidarity and act accordingly; Collective interest	Power and status are the motives for action.

[158] See Van Asselt (2000); Key references on Cultural Theory: Douglas and Wildavsky (1982) Rayner and Cantor (1987; Rayner (1987) Funtowicz and Ravetz (1985) Thompson (1990), Krimsky and Golding (1992); Schwarz and Thompson (1990).

[159] 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 (Van Asselt et al. , 1998)

[160] This adjustment was inspired by the discussions within the 'perspective' working group (autumn 1998 till spring 1999). Renaming was explicitly recommended by Prof. Kees Schuyt in a passionate discussion about the pros and cons of Cultural Theory.

[161] Wording inspired by Hella Haase's novel *Huurders en onderhuurders* ('Tenants and subtenants'), 1971.

[162] Especially Rotmans and de Vries (1997) and Van Asselt et al. (2000)

Within the 'science-in-perspective' perspective a deductive strategy for deriving perspectives from the participatory process also fits.

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 maintains 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 from the interactions in the participatory process. In its extreme form, this perspective implies that social interactions are unique, which in turn implies that the assessment is not reproducible and that the results cannot be generalised. In a less than post-modern variant, it is possible to infer patterns out of the empirical study of the interaction processes. So far, constructivist literature does not provide a scheme that can be applied in pluralistic efforts. Uncertainty management is a 'reality-in-perspective' mode thus implying that the assessment process is demand-driven and necessarily participatory.

Table 13 – Practical differences in perspectives on pluralism.

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 as complementary approaches	perspective-based with standard methods as supportive	fully perspective-based
Perspective framework	hypotheses	scientific paradigms	socio-cultural perspectives	perspectives resulting from participation

4.4 Uncertainty in perspective

This phase involves scanning the uncertainties with a view to relevant risks. The taxonomy of sources and types of uncertainty provided in Chapter 2 can be used to systematically assess and characterise the uncertainties involved (see Figure 1). The activity of identifying salient uncertainties will be an iterative effort. Salience in the context of decision support implies a degree of uncertainty that is significant and a high policy relevance[163]. Because salience has both a scientific and an evaluative dimension, the conclusion is that this step can be best taken through a participatory process. Whether the degree of uncertainty is high and whether the uncertainties are highly policy relevant can then be determined in an iterative and intersubjective[164] manner. It can also be decided that different sets of salient uncertainties are composed in relation to the various perspectives used in the specific

[163] Compare Funtowicz and Ravetz (1990)

[164] That is using a range of subjective interpretations to distill importance, without claiming that consensus implies objectivity.

assessment. Figure 9 sketches a participatory selection process. Heuristics as checklists, sensitivity analysis and NUSAP may help to estimate the degree of uncertainty.

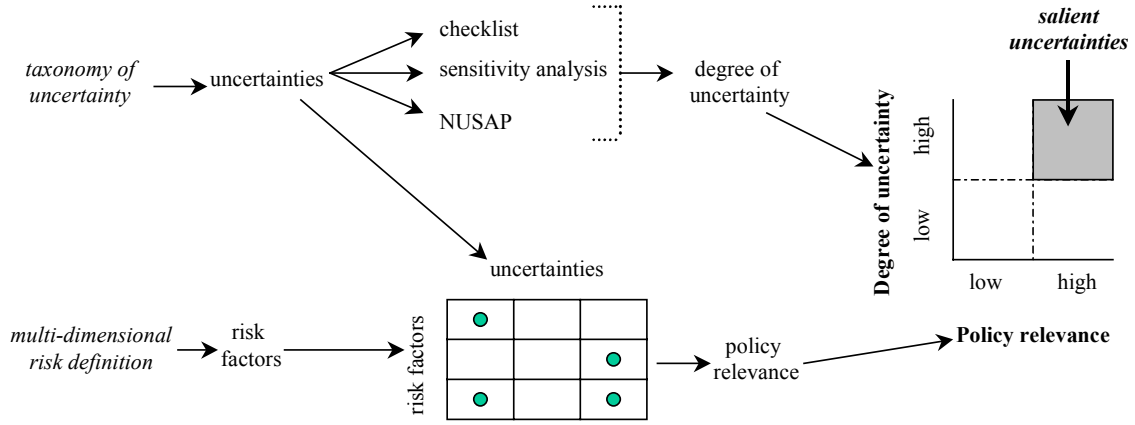


Figure 9– Possible procedure for selecting salient uncertainties.

Salient uncertainties can be clustered in terms of world view (i.e. uncertainties concerning the system) and management style (i.e. uncertainties concerning decisions)[165]. Uncertainties associated with worldview involve uncertainties pertaining to economic, environmental and socio-cultural processes. Interpretation of worldview uncertainties is usually expert-based. Table 14 provides an example of qualitative interpretations of salient worldview uncertainties in global sustainable development.

Table 14 – Example of perspectives in terms of worldview
(Source: Rotmans and De Vries, 1997)

	Hierarchist	**Egalitarian**	**Individualist**
Economy	• moderate desire for economic growth	• low desire for economic growth	• high desire for economic growth
Population & health	• physical limits • family planning programmes as driving force • health as human capital • health services	• environmental and social limits • societal developments as driving force • health as human asset • socio-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

[165] 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); Van Asselt and Rotmans (1996); Van Asselt and Rotmans (1997).

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

Uncertainties associated with management style deal with policy preferences in terms of strategies and options, and with institutional processes. Interpreting the salient uncertainties associated with management style involves scanning the strategies and options[166] 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 15 for an example).

Table 15 – Example of perspectives in terms of management style (Source: Rotmans and de Vries, 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 programmes for new energy supply and efficiency options	• carbon tax approaching 500$/tC in 2020, constant afterwards • R&D programmes on renewable resources	• no carbon tax
Water management	• increasing charges on water	• water-taxing • active policy on public water supply and coverage • R&D programmes on small-scale technology	• market pricing of water • high-tech R&D programmes 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)

[166] Techniques for option generation are found in the literature on policy and analysis; see, for example, Van Heffen et al. (1999) and Hoppe (1998).

The major outcome of this phase is a set of consistent perspective-based interpretations of salient uncertainties, in which worldview and management style are distinguished.

4.5 Scenarios in perspective

A scenario is defined as an alternative view of the future, created from mental maps or models that reflect a specific perspective on past, present and future developments[167]. 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 a 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. Such a development of perspective-based scenarios can be done in a qualitative or quantitative manner. The perspectives can be used to model different conceptualisations of the relevant dynamics through perspective-based model routes[168] in a quantitative model. In doing so a perspective-based scenario exercise will yield a variety of quantitative forecasts. The perspective-based interpretations of uncertainty can be used in a qualitative endeavour, in which perspective-based knowledge patterns are thought through. A combination in which perspectives are used to develop narratives to serve as a basis for model experiments can also be interesting[169].

It is important here to distinguish between autonomous and policy-driven developments. To this end, the various worldviews and management styles are systematically combined in order to explore different utopian and dystopian outlooks (see Figure 10).

Worldview ***Management style***	***Perspective A***	***Perspective B***	***Perspective N***
Perspective A	utopia	dystopia	dystopia
Perspective B	dystopia	utopia	dystopia
Perspective N	dystopia	dystopia	utopia

Figure 10 - Scheme for utopian and dystopian combinations.

In doing so, each scenario consists of a particular management style (composed of policy options) and a particular interpretation of how the world functions. In many cases, it would be interesting to go beyond the rigid management style and worldview scheme. For example:

- test a particular policy option or strategy against all worldviews;

[167] See Van Asselt (2000)
[168] Van Asselt and Rotmans (1995); Van Asselt and Rotmans (1996); Van Asselt and Rotmans (1997); Van Asselt and Rotmans (1999)
[169] Such an approach is currently used in assessing perspective-based strategies for the Rhine and Meuse rivers (e.g. Van Asselt et al. (2000)).

- i) subdivide the worldviews into economic, socio-cultural, ecological and institutional clusters[170], 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[171];
- explore the consequences of a future change of management style[172];
- combine these approaches.

These activities result in a broad range of scenarios covering a wide variety of legitimate interpretations of the underlying salient uncertainties relevant to the strategic debates. In doing so, this approach to scenario analysis puts uncertainty at the heart of the assessment. Such scenarios allow scanning the range of possible futures constrained by current state-of-the-art knowledge. Scanning what is possible, and what is not, yields the relevant information sketched in the above scheme.

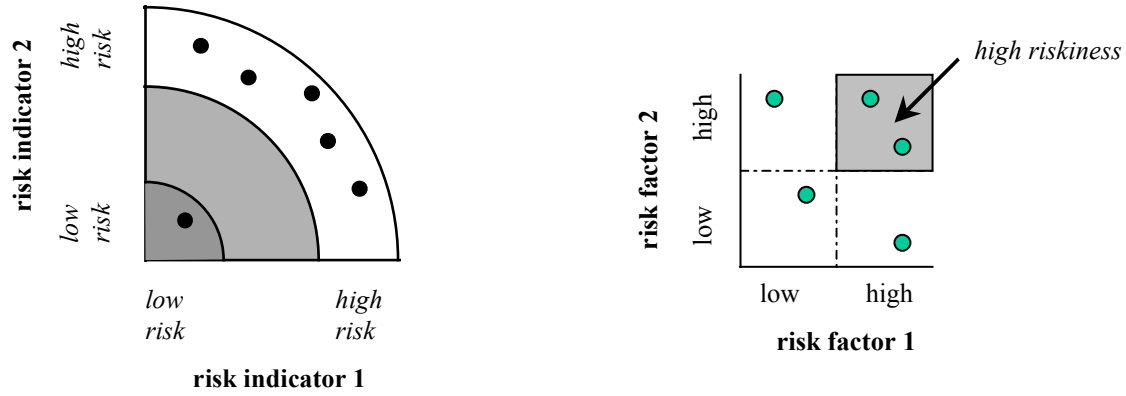
4.6 Risks in perspective

The previous stage can be considered as a phase in which divergence is a key principle. In the present phase, convergence is the aim. The challenge is to go beyond the multiple perspective-based 'sprinkler' of 'would-be-worlds'[173]. 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 robust conclusions are possible. In this process of convergence the notion of risk seems to be useful. In the 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 us to define low-risk, moderate-risk and high-risk areas for the resulting two-dimensional 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 may be interesting to consider. On the other hand, thorough analysis of the scenarios that have landed in the high-risk area may provide insights into 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 views of the future) will be assessed in terms of riskiness[174] and it indicates which strategies and options seem to be effective in view of long-term aims. Figure 11 illustrates 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 11 would be that the first strategy seems to be highly risky, while it is difficult to draw a similar robust

[170] This clustering is inspired by the distinction into economic capital, socio-cultural capital, ecological capital and institutional capital, which guides the ICIS research programme (see, for example, Rotmans (1997a), ICIS (1999b)).
[171] The introduction of surprises into scenario development is a key innovation of the VISIONS project (see Rotmans (1997b); Rotmans et al. (1999) and Van Asselt et al. (1998))
[172] See Van Asselt and Rotmans (1996) and Janssen and De Vries (1998) for this kind of experiment with perspective-based model routes.
[173] Casti (1997)
[174] See Van Asselt (2000)

conclusion about the second one. In this case, the conclusion would be that controversy this strategy is to be expected.



Legend: each bullet represents a scenario associated with a particular strategy/policy option. The total number of bullets represent the different scenarios that perspective-based assessment of the particular strategy/policy option yields.

Figure 11 – Two ways to create risk areas signifying a set of scenarios characterised in terms of two risk indicators.

In the case of more risk indicators similar exercises can be done by means of multi-dimensional visualisations such as the multi-star representation[175] (see Figure 12) or by means of an aggregation procedure that enables composition of risk estimates pair-wise (see Figure 13).

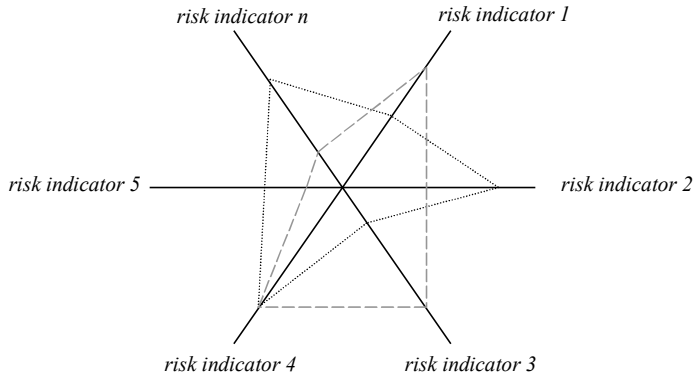


Figure 12 – Multi-star representation in which two scenarios are scored on various risk indicators.

By performing the assessment of risks in the above manner, it is possible to assess robust insights, i.e. insights that transcend the necessarily biased interpretations of uncertainty. Box 7 illustrates this type of insights, derived from the integrated assessment of global change and sustainable development using the TARGETS model.

[175] See also Van Asselt (2000).

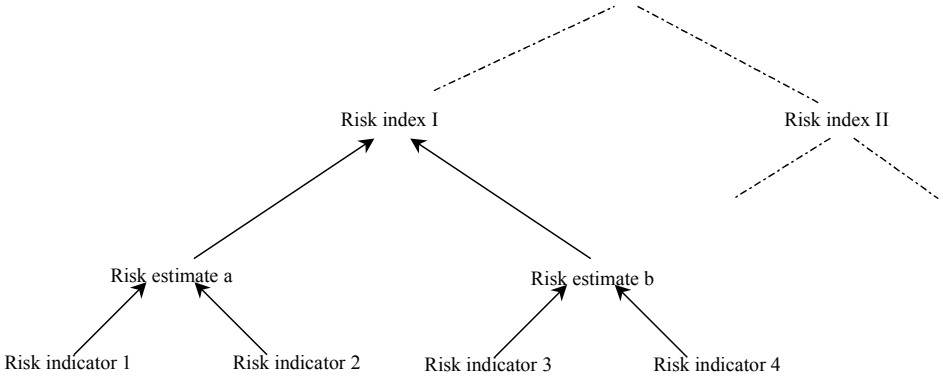


Figure 13 – Aggregation procedure for composite risk estimates.

Box 7 – Examples of robust insights derived from pluralistic integrated assessment

Population[176]

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[177]*:*

i)	low-risk:	population below 7.7 billion
ii)	moderate-risk:	population between 7.7 billion and 12 billion
iii)	high-risk:	population above 12 billion people.

for human health[178]*:*

i)	low risk:	health levels above a life-expectancy of 77 years
ii)	moderate risk:	health levels with a life-expectancy between 66 and 77 years
iii)	high risk:	health levels below a life expectancy of 66 years.

By implication, a future characterised by a population under the 7.7 billion with an average life-expectancy of more than 77 years is considered a safe situation in demographic and epidemiological terms.

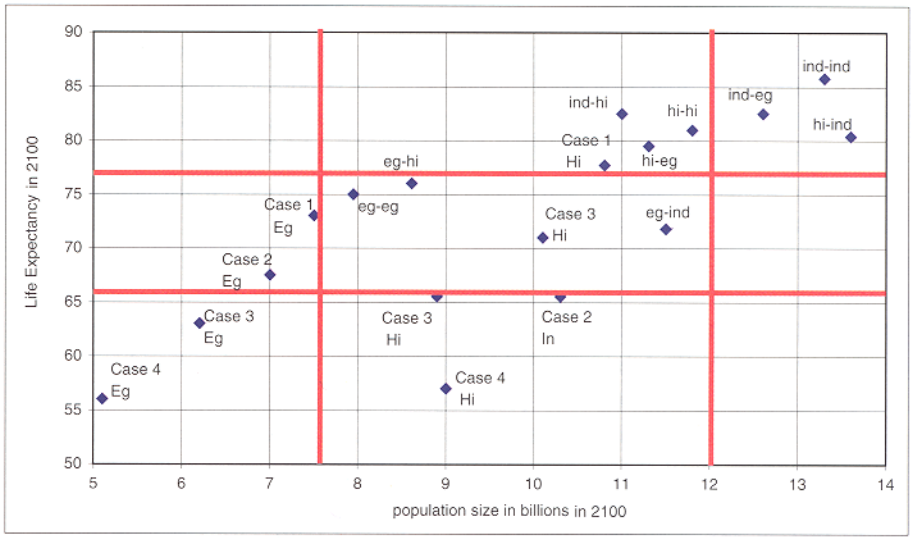


Figure 14 – Utopian and dystopian population projections (Source: Rotmans and de Vries, 1997).

[176] This description builds on Hilderink and Van Asselt (1997)
[177] Building on Cohen (1995)
[178] Building on current observed life-expectancy levels as reported by UNFPA (1996)

Analysis of Figure 14 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 21st century. On the other hand, none of the management styles yields a future that would be safe in every case. The egalitarian/environmental worrywart utopia is future-closest. Furthermore, the analysis of dystopian and utopian experiments suggests that moderate population sizes and fairly good health are most likely where society is to a certain extent collectively 'repairable', so that governing incentives might create favourable conditions. However, large populations are also reconcilable with an extremely good health in a market-oriented society. Figure 14 shows that the majority of countries in the future are not found in areas 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 population growth is irreconcilable, the experiments with the TARGETS model 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. What, in summing up, do the perpsective-based experiments yield in relation to the population and health controversy? From our current knowledge and a wide variety of interpretations of uncertainty, it can be concluded that a doomsday scenario featuring excessive population numbers in miserable health conditions is not credible .

Climate Change[179]

The outputs of the utopian experiments in terms of atmospheric CO_2 concentration and temperature increase are presented in Figure 15. Inspection of these graphs leads to the interesting conclusion that a high temperature increase (to about 3.5^0C by the end of the next century) can be explained by a relatively low CO_2 concentration (i.e. the egalitarian/environmental worrywart utopia).

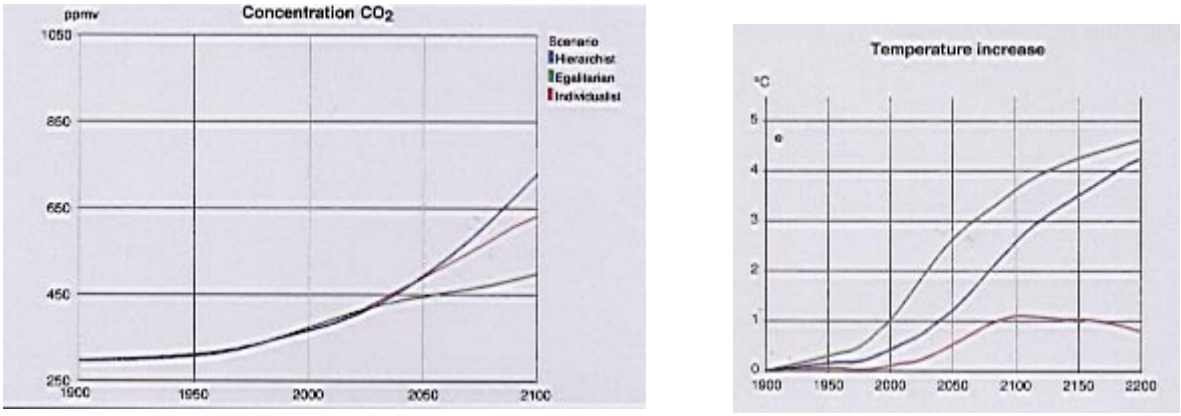


Figure 15 – Utopian projections for atmospheric CO_2 concentration and temperature increase (Source: Rotmans and de Vries, 1997).

On the other hand, a concentration of CO_2 in the atmosphere rising to about twice the present level (i.e. the individualistic/ market-optimistic projection) does not necessarily yield high temperature increases. This utopia features a temperature increase of about 1^0C in the course of the 21st century. Standard climate scenarios always show the concentration-temperature combinations low-low, middle-middle and high-high. How can one 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. The above comparison of utopian experiments 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/controllist as a middle-ground perspective. The utopian results with the CYCLES model[180] show that the hierarchist/controllist is not always in the middle. The hierarchist/controllist utopia shows the highest atmospheric concentration of CO_2. An explanation for this is

[179] This assessment builds on Rotmans and Van Asselt (1999b), which is a further assessment of experiments reported in Den Elzen et al. (1997).

[180] I.e. a submodel of TARGETS

that this perspective is more pessimistic than the individualist/market optimist where the development and penetration of energy-efficient technology and the market-mechanism is concerned with regard to alternative energy sources. On the other hand, the hierarchist/controllist perspective does not expect severe lifestyle changes as the egalitarian/ environmental worrywart perspective does. As a result the CO_2 emissions, and thus the atmospheric CO_2 concentration, in the hierarchist/controllist utopia are higher than in the two other utopian views of the future.

A more qualitative way to evaluate the riskiness of strategies, is to evaluate outlooks of the future in terms of the following questions on risks:

- what might happen?
- how plausible is this?
- what are imaginable consequences?
- how likely is this?
- what can we do about it?

These questions can also be used to deepen the analysis where the previous approach to risk analysis has been followed.

In the above, we have implicitly assumed that in all cases the risk indicator can be unambiguously determined. Although this may be so in some cases, for the major part risk definitions will differ. This means that the evaluation of desired/undesired prospects is perspective-dependent: which scenarios are considered highly desirable, and which nightmarish, are in many cases perspective-dependent. So pluralism may also be explicitly present in this step: scenarios are evaluated and weighted for different perspectives (see Table 16). The above approaches to risk analysis can then be used for each perspective to arrive at perspective-based estimates of prospects.

Table 16 - Evaluation of prospects according to perspective
(++ most desirable, + desirable, - not preferred, -- unacceptable)

Prospect (future view)	***Perspective A***	***Perspective B***	***Perspective N***
Scenario I	++	+	++
Scenario II	+	++	--
Scenario III	-	--	-
Scenario z	--	-	+

Using this perspective-based evaluation of the scenarios, we can assess whether there are scenarios, and thus strategies, that are more-or-less promising for all perspectives (see Table 16, scenario I), and which are considered to be unacceptable by the majority of them (see Table 16, scenario III). Risk comparisons in terms of relative riskiness can be useful in this assessment phase for assessing and comparing the various risk judgements, (see Box 8 for appropriate risk comparisons[181]). Risk in this case means that one or more perspectives, i.e. participants in the societal debate, are convinced that the issue under concern may inhibit undesirable and unacceptable futures, and that the state-of-the-art knowledge does not allow exclusion of these futures. This classification of 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 a future considered in one or more perspectives to be highly undesirable. In this way, robust recommendations can be deduced.

[181] See Van Asselt (2000).

BOX 8 – Risk comparison schemes

- ***the same risk at two different times***: 'The risk associated with *x* is about *y*% less than *z* years ago'.
- ***comparison 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 our calculated the worst-case risk estimate is *y*; on the baisis of methodology *2* we arrive at estimate *z*, whereas that of organisation ABC is *v*'.
- ***the risk of doing something versus doing nothing***: 'If measure *a* is implemented, the risk will be *x*, but if not, the risk will be *y*.'
- ***alternative policy options:*** 'The risk associated with option *a* is *x*, and the risk associated with option *b* is *y*'.
- ***the same risk as the risk experienced elsewhere:*** 'The most serious problems associated with *x* have been encountered at *A*, while here the risk is only about *y*% distance [*OK?]* from *A'*.
- ***risk from one source of a particular negative effect compared 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'.

Another aspect of robustness is that the recommended strategies and options are flexible enough to be changed or reversed if new insights emerge. Therefore it is important to know which uncertain, but imaginable, developments could potentially undermine the effectiveness and adequacy of the proposed strategies and options. In other words, which signals will, in the future, make it evident that we have to adapt the chosen strategy? By doing this, the assessment will produce indicators that are relevant for monitoring. Such signalling is crucial to support adaptive and sequential decision-making through information and feedback. The main focus is therefore on exploring how easy or how difficult it will be to change the proposed strategies. The consequence of this evaluation will be, that notwithstanding the recognised promises, some strategies are rejected, while others are transformed. Furthermore, it may result in the creation of innovative strategies and options not yet considered. In order to test the robustness of these transformed and newly introduced strategies, it is necessary to test them against the possible futures, implying 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 complex issue under concern can be deduced. The outcomes associated with this last stage are different types of robust recommendations, both sensible and understandable to decision-makers. Types imagined follow below:

- 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 indicated in the above list, there are different ways to achieving robustness. In the case of agreement (i.e. the various valuations of the strategy resulting in a fairly unequivocal opinion about the riskiness of the strategy), the robust conclusion consists of a recommendable strategy or a strategy that should be excluded from consideration. In case of disagreement (i.e. the risk estimates covering the whole range from low to high risk), the robust conclusion consists of a kind of warning: e.g. this particular strategy is likely to involve a clash of opinions. The advantage is that it may enable one to focus the debate by indicating the salient uncertainties.

Apart from recommendations that aim to facilitate decision-support, it is advisable to explore the salient risky uncertainties and uncertain risks which would benefit from additional scientific research? In this way, the assessment can also 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 uncertain risks and risky uncertainties crucial for *future* decision-making. Research always takes time. The consequence is that if research is initiated at the moment an issue is a topicality, either time pressure is expected to corrupt the research results or results are expected to arrive too late, which will make them irrelevant to decision-making. Assessments in line with the PRIMA approach can therefore be seen as an investment, both in the future analytical and methodological quality (by creating a time-span for the research) and in the usability and timeliness of future supply-driven decision-support.

4.7 Quality assessment

Quality assurance is central to the PRIMA approach. To this 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. Uncertainties or risk factors that did not seem crucial in considering the broader complex issue may indeed be crucial now that 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.

In view of quality assurance, it is also important that the assessment does not stop with recommendations for decision-making. Transparency on the analytical and methodological quality of the assessment is needed to allow clients themselves to make an informed judgement about the quality of the assessment. It would therefore be recommendable to accompany the conclusions with a summary reviewing the credibility of the data sources, the disciplinary quality of the knowledge elements used, the degree of interdisciplinarity of the assessment process, incl. the level of collaboration with disciplinary experts, and the level of participation[182]. For the first two issues the pedigree qualifications proposed by Funtowicz and Ravetz[183] can be used (see Table 17).

[182] See Rotmans and Van Asselt, 2000 (in press), which reports a first attempt to perform such a quality assessment as the final step in the assessment process.
[183] Funtowicz and Ravetz (1990). See also Chapter 3A for a summary of these pedigree qualifications.

Table 17 – Pedigree matrix.

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

In summarising the other issues the following questions may be useful:

- who were involved and how were they selected?
- at what phases in the process and with what intensity was this involvement?
- what has been done with the input of interdisciplinary experts and non-academic participants?
- do the contributors (analysts, external experts, stakeholders, etc.) recognise themselves in the assessment?

The responsible investigators can make such a quality assessment of the process. However, it is advisable to involve peers or even an extended peer community in this effort.

4.8 Conclusions

The ideas presented above are meant to structure a creative process and to stimulate creativity through structure. The PRIMA approach is not meant to be a blueprint for uncertainty management, but aims to serve as a theoretically sound heuristic for practitioners. The major advantage of using the PRIMA approach is, in principle, that it allows policy analysts to motivate the level of robustness of the recommendations thanks to the comprehensiveness of the analysis. In other words, salient uncertainties and a wide variety of legitimate interpretations of the uncertainties are considered in assessments where different risk factors are involved.

5 DEALING WITH UNCERTAINTY

THE 5th ENVIRONMENTAL OUTLOOK ASSESSMENT PROCESS

During the Environmental Outlook process, interest was growing on exploring how the PRIMA approach could be used in the assessment process for the 5th Environmental Outlook. This chapter reports the PRIMA activities carried out in the February 1999 - March 2000 period, i.e. a focus group involving various people from RIVM's management, a workshop with analysts, an open lecture for those directly and indirectly involved in the 5th Environmental Outlook process and a review workshop with the 5th Environmental Outlook project team. These activities enhanced awareness of uncertainty and provided the practitioners with ideas on how to consider uncertainty in their contributions to the Environmental Outlook. Ideas and concepts associated with PRIMA were also used to communicate on 'uncertainty' in the 5th Environmental Outlook report.

The previous chapters indicated the practical and theoretical challenges associated with uncertainty management in the light of improving the quality of decision support. Over the course of time, the interest in using the theoretical insights on uncertainty, the lessons learned from the retrospective analysis of the Environmental Outlooks and the suggestions for uncertainty management as embedded in the PRIMA framework grew. A critical mass of people believed that PRIMA activities could advance RIVM's learning and search process. To this end, the project team was invited to design ways to implement the ideas and insights on uncertainty management outlined in the practice of the 5th Environmental Outlook.

Applying PRIMA in its full form would be to develop an 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; however, the models are kept as they are and do not comprise perspective-based model routes. This implies that the pressures on the environmental system are put into perspective. Finally, even if 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. In this way, the conclusions can be put into a broader perspective, which could improve the quality of the assessment product. We should realise that the 5th Environmental Outlook was well under way at the time it was explicitly decided to explore the use and usefulness of PRIMA in practice. It was therefore impossible to design the whole assessment process according to the ideas of pluralistic uncertainty management. We have tried to implement PRIMA activities that could easily coupled to state of the process.

The flow chart illustrating the PRIMA approach (see Figure 8) served as starting point in the design of concrete activities and steps. We decided first to set up a focus group with members of the RIVM management team responsible for environmental assessment to discuss the insights gained from the retrospective analysis, to introduce the PRIMA approach and to assess how the lessons learned and ideas could be used in the 5th Environmental Outlook process. The focus group's task was to seek support for the PRIMA approach and choose the perspective scheme to be used in the pluralistic endeavour.

Whether the proposed points of departure were considered to be appropriate in the eyes of the practitioners was discussed with the focus group.

The retrospective research on the previous Environmental Outlooks has revealed that RIVM's expertise is needed to outline salient uncertainties. Explicitly stated was that more knowledge on uncertainty in 'the heads of the assessors' existed than in the assessment reports. Secondly, because the PRIMA approach involves the use of collective expertise to arrive at judgements on the salience of uncertainties, a group method came to be preferred above individual methods (as surveys and interviews). Thirdly, the aim of the 'uncertainties-in-perspective' phase was to scan uncertainties and interpret them for the chosen perspectives, which implied that we were not that much interested in a group discussion. We wanted to create a group setting in which exercises are performed in the plenary and/or in facilitated subgroups. Therefore we decided to organise, as second step, a workshop with practitioners from the various departments and laboratories within RIVM participating in the 5th Environmental Outlook assessment process.

To share the insights gained on uncertainty management in relation to environmental assessment with a wider group within RIVM an open lecture was organised for everyone directly or indirectly involved in the 5th Environmental Outlook process. The contributions of those attending this lecture provided some signals on what practitioners were struggling with in the uncertainty arena.

Besides this, a draft version of the 5th Environmental Outlook was screened from the perspective of uncertainty. In this 'review', lessons learned from the retrospective analysis and insights associated with the PRIMA approach were used as heuristic to providing feedback. The feedback was organised through an interactive discussion in which the MV-5 project team was challenged by the uncertainty analyst to rethink and discuss how they were dealing with uncertainty in their report. This workshop served as a basis for further internal discussions and work sessions among the project team members.

In this chapter we have summarised and evaluated the above activities in chronological order.

5.1 Focus group

The focus group, consisting of a selection of the 5th Environmental Outlook-team and of RIVM's environmental management team (see Table 18) carried out a discussion on the insights gained from the retrospective analysis, an introduction to the PRIMA approach and a discussion on how the lessons learnt and ideas assembled could be used in the 5th Environmental Outlook process. Next to that, the focus group was used to set the scene by defining the complex issue at hand and choosing the perspective scheme for the pluralistic endeavour.

Table 18 – The focus group

Name ***(in alphabetical order)***	**Experience in MV**	**Participation in focus group**
Ronald Albers	Since '90 at RIVM. Author MV-2. Chapter co-ordinator MV-3. Project leader MV-4. Current position: Head of 'policy analysis and scenarios' department.	*Invited, other obligations*
Leon Braat	Since '90 at RIVM. Model manager and co-ordinator of data and model use in MV1-MV4. Current position: Project leader MV-5. Head of modelling department.	*Invited, other obligations*
Klaas van Egmond	Since 1972 at RIVM. Director Environment in the Board of Directors since 1988, and thus assuming final responsible for MV-1-5. Since 1996 also 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 Environmental Balance reports '97 and '98. Current position: Head of Laboratory for Waste Materials and Emissions	X
Fred Langeweg	Founding father of Environmental Outlooks (MV). Deputy Director of the Environmental Policy Assessment Bureau, supervisor of MV-1-5	X
Rob Maas	Since 1983 at RIVM. Project manager of MV-2-4. Head of the Department for Environmental Assessment.	X
Dirk Onderdelinden	Since '97 involved in MV. Senior reviewer. Integration assessor.	X
Rob Swart	Since begin '90 involved in MV-1. Scenario analyst. Chapter co-ordinator.	*Invited, abroad*
Keimpe Wieringa	Author MV-1. Member of project team MV-2. Scenario analyst and chapter co-ordinator. Project leader MV-3. Involved in European Environmental Outlook during secondment at the European Environment Agency. Current position: responsible for scenario management MV-5.	*Invited, other obligations*

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[184]. The focus group is an established social scientific research method, originating from marketing research. A focus group has the advantage of, in principle, allowing for collective thinking. It also induces profounder argumentation because the group members themselves raise questions and sharpen each other's arguments.

[184] Dürrenberger et al. (1997)

The focus group was confronted with the preliminary conclusions on uncertainty management in the previous Environmental Outlooks and with tensions and conflicts that arose from the whole set of interviews. The input was provided in the form of transparencies presented to the focus group, and the participants were invited and encouraged to react[185]. The focus group agreed with the conclusion from the retrospective analysis that dealing with uncertainty has not been guided by an explicit strategy. The participants shared the challenge of improving RIVM's abilities and capabilities to address uncertainty in assessment efforts.

The second part of the focus group was devoted to setting the scene for future activities through defining the complex issue at hand and choosing the pluralistic stand that would be used in implementing PRIMA activities in the 5th Environmental Outlook assessment process. Building on the analysis of the previous Environmental Outlooks, we formulated the following 'RIVM's dilemma' as input for the group discussion:

> *Is a high environmental quality reconcilable with socio-economic targets? And if so, to what extent can the government contribute to this and with what kind of policy measures?*

This problem, considered as an adequate description in outlining the problem addressed in the 3rd and 4th Environmental Outlooks, was discussed. One of the participants brought forward that the suggested phrasing in fact reflects 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 would be more realistic to ask what environmental quality is attainable in the light of current economic and social goals. Someone else suggested that one way out would be to phrase the dilemma symmetrically. Phrasing in this spirit would look like this:

> *Are environmental quality and social-economic targets reconcilable and, if so, in what ways; to what extent can the government contribute to this and with what kind of policy measures?*

In principle, formulating the dilemma as such leaves room for the above interpretation of assessing which kind of environmental quality is attainable in the light of current economic and societal goals. This formulation also allows us to contemplate the priority between economic goals and environmental quality objectives, 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 for defining the starting point from different perspectives, instead of reasoning from one umbrella dilemma. On the other hand, the focus group agreed that the proposed phrasing would basically cover the crucial ingredients addressed in RIVM's environmental assessment endeavours.

The second step involved proposing an approach to pluralism. In order to figure out which pluralistic principle best matches RIVM's perspective and ambitions, we further analysed the data from the interviews, the focus group and the questionnaires, concluding that the attitude of the respondents goes beyond the objectivist perspective[186]. Building upon the

[185] See Appendix 2 in Van Asten (2000)
[186] See Langendonck (1999) and Van Asselt (2000) for a more comprehensive argumentation

empirical data, one can argue that either the 'theory in perspective' or the 'science in perspective' attitude would seem to be most appropriate. Because RIVM had gained experience with the 'science in perspective' attitude via the TARGETS endeavour[187], we proposed the 'science in perspective' attitude as philosophical starting point for the pluralistic exercise.

Consensus was achieved on 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 [saying – ed.] 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 (..) than to turn the handles of models.'

The focus group also agreed that not only scientific perspectives be considered, but were especially interested in societal perspectives, as is clear from the following quotations:

- 'I can imagine there are some actors in society who 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.'

Following from these quotations, the focus group advocated a pluralistic attitude going beyond 'theory-in-perspective'. This means that the proposed 'science-in-perspective' perspective would seem 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, the argument was that it is not easy to unveil perspectives, and thus basic assumptions, in a discussion with societal actors. The discussion resulted in some consensus that the difference between the two approaches was not too fundamental in view of RIVM's ambitions. In the end, the focus group supported the idea of experimenting 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 using the three perspectives associated with Cultural Theory[188], 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 did not form a point of discussion. The focus group had some problems with the controllist, as expressed by the following quotation:

> 'I do not feel so much kinship with the controllist-view. I think this perspective is very different from the other two. (..) The controllist is a strange figure. I can't associate it. (..) It seems to be a bit of this and a bit of that.'

[187] See Rotmans and de Vries (1997) and Van Asselt (2000)
[188] See Van Asselt (2000)

Notwithstanding the above reservations, after a thorough discussion, the majority of the focus group considered it worthwhile to experiment accordingly with the PRIMA approach in a workshop with RIVM practitioners.

5.2 Workshop - Uncertainty in perspective

The half-day workshop at the RIVM in June 1999 involved 18 participants (all practitioners in the 5th Environmental Outlook process). The participants were selected and invited by the project management of the 5th Environmental Outlook[189]. Prior to the workshop, the participants received a questionnaire and the discussion paper, 'Uncertainty and the 5th Environmental Outlook'[190], in which the major ideas underlying the PRIMA approach were summarised.

The PRIMA workshop with RIVM practitioners involved the following exercises:
- brainstorm on uncertainties relevant for the 5th Environmental Outlook
- clustering of the uncertainties
- dividing the group of participants into three subgroups, each group representing one specific cultural prespective, and letting them interprete the uncertainties from that perspective.

In the closing plenary, the subgroups presented their results, and the workshop and its output were discussed in view of the 5th Environmental Outlook. The workshop's character led to a wealth of information involving notes of the workshop facilitators, audio or videotapes, pictures, and, most important, the material produced by the participants in the course of the workshop. The workshop was also accompanied by two questionnaires, one for filling out *before* the workshop[191], in order to be able to sketch the group profile and control for bias, and a second for completing *after* the workshop, so as to use the participants' evaluations and feedback[192].

The programme consisted of the following components:
- Opening - Leon Braat, the project leader of 5th Environmental Outlook, and Fred Langeweg, director of the Environmental Division
- Introduction to the workshop
- Brainstorming on uncertainties in the 5th Environmental Outlook
- Clustering
- Working groups per perspective
- Plenary reporting
- Closing discussion

In this chapter, we focus on the heart of the workshop, i.e. the brainstorming and clustering, the working group output and the closing discussion[193].

[189] See Van Asten and Van Asselt (1999) and Van Asten (2000)
[190] See Van Asten and Van Asselt (1999)
[191] See Van Asselt (2000)
[192] See Van Asten and Van Asselt (1999) and Van Asten (2000) for the full questionnaire responses.
[193] For the full workshop report, see Van Asten and Van Asselt (1999) and Van Asten (2000).

Surfacing important uncertainties

The objective of brainstorming and clustering was to get insight into uncertainties salient to the 5th Environmental Outlook. To this end, each participant was given a number of Post-Its[194]. 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 quantify the uncertainty somehow (uncertainty-range). The Post-Its were collected and divided into four categories: Institutional, Socio-Cultural, Environment and Nature, and Economy[195].

In total, the participants filled in 99 Post-Its[196]. In Appendix 3[197], the various Post-Its have been clustered into the above categories. It should be realised that this only gives a first rough analysis of the workshop output; furthermore, this workshop was the first round of collective expert judgement. The idea was to have these articulated uncertainties further reviewed, classified and described in a next expert round[198]. The sources of uncertainty[199] mentioned on the Post-Its are given in Figure 16, with the number of times mentioned in parentheses. Many of the articulated uncertainties appeared to involve variability and structural uncertainty[200] more than reliability. However, the analyses of the previous Environmental Outlooks[201] 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), which seemed to imply that '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 had helped them to consider uncertainty systematically[202].

The brainstorm and clustering surfaced an interesting list of uncertainties. The variety expressed 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'. A second check of the list is clearly needed before it can be decided if the above clusters are the most relevant, and if the set of surfaced uncertainties is comprehensive enough in view of the dilemma the 5th Environmental Outlook aims to address.

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[194] These are small yellow sheets of paper with a sticky strip on the back.

[195] This division is generally used by ICIS for IA studies to structure the various components of complex problems; see, for example, ICIS (1998; 1999a; 1999b); RIVM and ICIS (1998); Rotmans (1997a); 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; mutual interrelationships are not indicated, which is not say that this is the ultimate categorisation to be used in Integrated Assessment studies.

[196] 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 on these post-its.

[197] We limit ourselves here to the most important and clearly expressed uncertainties. For a full overview see Van Asten and Van Asselt (1999).

[198] See Chapter 6

[199] At the time of the workshop we had not yet distinguished between reducible and irreducible ignorance (compare Chapter 2).

[200] See Chapter 2 for the definitions used.

[201] See Chapter 3, Van Asselt (2000)

[202] See Van Asten and Van Asselt (1999) and Van Asten (2000).

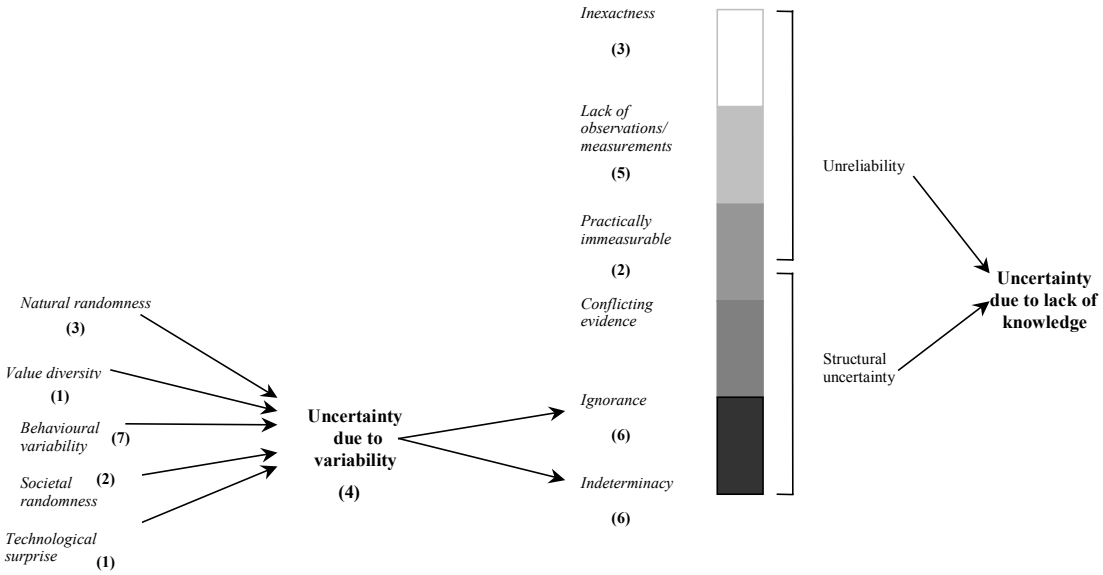

Figure 16 – Sources mentioned at Post-Its

In the discussion following this brainstorming and clustering, participants were shown to have found the classification of uncertainties (economic, institutional, social-cultural, and nature and environment) useful. The same can be said about the typology of sources of uncertainty. We tested the typology as a tool to stretch the participant's mental maps about uncertainty and as a means to facilitate communication on 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 about 50% responded that the workshop helped in systematically thinking about uncertainty.

It was furthermore argued that the list of uncertainties produced, although a first attempt, enabled them to derive the uncertainties that can be addressed through scenario analysis or using standard statistical methods, and the uncertainties that remain which must be addressed in another way.

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 a perspective framework. According to the PRIMA approach, this implies that the surfaced uncertainties relevant to the Environmental Outlook had to be interpreted according to these three perspectives, with ultimately three internally consistent knowledge patterns as result.

How to arrive at perspective-based interpretations of the surfaced uncertainties? We had to design an exercise to get the RIVM practitioners to 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 4 were used to introduce the perspective. In order to put themselves in the perspective, each group held a brainstorming session about what their perspective was associated with. The idea was that through the brainstorming, the participants would 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, through discussion, interpretations of uncertainties in tune with the assigned perspective. Facilitators familiar with the perspectives and the PRIMA approach[203] introduced the perspective to the participants and facilitated the group work; an explicit guideline with regard to the group work was not to interfere with the interpretations but just to enhance discussion and group thinking.

The output of the three perspective working groups will be discussed below. First, the 'associations' triggered by the assigned perspective will be given, followed by the descriptions of the perspective-related uncertainty interpretations. The main lines of reasoning associated with the assigned perspective are summarised at the end of each subsection.

Output of the controllist working group

Associations of the working group participants with the controllist are given in Box 9.

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 for Environment
Big brother is watching you

Box 9 – Associations with controllist's key statements.

The working group argued that if RIVM had to produce an Environmental Outlook within a controllist society, it would pay special attention to measurements, collection of knowledge and measuring the policy objectives.

For the Environmental Outlook, the controllist would make agreements with the institutions providing the information. These institutions should indicate what topics are uncertain and what uncertainty-ranges should be employed. This is very similar to the Environmental Outlook as it is now produced. 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.

[203] Marjolein Van Asselt, Frank van Asten and Nicole Rijkens; see Van Asten and Van Asselt (1999).

According to the vision of the controllist, *science* is based on knowledge and experience. The starting point for the controllist is carrying out aggregation and integration 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/she cannot do anything with uncertain answers but is only interested in uncertainties that can be quantified ('certain uncertainties'[204]). 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. The role of both models and institutions are regulated by law. The controllist believes in the reliability 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 (in terms of high to low) to more functional standards. For the noise problem, for example, the peaks will be removed, but the noise cover may 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. Controllists 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 e.g. emission policy.

The behaviour of people must be channelled 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 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 controlist's perspective.

The controllist expects the translation of the national government's policy to the local governments to work. In the controlist's perspective, the central government can largely enforce its policy by making use of hierarchy. International policy, especially EU policy, is of increasing importance for the controllist. Where international policy is developed, 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 form an example: the central government has ideas, but local governments and/or commercial parties make the most of policy. The controllist will worry if no policy is introduced for a certain problem, or if the policy is delayed.

[204] Compare Chapter 3

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 plans cannot adequately deal with this, the controllist does not know what 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 Betuwe railway line (freight railway line from Rotterdam into Germany), the controllist is confronted with larger economic uncertainty than was expected. The initial research predicted that the Betuwe railway line would not be so expensive and the desired economic profit with minimum environmental effects would be realised. Fairly soon afterwards, however, it was known that the project would be considerably more expensive and that it would generate much less economic profit. Since an abrupt change of policy does not fit into the image of the controllist, the project will be slowly tapered off. The controllist will not take a 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 to right wing, since this creates risks. The fact that Paars 1[205] actually carried out the CDA's[206] 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 with respect to the climate problem. On the one hand, an attempt will be made to work out the system in fine detail, including all uncertainties involved. On the other, there will be inherent uncertainty, which makes it difficult for the controllist to deal with it. 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 century. Controllists are not yet convinced 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. Spatial arrangements concerning human activities will be regulated and managed.

Controllists will invest in *technology*. They are forced to do so because otherwise they will not be able to regulate certain problems. Radical innovations and breakthroughs, also in knowledge, however, do not fit 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 a controllist keeps avoiding risks, so innovations will have to be tested thoroughly.

[205] The first Dutch coalition government under Prime Minister Kok without the Christian Democratic Party (1994-1998).
[206] The Christian Democratic Party, which had governed since the second World War; it did 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.

Summing up, the controllist perspective applied to uncertainties relevant for the Environmental Outlook involves the following interpretations of uncertainty, where risky uncertainties are those considered threatening to the perspective under concern:

Table 19 – Output of controllist working group summed up

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 levels of government (regional, local) works
Instability, disasters	*Risky uncertainty*
Who decides?	Governments
Type of policy	Standard-setting; Regulation of economic sectors and consumption patterns by levies and covenants; No drastic measures/changes in policy: no Schiphol in sea or slowing down of the Betuwe railway line
Behaviour	Behaviour according to rules and fixed patterns. *risky uncertainty*
Consumption patterns	Regulation of economic sectors and consumption patterns by levies and covenants
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
Worldwide supplies of 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 covenants
Global recession	*Risky uncertainty*

Output of the market-optimist working group

Associations resulting from brainstorming in the market-optimist working group are given in Box 10.

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

Box 10 – Associations with the market optimist.

The working group argued that a market optimist would have a strong belief in company dynamics and less in management by government. The market optimist 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 on its own. 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 appear as a result of pressure from consumers.

The *economic outlook* 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, the market optimist's possibilities. The risks that result from economic fluctuations, changing 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 up to the year 2030. Will the boom period continue or will there be a recession? And, if so, when? For a market optimist, it is important that this kind of question be 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, energy 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: which rules this company will have to comply with? 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, so as to a obtain a competitive advantage. The concept of effectiveness will have to be studied from a completely different context, not only from the position of the government but also from business.

The market optimist worries about taking risks on where to set up a business. A problem here is that demands are placed on the *location* of a business in the Netherlands; these vary from average to high, as long as they are not exceptional or constantly changing. A hog 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 as 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 locations in the

Netherlands, where the situation is really disastrous, for example, the Randstad[207]. This is not very interesting for the market optimist, who looks for areas where he can develop, where opportunities are and where employees like to live. The market optimist wants to know what problems may occur and what policy will apply to a specific area. To prevent problems with the location of businesses, environmental risks must be mapped out in the Environmental Outlooks.

The location of businesses 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 finding out if it is nice to live there, if the location has nature areas nearby and if there is not too much disturbance. The areas concerned are not necessarily large such as the Hoge Veluwe[208] but may be small, like nature areas surrounding cities. Biodiversity is not valued, but nice trees are. People want to have good-quality natural surroundings, but above all they want them well-organised and there do not necessarily have to be wild buffaloes walking around. The presence of nature reflects our well-being. Companies can invest in it: nature and the consumption of nature will become a new market.

Summing up, health, welfare and nature are very important. The spatial planning of these services then also becomes very important. 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[209] is well thought- out, but the direct environment is more important to people. Following 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 severe economic losses will occur.

The Environmental Outlooks so far have aimed to address solutions associated with the government, but nothing has been said about *environmental programmes initiated by business*, such as eco-labelling and green programmes by Albert Heijn[210]. The multinationals will see to the environment themselves if it suits them. They can even fulfil a leadership role here. This possibility must not be underestimated; the market optimist will definitely want the Environmental Outlook to comprise an inventory of environmental initiatives taken by companies creating win-win situations. The market optimist argues that the market can regulate itself. For Albert Heijn, for example, it is important that the Dutch government does not introduce strict rules on the country of origin delivering oranges or on the use of packing materials, etc. Albert Heijn will respond that clearly informing consumers on what a product contains, where it comes from and how it has been produced, will have much more 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.

[207] An urban conurbation in the west of the Netherlands consisting of Amsterdam, Rotterdam, The Hague and Utrecht.
[208] A Dutch nature reserve
[209] Schouten et al. (1999); Ten Brink et al. (1998); Van Vliet et al. (2000)
[210] A large Dutch supermarket chain

The environment as such will only form a small link in this whole. 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? The market optimist is especially concerned with how risks are perceived. 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 wants the Environmental Outlook to find out the issues that 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 carefully scrutinised. Otherwise, a possible panic reaction can disturb the market.

Summing up, the market-optimist perspective applied to uncertainties relevant for the Environmental Outlook, as presented by the associated working group resulted in the following interpretations of uncertainty, where risky uncertainties are those considered to be threatening to the market optimist and important uncertainties are those posing challenges:

Table 20 – Summary of output of market-optimist working group

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 important
Climate variability	Not important, unless there is a 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 from consumer pressure
Behaviour of economic sectors	Role of multinationals; environmental programmes initiated by companies
Global recession	*Risky uncertainty*

Output of the environmental worrywart working group

Associations put forward by the third working group for the environmental worrywart are given in Box 11.

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

Box 11 – Associations with the environmental worrywart.

The environmental worrywart working group argued that this perspective would question RIVM's role, where RIVM is thought to be collaborating 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. Worrywarts will always be concerned about nature, but even more so when something abnormal takes place, such as an increase in temperature by a couple of degrees, despite great enforcement and global agreements. The environmental worrywart emphasises the vulnerability of nature. *Environmental pollution*, such as air pollution, noise disturbance, disruption of the ecosystem and vulnerability are important themes 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. The worrywart tries to protect nature against threats, especially those caused by humans, of less known or unknown causes and 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 of or worry about the known'. The environmental worrywart does not want 'artificial' nature created by humans: worrywarts try to realise large, connected nature areas with high biodiversity that can sustain themselves.

The environmental worrywart is directly concerned with 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[211] 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 agriculture, 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 worries especially 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. The worrywart has considerable problems 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 at 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, but favours integrated process technology. The environmental worrywart will be mainly concerned with closing cycles, using natural processes, saving energy and recycling.

[211] Directorate General for Environment of the Ministry of Housing, Spatial Planning and the Environment (VROM).

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: since there is a natural tendency to growth, it cannot be monitored strictly enough to be prevented. 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 policies.

The environmental worrywart is *fairly locally oriented*, but is also concerned with the 'outside world', because this influences the local community. The environmental worrywart, therefore, strives for global agreements, placing a lot of importance on the principle of justice. Worrywarts will not like it if other people emit the CO_2 that they try not to emit, or use pesticides that they refuse to use. They want to make reliable agreements with the G7 countries about the consumption pattern, demography, CO_2 emissions and oil prices, even though they have doubts about whether this can be achieved. They would like to give development aid to preserve the Amazon rainforest.

Summing up, 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:

Table 21 – Output of environmental worrywart working group summarised

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 production of food; closed cycles
Technology	Problems cannot be solved by technology; eco-technology is a necessary evil; integrated process technology
Behaviour of economic sectors	Steady-state economy; economy is not an aim

Analysis of the workshop output[212]

Analysis of the surfaced uncertainties results in an output involving other uncertainties and other sources of uncertainty then is usually considered in the Environmental Outlook. Examples of uncertainties that have not been addressed in previous Environmental Outlooks[213] are 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. In the following we explore how the output of the 'uncertainties-in-perspective phase' could provide a valuable input to the 5th Environmental Outlook process[214].

The set of perspective-based chains of interpretation 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 programmes 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 practice could be characterised as controllist. Furthermore, this perspective was assumed to be only interested in uncertainties that can be quantified and reduced by plans and regulations.

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

The working groups' output enables us to raise interesting ideas about the Environmental Outlook and the underlying assessment process. The market-optimist working group suggested broadening the scope from a focus on the Netherlands to a wider northwest European perspective. In tune with this, an argument is made for a three-way shift in Dutch environmental policy in the Environmental Outlook's traditional focus. On the one hand, an Environmental Outlook should address European environmental policy as well. On the other, the Environmental Outlook should not only focus on governments, but 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 have concentrated on accumulation of environmental and health impacts. The perspective exercise reveals that it would be interesting to map out environmental and health profiles that enable us to compare locations, if this is technically possible. Furthermore, the environmental worrywart working group brought to the fore that RIVM is not always

[212] A more through analysis of the workshop output in terms of review and analysis of the perspective-based interpretations and evaluation of the process according to lessons learned on implementing PRIMA in practice can be found in Van Asselt (2000). Here we limit ourselves to a summary of insights relevant in consideration of uncertainty management in the 5th Environmental Outlook.

[213] Van Asselt (2000)

[214] The perspective-based interpretations of uncertainty are summarised per category in Appendix 3.

regarded as an independent authority, but is sometimes seen as a continuation of government. This would imply that RIVM's assessment process has to be more participatory[215].

The list of surfaced uncertainties can be used as input to the design of sensitivity analysis, and the choice of model experiments. Even where these listed uncertainties are not addressed in the assessment itself, the list can be used in framing the scope of the assessment and 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 practitioners who have to integrate and edit the various contributions.

Specific uncertain areas are highlighted in the perspective exercise. The workshop output allows identification of the issues and assumptions critical to societal debates (see Table 22). It was argued in the closing discussion at the workshop that if these issues are not addressed in the 5th Environmental Outlook, RIVM can expect critical questions from societal actors, regardless of whether figures are available or not. This insight into critical issues so far not addressed in the Environmental Outlook can be used to broaden the assessment or to develop a communication strategy. The workshop output can be used to develop or evaluate the content list for the 5th Environmental Outlook. Not all issues can be addressed quantitatively, but it may 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 scan the robustness of the recommendations derived from the assessment and to put the conclusions in perspective.

Table 22 – Critical issues and assumptions derived from workshop output

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

The perspective-based chains of interpretations can in principle be used in RIVM's environmental assessment endeavours in the following ways:

- 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 routes in the model equipment used in RIVM's environmental assessment process;
- as a heuristic means in expert judgement about uncertainties that are not implemented in models, but for which interpretation is nevertheless needed in the assessment process.

The above implies systematically 'thinking through' what-if questions in one way or the other. Doing so would yield a broad range of scenarios covering the wide variety of

[215] See Van Asselt (2000).

legitimate and relevant interpretations of the underlying salient uncertainties. The next convergence step would then include that insights relevant for decision-making be extracted from the collection of possible futures. As discussed in Chapter 4, 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 of or 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 will then be important for decision-making in the future.

Participants' evaluations of the uncertainty workshop

From the data gathered in the ex-post questionnaire[216], it became clear that the participants considered the workshop useful for assessing issues welcomed into the Environmental Outlook; it also enabled them to explore uncertainty in a systematic manner. Two-thirds of the respondents[217] considered the workshop as a means to think (more) systematically about uncertainty. Furthermore, half the respondents argued that the workshop changed their thinking about uncertainty. In general, the workshop was considered useful, even when 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 yet another 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 fairly positive: it was considered to be a well-organised workshop characterised by 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 appreciated the fact that 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 practice. In the questionnaire prior to the workshop[218], the respondents expressed a neutral attitude towards a perspective approach. In the questionnaire completed after the workshop, half 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?'.

The majority of the respondents (65%) stated that they would be able to apply the perspective approach, with only10% doubting whether they could. The majority of the respondents considered the perspective approach to be an interesting alternative to uncertainty management and one that can supplement existing approaches. On the other hand, the answers to the open questions indicate that the perspective approach is evaluated by some as not being concrete enough to be applied; this is illustrated below:

- 'The perspective method' does not (yet) have enough body, in my opinion.
- It remained unclear as to what aspect the perspective approach provides a better view of uncertainty.

[216] See Van Asten and Van Asselt (1999) for a detailed report of the questionnaire results.
[217] Of the 18 participants.
[218] See Van Asten and Van Asselt (1999) for a detailed report of the questionnaire results.

Only one respondent stated explicitly that the perspective approach is not desirable 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 was 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 on to how to deal with uncertainties in scientific decision-support.

5.3 Open lecture 'Environmental Outlooks and Uncertainty'

On January 12th, 2000 the evaluation of the Environmental Outlooks from the perspective of uncertainty was presented in a lecture, which was open to all RIVM's analysts involved in the MV-5 process. The aim of this lecture was to raise constructive awareness on uncertainty and uncertainty management in the light of the 5th Environmental Outlook. The lecture three topics: 1) an introduction to uncertainty and the perspective method, 2) a summary of the assessment of the previous Environmental Outlooks, and 3) RIVM's perspective to uncertainty and ideas for improvement of the MV-5.

Generally, those attending seemed very interested in the research outcomes and were receptive to the proposed ideas in relation to MV-5. One of the issues raised by the audience was the role of policymakers in this process.

The discussion was closed by RIVM's project co-ordinator, Leon Braat, who made clear that the PRIMA approach can help RIVM to analytically support its work on the Environmental Outlooks. He argued that PRIMA may lift the MVs to a higher product-level and that it may bring the organisation a big step further, providing the scenarios with more colour, so that communication with politicians in The Hague becomes easier. The conclusion of the lecture was that practitioners involved in the MV-5 process had been motivated to aim for dealing systematically with uncertainty in the MV-5 process.

5.4 Interactive-review workshop:'Preliminary draft MV-5 & Uncertainty'

Another activity developed to encourage uncertainty management in the 5th Environmental Outlook was a review of a draft version of the MV-5 text through 'uncertainty glasses'. In this review, lessons learned from the retrospective analysis, insights associated with the PRIMA approach and the output of the uncertainty workshop were used as heuristic in providing feedback. The feedback was organised through an interactive discussion, in which the MV-5 project team was challenged by the uncertainty analyst to rethink and discuss the way they were dealing with uncertainty in their report. This workshop served as a basis for further internal discussions and work sessions among the project team.

The workshop with the MV-5 project team took place on February 3rd, 2000. To stimulate critical discussion, an interactive presentation was prepared that covered the following issues: 1) scenarios and uncertainty, 2) explicit communication of uncertainty, 3) linguistic strategy, and 4) the use of perspectives:

From the draft text it could be inferred that scenarios were used to address uncertainty, but the way this was communicated was quite ambiguous. The argumentation in the extract on scenario choice in the draft-text of Chapter 2 did not spring from uncertainty. Restructuring was suggested by first discussing uncertainties relevant for the MV-5 assessment, of which the overview could benefit from the lists of uncertainties generated at the uncertainty workshop. Then a discussion would be launched on uncertainty providing room for different legitimate interpretations, and on scenarios as a way to assess such alternative estimates of future developments. The next step would be to discuss which scenarios are used to this end in the MV-5 assessment, while explaining what this choice implies the assessment. Discussing the limits of the EC and GC scenarios a priori would enable the reader to judge the scenario-based assessment. Major limitations that can be derived from both the research on uncertainty and the Environmental Outlook, and which can be inferred from the draft texts are:

- that the rather distinct story-lines are not developed into clearly different quantitative scenario estimates;
- the extrapolative and linear character;
- consumption-driven calculation of production trends;
- rigid assumptions with regard to the relationships between economic growth, population development and technological innovation;
- a rather limited discounting of foreign developments.

In terms of the perspectives, the two scenarios can both be associated with the market-optimist perspective. As a consequence of these limitations, it is clear that statements with regard to future pressures on the environment and environmental quality have to be phrased carefully, because the full spectrum of possible futures has been not assessed. Furthermore, through the draft text, scenarios were referred to in different ways (from ‘more-or-less extreme alternative sets of assumptions’ to ‘plausible realities’). As a consequence, the message that the scenarios form a means to deal with uncertainty gets lost in ambiguity and ambivalence. Furthermore, the two scenarios are not consistently used throughout the causal analysis: at different points only one scenario was used, and without motivation. The project team argued that this is the case if the estimates associated with the two scenarios do not differ significantly. At several points in the draft text, forecasts were even presented without any reference to scenarios. Furthermore, the estimates associated with the scenarios are presented without using the various assessments of the future to draw robust conclusions. This feedback was illustrated with some text examples building on the draft text. In the draft text, for example, it was stated that:

> ‘The decrease in manure production is largest in GC (39%), which implies 50 mln tonnes in 2020. The decrease in EC is somewhat lower (30%) and leads to 57 mln tonnes. The decrease is due to a decrease of the size of the cattle and the manure production per head’

To illustrate how such scenario-based assessments can be used for robust statements while transparently communicating relevant uncertainty, a ‘rewritten’ statement was proposed to the MV-5 team:

> ‘The expectation is that the manure production will decrease. Taking uncertainties with regard to the future size of the cattle and the manure production per head, the decrease will be 30-40%, which would imply 50-60 mln tonne manure in 2020.’

Building upon this analysis, recommendations were made with regard to the structure of chapters, and the structure and the nature of texts in the MV-5 report.

An important observation was that in the draft text only the following uncertainties were explicitly mentioned:

- world trade
- new technological possibilities
- the attitude of citizens towards environment and nature
- European integration
- spatial developments

It was argued that this overview is limited in view of the list of uncertainties produced in the uncertainty workshop. It was remarkable that in this preliminary version of the Environmental Outlook environmental uncertainties were not mentioned. The overview of uncertainties as developed in the workshop could be used as source of inspiration for outlining relevant socio-cultural, economic, environmental and institutional uncertainties. Furthermore, uncertainties with regard to technological and spatial developments were not explicitly addressed in the assessment in the chapters following.

From the text analysis it can be deduced that in this draft text uncertainty was primarily used to justify that issues were not addressed in the Environmental Outlook. Examples of such draft quotes are:

- 'Due to uncertainty with regard to the way of implementation, this law is not accounted for in the MV-5';
- 'New plans with regard to manure are not considered because of uncertainty';
- 'Reduction measures pertaining to other greenhouse gases of which the effects are uncertain are not taken into account'.

It is remarkable that such uncertainty expressions in the draft text are solely used in such a general justification sense, and not in relation to estimates, statements and conclusions, with two notable exceptions that satisfy the rule:

- 'The uncertainty of these numbers (foreign VOS emissions, MvA) is, however, considerably larger than for other substances';
- 'The knowledge around fine dust is under development'.

Summing up, the draft MV-5 text (February, 2000) did not breathe the spirit of uncertainty management: which implies that uncertainty is at the heart of the assessment and salient uncertainties are explicitly used as building blocks in the assessment.

In conclusion, this question was raised : 'How can the draft MV-5 be improved in terms of uncertainty management?' Suggestions for improvement have been discussed and further considered by the MV-5-team around the following issues:

- the scenario chapter
- the use of scenarios in the assessment
- the use of the uncertainty lists produced in the uncertainty workshop
- the use of the general taxonomy of sources of uncertainty as checklist
- textual inconsistency with regard to uncertainty
- how linguistic expressions can be used systematically to communicate uncertainty in a relevant way
- the use of perspectives (and the perspective workshop output) as a scheme to evaluate assumptions and 'certainties' in the text, as a source of inspiration for variants of calculations, as a means to put the conclusions into perspective and as a tool to stimulate creative thinking about policy options

Because the discussions were so lively and interesting, no time was left for the prepared exercises (see Box 12) in which pairs would evaluate the text of other authors through the 'uncertainty glasses'; however, these exercises were taken along by the project team as a

source of inspiration for further internal review among themselves. The MV-5 project team expressed their interest in considering uncertainty in order to avoid 'weak' conclusions, but on the other hand they also wanted to prevent the MV-5 from being soaked in uncertainties that are not relevant to decision-makers. From the workshop it was clear that the project team was struggling with this dilemma: finding a balance was considered delicate and difficult.

Box 12– Tasks for those attending the review workshop.

- **In general**

Read through the text and check for:
- lack of clarity / points of discussion
- repetition/ redundancy
- contradictions / inconsistencies
- structure/ logic
- balance major lines with details

- **Uncertainty**

➢ **Task 1**
- Read through the text and mark sentences/statements/conclusions in which uncertainty could play a role (use the list of the previous workshop as source of inspiration).
- Use the uncertainties list and/or the taxonomy of sources of uncertainty to check which specific sources of uncertainty are of importance in the selected text *(N.B. the uncertainties list may be supplemented)*.
- Try to deduce from the text whether, and if so, how these uncertainties were handled in the underlying analysis.
- Analyse whether and how uncertainty is made transparent in the text (formulations, ranges).

➢ **Task 2**
- Select statements (incl. texts, figures, numbers) concerning the future.
- Analyse how scenario estimates were used in order to make quantitative statements.
- Explore how the numerical investigations could have been used better in order to communicate uncertainty in a constructive and relevant manner.

➢ **Task 3**
- Compare what is said in this draft MV-5 text (incl. numbers, figures, etc.) with what is said in the MV-4 about uncertainty concerning the selected topics.
- Is the knowledge concerning uncertainty as expressed in MV-4 used in MV-5, if not, how can it be used to improve the MV-5 text?

5.5 Conclusion

Different activities have been carried out in the context of the 5th Environmental Outlook process in which uncertainty was explicitly at stake. From the above discussion, it is clear that these activities were considered important enough for the practitioners to invest time and effort. These activities enhanced awareness of uncertainty and provided the practitioners with ideas for considering uncertainty in their contribution to the Environmental Outlook. The activities reported in this chapter can be primarily characterised as learning on the job. This chapter should in the first place be read as documenting this ongoing learning process.

The current chapter focuses on PRIMA activities and thereby does not give a comprehensive overview of how uncertainty was actually managed in the Environmental Outlook process. It is clear that ideas and concepts associated with PRIMA were used to communicate about uncertainty in the 5th Environmental Outlook report (especially Chapter

1)[219]. However, more insight into how uncertainty was dealt with in practice is useful in view of the aim that RIVM can broadly benefit from the MV-5 experience. It was decided to interview RIVM analysts that have been involved in the MV-5 assessment process. The next Chapter reports this supplementary evaluation of uncertainty management and the 5th Environmental Outlook through the eyes of the practitioners themselves.

[219] RIVM (2000)

6 LOOKING BACK

EVALUATION OF THE ASSESSMENT PROCESS

This Chapter reports the analysis of a number of group interviews with various analysts who played a leading role in the 5th Environmental Outlook process. From the attitudal data it is clear that uncertainty is considered to be inherent to science (i.e. a constructivist attitude). A shared ambition to explicitly address uncertainty in the MV-5 assessment process was observed. The following uncertainties were collectively judged as being critical to MV-5: human and ecological effects, effectiveness of policy/measures, foreign developments, behaviour, climate variability, emissions, technology and economy. The interview data seem to suggest that the way uncertainty was dealt with on the level of the MV-5 assessment can be described as an internal informal intuitive process of expert judgement and peer review that was not completely transparent nor fully documented. This inadequate handling of uncertainty was argued as being not simply a question of time and priority, but also that more learning is needed. The empirical evidence reported in this paper indicates a growing conviction that systematic uncertainty management is definitely needed. To facilitate the required learning it is essential that substantial time, effort and expertise is invested. Arguments are also put forward in this Chapter that uncertainty management should be a strategic priority throughout RIVM.

To evaluate how uncertainty was actually dealt with in the 5th Environmental Outlook process, ex-post[220] group interviews were held with the analysts who played a leading role. These group interviews served to further describe the ongoing learning process and to derive the lessons learned with an eye to future assessment processes like the 6th Environmental Outlook. The interviews, lasting two hours, involved between 4 and 7 people, including 2 interviewers[221] and 1 note-taker (see Table 23). In total, 8 interviews have taken place with 13 respondents in total. Each person interviewed is scored as part of the data analysis.

Prior to the interviews, the respondents received a discussion memo with some of the questions, which they were asked to prepare for (see Appendix 5). This interview check-list was not used as a rigid scheme, but as a framework to stimulate group discussion, implying that some questions were not explicitly asked, because they had already more or less been addressed, or from the previous dialogue it was clear that these questions were irrelevant. The full interview guide (Appendix 6) covered the following issues: background and expertise of the interviewees, attitude towards uncertainty, uncertainty management in the MV-5 as a whole and uncertainty management specifically directed to the topic for which the respondents were responsible. Furthermore, additional questions inspired by the input of the respondents were also asked. In this way, most of the group interviews developed from question–ask patterns in the early stage of the interview to animated group discussions evolving from uncertainty topics in which both the respondents and the interviewers actively participated.

[220] In the final stage of the 5th Environmental Outlook assessment process (June – September 2000), when the texts were finalised

[221] The interview teams consisted of one RIVM uncertainty expert (Anton van der Giessen, Peter Janssen or Peter Heuberger) and, as the external expert on uncertainty management, Marjolein van Asselt, who was replaced by Isabelle Geuskens for one interview.

Table 23 – interviews with MV-5 experts

Respondent	*Dept./ Lab.*	*Responsible in MV-5 for:*	*Interviewers*
- Hans Eerens *- Jeannette Beck*	*LLO*	*Large-scale air-pollution*	*-Marjolein van Asselt* *-Peter Heuberger* *-Isabelle Geuskens*
- Annemarth Idenburg *- Dick Nagelhout*	*LAE*	*Breakthrough technology*	*-Marjolein van Asselt* *-Anton van der Giessen* *-Isabelle Geuskens*
Eric Drissen	*LAE*	*Scenarios*	*-Marjolein van Asselt* *-Peter Heuberger* *-Isabelle Geuskens*
- Dick v/d Meent *- Rob Alkemade* *- Rick Wortelboer* *- Marijke Vonk*	*ECO* *LBG* *LWD* *ECO*	*Nature and environmental effects*	*-Marjolein van Asselt* *-Peter Janssen* *-Isabelle Geuskens*
Joop Oude Lohuis	*LAE*	*Energy*	*-Marjolein van Asselt* *-Peter Janssen* *-Isabelle Geuskens*
Leon Braat	*CIM*	*MV-5 general*	*-Marjolein van Asselt* *-Peter Janssen* *-Isabelle Geuskens*
Kees Vringer	*LAE*	*Consumption*	*Peter Janssen* *-Isabelle Geuskens*
Hans van Grinsven	*LBG*	*Eutrophication and desiccation*	*-Peter Janssen*[222]

A number of topics emerged from the interviews that are relevant when considering the question of how uncertainty was actually dealt with in the 5th Environmental Outlook process according to analysts who have been involved in the process. In the following, the group interview data is discussed around these themes, i.e.:

- attitude towards uncertainty;
- identifying and prioritising uncertainties;
- management of uncertainties;
- learning process.

6.1 Attitude towards uncertainty

Table 24 summarises the longitudinal data[223] related to attitude towards uncertainty. Strong disagreement is associated with a constructivist attitude, while strong agreement reflects positivist norms and values[224]. The patterns in the collective answers indicate that strong positivist associations are rarely found within the group of respondents, while a clear constructivist tendency can be observed there, implying that the attitude of the respondents involved recognition of uncertainty as inherent to science and scientific decision-support. In motivating their answers, they brought forward that science attempts to gather knowledge, and that science is about posing questions. They furthermore argued that what is considered certain with the current state of knowledge, can be questioned again due to new knowledge. Two respondents observed that people who don't know that much about the topic are

[222] This interview was additonal to the series of interviews.
[223] The attitude was also tested among the respondents participating in the interviews held in the retrospective phase (see Chapter 3) and among the participants to the uncertainty workshop (see Chapter 5).
[224] For a discussion on constructivists and positivists, see Chapter 2.

usually more certain than more knowledgeable people. It was also brought forward that 'good science' implies a situation in which the researcher is aware of uncertainty. The elaborations of the respondents taught us that the dominant neutral attitude with regard to the statements on measuring and quantitative uncertainty estimates should be interpreted as balanced judgement: measuring as part of knowledge, but some areas are not suited to measurements; although uncertainty can be expressed quantitatively, there will always be uncertainties for which quantitative estimation [*alt:* assessment] is impossible.

Table 24 – Attitude of the respondents towards uncertainty
(shaded blocks highlight clear majorities;
Score-rating: -- refers to 'strong disagreement',...., ++ refers to 'strong agreement')

Statement	***Interviews***					***Questionnaire Workshop***					***Interviews 5th Environmental Outlook***				
	--	-	o	+	++	--	-	o	+	++	--	-	o	+	++
Knowledge is truth	1	5	1	1	0	6	7	1	1	1	6	7	0	0	0
Science is solving uncertainties	1	2	1	4	0	1	6	1	4	3	2	7	2	1	1
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	1	6	2	4	0
Uncertainty is poor science	4	4	0	0	0	12	2	1	0	0	7	6			0
Measuring means knowing											3	4	5	1	0
Uncertainty can be captured in numbers											1	3	5	4	0

The respondents agreed that compared to previous Environmental Outlooks there has been more awareness of uncertainty and more attention paid to uncertainty in the process. According to the interviewees, there was a shared ambition to explicitly address uncertainty in the assessment process. Such an ambition corresponds to the rather constructivist attitude among RIVM employees revealed by the responses, and by the previous interview and questionnaire data. In their descriptions of how they actually dealt with uncertainty in their own practices, however, uncertainty was still often approached as an obstacle to firm and strong policy recommendations. For example, it was argued that:

> …'It is of no use to policymakers to sketch one hundred possible worlds of what might happen. It's better to portray five worlds which are relevant'.

and:

> 'You cannot state 'maybe' twenty-five times on one page. It has to be legible to policy-makers'.

Notwithstanding their uncertainty awareness, three respondents explicitly acknowledged that some of the information concerning uncertainty is not considered primarily as policy relevant information:

> 'You make an MV as an instrument to support policy makers. This means that you need to sketch worlds that are relevant for policy-makers for the moment. If you state: a major disaster might occur somewhere in the world, politicians will think: I cannot do anything with that information right now.'

From this observation it can be concluded that there seems to be a tension between the general attitude towards uncertainty on a rather abstract level on the one hand, and how uncertainty is approached in the actual practice on the other.

6.2 Identifying and prioritising uncertainties

One way to get insight into how uncertainties were managed and whether this approach can be considered as adequate in view of the aims associated with an Environmental Outlook is to identify which uncertainties are salient and trace whether and, if so, how, these uncertainties have been addressed in the assessment. The pitfall in discussing uncertainty is that everything is considered to be uncertain, which leads to the nihilistic conclusion that nothing can be said. To this end, the explicit aim of the interviews was to figure out which uncertainties and which sources of uncertainty are crucial to the MV-5 endeavour and whether and how these were considered and/or dealt with in the MV-5. To this end, we aimed to use the expertise of the analysts to arrive at a collective judgement on salient uncertainties. In the uncertainty workshop, important uncertainties were surfaced through brainstorm and clustering (see Chapter 5). We used this workshop output to challenge a more structured and 'second thought' expert articulation on uncertainties salient to the 5th Environmental Outlook. In a certain way the group interviews were used to validate the brainstorm output. The full overview of the rankings in given in Appendix 6.

From the evaluation of uncertainties the following conclusions can be drawn:

- The majority of the respondents consider human and ecological effects (dose–effect relationships and responses of ecosystems) to be important uncertainties, while none of them considered these environmental uncertainties unimportant. We can therefore conclude that these uncertainties can be characterised as salient.
- A number of uncertainties got many positive rankings, but some judged them as unimportant, such as effectiveness of policy/measures, foreign developments, behaviour, climate variability, emissions, technology and economy. Although this implies that these uncertainties are salient to important topics to be addressed in the Environmental Outlook, they do not seem to pertain to all issues addressed.
- Some uncertainties got primarily positive rankings, but only from a small number of respondents. This implies that these uncertainties are salient for particular MV-5 topics, but are not considered to be salient to the assessment as a whole. From the interview data, the following uncertainties can in this respect be considered as critical: the 'attitude towards nature', and the 'feedback mechanisms of the ecosystem in response to climate change'.
- A number of uncertainties got both positive and negative ratings, implying that consideration of these uncertainties as being relevant is very much issue-dependent. Uncertainties that belong to this category are: inner city traffic problems, climate variability, global supplies and natural variability.
- Some uncertainties were rated predominantly negative. The respondents' opinion can be concluded as seeing these uncertainties as not being critical to the Environmental Outlook as a whole, i.e. disasters and conflicts, global recession, policy objectives, social developments, demography, and structure and size of Dutch industry.

Furthermore, a number of uncertainties were added during the group interviews. These are individual judgements that have not been reviewed by peers. The following are considered to be relevant for MV-5:

- intergovernmental developments (as covenants);
- spatial differentiation (e.g. emissions);
- mobility and transport;
- intensity of products (e.g. energy, space);

- definition of the quality of nature;
- scale;
- deposition;
- structure and extent of Dutch agriculture;
- implementation of technology;
- infrastructure;
- competitive position of the Netherlands;
- price of energy;
- Dutch employment market.

The respondents were asked to indicate the relative importance of the sources of uncertainty associated with Van Asselt's (2000) typology of uncertainty (see Table 25). From the table it can be concluded that some of the sources, i.e. behavioural variability, societal randomness, technological surprise, conflicting evidence, natural randomness, value diversity, ignorance and indeterminacy were, at least by one of the respondents, valued as being highly important to the 5th Environmental Outlook. All respondents who ranked behavioural variability and natural randomness considered these sources to be important; however, these sources were considered irrelevant (marked with * in Table 25) by 1 or 2 colleague experts.

Table 25 – Ranking in the interviews for 10 of the 13 respondents (3 of did not fill in the scores)

Sources of uncertainty	***Ranking in the interviews for the 5th Environmental Outlook (* =considered irrelevant)***									
Behavioural variability	*3*	*4/5*	*2*	*3*	*4*	*3*	*	*2*	*	*1*
Societal randomness	*10*	*3*	*	*6*	*5*	*1*	*	*1*	*	*4*
Technological surprise	*1*	*4/5*	*6*	*4*	*6*	*2*	*	*3*	*	*5*
Conflicting evidence	*4*	*1*	*4*	*2*	*2*	*	*5*	*7*	*6*	*2*
Natural randomness	*2*	*2*	*1*	*1*	*3*	*	*	*	*3*	*3*
Value diversity	*9*	*7*	*	*8*	*9*	*4*	*1*	*8*	*	*
Inexactness	*7*	*9*	*	*9*	*7*	*	*	*6*	*5*	*
Lack of observations / measurements	*11*	*10*	*	*10*	*	*	*4*	*5*	*2*	*
Practically immeasurable	*8*	*11*	*7*	*5*	*8*	*	*	*4*	*4*	*
Ignorance	*6*	*8*	*3*	*7*	*	*5*	*3*	*	*1*	*
Indeterminacy	*5*	*6*	*5*	*11*	*1*	*1*	*2*	*	*	*

The divergence in the scores in the table indicates much dissensus on the collective level about the salience of the various sources. This divergence might (partly) be explained by the fact that the respondents scored the relevance of sources in view of the topics they were responsible for. This would then imply that the relevance of sources differs per topic. On the

other hand, it may also be the case where there are major differences in how the respondents interpret the sources of uncertainty or there may be a wide difference of opinion between the various experts. Our interpretation of the interview data is that, generally speaking, the respondents had similar associations with the sources of uncertainty. The empirical material does not allow hypothesis on whether the spread in scores can be explained by difference in topic or whether this spread is the result of fundamental disagreement among experts.

6.3 Management of uncertainty

From the interviews it can be concluded that notwithstanding the efforts to incorporate uncertain assessments into the policy analyses, a general strategy for uncertainty management in the 5th Environmental Outlook was lacking. That practitioners have attempted to improve dealing with uncertainty in their MV-5 activities also emerged from the interviews. As a consequence, the way uncertainty is dealt with was shown to differ from individual to individual, from laboratory to laboratory and from chapter to chapter. Analysts were requested to fill in fact sheets on their input to the MV-5; this information is in principle used in the background documents. The fact sheet contained questions on uncertainty and therefore - on the level of subanalysis - it provides information on the uncertainties which have been considered. On both levels - subanalysis as well as individual research - the following approaches have been used by RIVM practitioners to explore uncertainty with regard to their specific issues:

- economic scenarios;
- sensitivity analysis used to explore the impact of uncertainty in model inputs and parameters on the output variables;
- internal review, as the following quote illustrates:

  > 'We always check if emissions correspond with previous deliveries; if something seems to be incorrect we get in touch with LAE (RIVM laboratory for emission research –ed.). We observed, for example, that for one emission file the calculations were twice as high as the measurements.'
- expert judgements and counter-expertise;
- scientific consensus formation;
- internal peer review and feedback;
- linguistic expressions.

One of the differences with the previous Environmental Outlooks is that in the 5th Environmental Outlook process the linguistic strategy was explicitly recognised as a way to address uncertainty. From the interview data it can be concluded that a collective attempt was made to systematically use so-called uncertainty expressions[225] in the text. Besides this, textboxes were used to present brief background information on computational methods, assumptions and uncertainties in a narrative, qualitative or semi-quantitative manner. According to the respondents involved in the MV-5 project team, the presentation of uncertainty in writing and text received continuous attention during the editing phase, as the following quote illustrates:

> 'As a team we had discussions about that, that we should use a more conscious pen to formulate our texts in terms of uncertainty. In the book this occurs in the main text and in different textboxes. Yet at a certain moment you tend to choose for legibility, or you get 25 times 'maybe' on one page. We still need to practice which style to use to take the reader along, yet to make him aware that the Environmental Outlook is an exploration of the uncertain future.'

[225] Compare Chapter 3.

The following quote illustrates how uncertainty was addressed in a particular analysis underlying the MV-5 assessment:

> 'Sometimes we ran a model developed by others to do the same calculations, or for some issues, a special expert team was gathered to explore the matter. For example, for acidification, we looked at measurements, but also at the results of MBs (Environmental Balances - MvA) of the past. The outcomes were different, which surprised us. We met together several times as a team of experts (people from the MBs, people involved in the nature assessments and more or less everyone who was involved in acidification). Many issues turned out to be underexposed; a whole list of uncertainties, ranging from a scientific problem to the fact that it also costs a lot of money to measure acidification, was compiled.'

As discussed in the previous section, the respondents were asked to indicate which uncertainties they considered important. They were also asked to explain how these uncertainties were dealt with in the MV-5. Table 26 summarises the answers[226] where it is indicated if, and if so, how, uncertainties – which they themselves had judged to be important - were treated in the assessment process.

Table 26 – Indication of how uncertainties considered important were dealt with in the MV-5 (deduced from the interviews)

Responsible in MV-5 for:	Important uncertainties	Dealt with (yes of no)?	How dealt with
Large-scale air pollution	Openness of Europe 2030	Yes	Despite what will be decided in the future, it is assumed that economic developments will not be significantly influenced within this period of time (2030).
	Human + ecological effects	Yes	Problems of fine dust and ozone are difficult to model; measurements deviate. Both emissions were treated conservatively: worst-case scenario.
	Response of ecosystem (fauna + flora) to the decline in quality of the environment	No/yes	-Fauna is hardly described in the MV-5 models -Flora: the response was modelled for the first time, but verification by other experts did not take place yet.
Breakthrough technology	Behaviour / interaction with technology	Yes	Divergent integrated views of the future.
	Consumer behaviour	Yes	Divergent integrated views of the future.
	Technology	Yes	Divergent integrated views of the future.
	Economy	Not really	It is assumed that there will be economic growth (this means that the same assumption is used for all the integrated views of the future)
Scenarios	Effect and implementation of measures	Yes	Effect and implementation of policy was studied on a target-group level, but this was not extrapolated (no integrated approach).
	Consumer behaviour	Yes	Co-operation with EIM (economic research institute), expert judgement
	Technology	Yes	Scenarios, yet technological innovation remains a black box.
	Structure + size of Dutch industry	Yes	Captured in the scenarios, but these do not give enough variation in economic structure

[226] Note: not all the issues considered important were explicitly discussed; the table reflects those further elaborated.

Nature and environmental effects	Response of ecosystem (fauna + flora) to the decline in quality of the environment	Yes, treated in the reportage. No, not treated in the MV.	What is ecosystem quality exactly: vagueness of definition.
	Collective (basic) emission (ERC)	Yes	It is assumed that what is known is incorporated in the 30% range delivered by LLO.
Consumption	Consumer behaviour	Yes	Scenarios as input, supplemented with expert judgement of EIM, use of models
	Global supplies	No	Feedback on what this means for consumer behaviour is not accomplished
	Economy	Yes	Captured in the scenarios
	Global economic recession	Yes	Captured in the scenarios
MV general	Behaviour	No	Not taken into consideration on an individual level, only on a group level, for which the uncertainty aspect is expressed in a scenario (no discontinuity in behaviour within a period of 30 years).
	Consumer behaviour	Yes	Assumptions about the pattern of spending were extrapolated, in the perspectives-chapter alternatives have been explored.
	Social developments	Yes	Trend extrapolations for population growth of the UN were used in combination with a B1-vision (IPCC).
	Demography and migration	Yes	Is connected to social developments
	Inner city traffic problems	Not much	Linked to development of mobility
	Collective basic emissions	No	Difficult
	Speed of change	No	
	Global supplies	Yes	Major uncertainty factor: how?

Some of the respondents explicitly acknowledged that uncertainties they characterised as being important had not been assessed in the model calculations and during the interviews and they tried to understand why not:

- 'Openness of Europe is considered an important uncertainty. The discussion was: are countries like Turkey a member of the EU and what does this mean for the economic development of Europe? In Latvia and Estonia, there might be many more if things go on, but it can also go wrong. We struggled with that. The way we took this along was to say that Turkey or other countries may be included successfully or unsuccessfully within the EU, but in our scenario we assume (for now) that this will lead to a Europe moving at different paces, in which the economic developments in this period of time are not so heavily influenced by that. This is a very disputable point of view, but at least we could prevent being forced into a situation in which we had to tell what Europe would look like politically in 2030! We did not perceive this as our task and we don't feel we can contribute to that discussion. Regardless of the decisions that are made, we assume that they have no influence.'
- 'From different perspectives, we looked at the possibility of changes in consumption pattern, production structure and changes in the possibilities to introduce new technologies. This shows that it is a relevant source of uncertainty for the MV. But it is only introduced in the text, in the style of writing; not in the sense that we will make alternative scenario variants for it. So honestly, I don't think we treat it as a major source of uncertainty, we did not assume there will be a major discontinuity in values and norms in the next 30 years.'

Scenarios were explicitly brought forward as an approach to deal with uncertainty throughout the MV-5. In the group interviews, the question arouse on whether the scenarios used were adequate in addressing the relevant range of possible futures. The majority of the

respondents considered the two CPB scenarios used as being too limited and outdated to adequately deal with uncertainty in environmental management and policy:

- 'I am not satisfied with the range the scenarios offer for possible developments. Worst of all, they are four years old and outdated for a number of possible expectations'.
- 'The scenarios are only partly interesting to sketch a picture of the future. They hardly differ (only 0.6% per year) and if you work with ranges as we did, you will see that these overlap.'
- 'The scenarios are not distinguishing enough to be any sort of uncertainty analysis whatsoever. We lack a 'nature scenario'.'
- 'I would have liked to use different scenarios, scenarios that include explicitly in what kind of world the consumer lives. The two scenarios do not differ enough, they have a very macro-economic perspective, they do not include the point of view of the consumer, are not micro-economic at all.'
- 'It would have been much nicer to develop scenarios in which you explore two different worlds: for example, one world with a high-level technological development and another scenario in which one invests in social development. If you offer two worlds like these – like offering policy with clear decisions: 'will we invest in technology or social cultural developments?' - you paint how consumers live and how they might react.'
- 'The scenarios do not include extremes. As consequence, we do not have a broad view of what technology might bring in the future. This means that you give policy-makers a narrow picture of the future, you deny them the broader perspective, and in doing this you do not see the possibilities or dangers at the edges.'

Two respondents argued that notwithstanding the limitations associated with the CPB scenarios to realise the aims of the MV-5 in assessing whether environmental targets can be reached with current policy, it is legitimate to use the CPB scenarios in the environmental assessments. The majority of the respondents do not agree with this judgement, because of the following weaknesses associated with the CPB scenarios (compare Chapter 3):

- The scenarios are predominantly determined by economic growth, however, as the following quotation illustrates, other variables are important for the environmental assessment:
  'The scenarios are based on economic growth; this is the basic building block from which the other variables are determined. But other factors than economic growth determine emissions. For greenhouse gases, the assessment involves but one scenario, GC, which implies that it builds its case on developments that might also turn out completely different.'
- Rigid assumptions and mere extrapolations: no discontinuities, use of classical axioms which are not tested, reasoned from production, technology as black box, systems do not change (no innovation):
  - 'What happens now is that current developments are extrapolated. This means that you do not include discontinuities, while we learned from the past that these are of major importance.'
  - 'The scenarios do not include disasters, extreme events and social/behavioural discontinuities; they are just an extension of the trend, including some ranges and differences in level.'
- Uncertainties at the beginning of the chain, which are crucial in view of the state of the environment, are not taken into account. These include technological breakthroughs, lifestyle/consumption patterns, energy costs and structural economic changes.
- A scenario is a coherent, internally consistent description of a potential future, but the effects of developments explored in the outlooks are not fed back to developments presumed at the beginning of the chain:
  - 'For example, we say that climate change will occur and that as a consequence the temperature will rise. But the fact that the higher temperature leads to less gas consumption in the winter is not taken along in the same emission stories. This kind of feedback is not taken into consideration in the scenarios; they are really input scenarios, we receive them and start calculating and no further questions are asked. First, one should try to keep the total picture within the scenario consistent.'

- 'The yield of agricultural crop and ornamental plants is determined by the concentration of ozone, for example, tulips which do not look nice, with stains which are caused by ozone, do not sell well. You also have fewer apples and pears on the trees, less grass for cows, or maybe more, that depends on what you believe. So ozone has consequences for the yield of agricultural crop, we're talking about 5% to 6 %. (..) If you lose agricultural crops, the economic revenues of the farmers are also affected, which is not considered.'

However, not everyone agreed with this observation:

- 'Feedback does take place. The MV is only one step in the process, the policy process as a whole involves iterations. There are three steps we use to close the chain: first, we make an MV that is 'policy-poor', which paints a picture of the future. Then there is the NMP4 process, in which targets and measures are formulated[227]. In the end, this package is assessed MV-wise, and the results are compared with the targets. This last phase results in the so-called 'Environmental Performance Reports'. For example, the CPB is asked in that phase to investigate whether the environmental costs that result from the implementation of measures (..) leads to a macro-economical change.'

The majority of the respondents argued that a more comprehensive assessment involving a broader set of scenarios would improve the quality of RIVM's decision-support activities, while a minority argued that such a broader assessment was not within RIVM's mandate and not relevant to RIVM's decision-support task:

- 'I wonder if this would serve policy-makers, as you always start from the present with a lot of conservative processes that will be around for the next decades. It makes sense to look at different worlds when considering a period of hundred years, in which you include the slowness of change of those large-scale processes. Then you do have to look at more extreme pictures. But for a period of thirty years, the most useful estimates are those that are close to the trend. I do not think that current policy will be pleased with very extreme pictures for which the plausibility will be under dispute, and as a consequence will be thrown away.'
- 'It is interesting to make different scenarios like a learning or research activity, into a creativity-stimulating activity, but it is a waste of time for policy-makers.'
- 'We have to make the MV to support policy-makers. This means that you have to sketch worlds that are relevant to them at the moment. If you state 'a major disaster might occur somewhere', policy-makers will think: 'I cannot do anything with that information right now'.'

The existing criticism of the two CPB scenarios resulted in a number of efforts in the context of the MV-5 process to explore alternatives, apart from the PRIMA activities reported in Chapter 5. For example, it was discussed with CPB to change assumptions; in the project on breakthrough technologies, divergent integrated views of the futures have been developed and the IPCC scenarios were translated into scenarios for the Netherlands. Some other initiatives are discussed in the following quotes:

- 'We wanted to show that economic growth does not embrace everything. Therefore we did a sensitivity analysis on social developments for one scenario context, so as to show that you can already have five or six parameters that may vary within one economic scenario, resulting in a range of possible emissions. Basically, we built a GC line with sensitivity ranges around it.'
- 'We needed to look ahead and therefore we needed to do more than just look at the CPB data. Based on the monitoring data we have tried to make an extrapolation of the consumption pattern, after which we consulted a number of experts. The data that resulted from this process were supplemented with data that we received from model procedures, and this collection resulted in estimated consumption patterns and environmental pressures.'

However, most of these alternatives were not yet considered mature enough to be used in the MV-5, or there were other reasons why the associated material was not employed:

- 'CPB had no time to make new scenarios. It meant that they had to start estimating again and they did not want to do this.'

[227] Environmental Plan Process within ministries under auspices of the Ministry of Environment (VROM).

- 'Breakthrough technologies are hardly acknowledged in the current scenarios, while they can have a gigantic impact, which you cannot describe – certainly not with CPB scenario methodology – because those models cannot handle it technically, as they only extend trends. So we developed integrated views of the future, we tried to identify driving forces: 'if things are like this and that, how will this affect the 'shape' of the world?' (..) This hardly shows up in the MV. (..) At the end, the whole chapter focuses on: what is technologically possible to solve persistent environmental problems?'
- 'We have been playing with them (i.e. the desegregated IPCC scenarios for the Netherlands - MvA) in the context of the last chapter. But this was withdrawn later, and now we present it as a thought experiment.'
- 'Yet we also made use of other research as to which alternative scenarios were used and we presented those trends to the experts, asking them to attach ranges. In doing so the trends were put in perspective. It has been used as an aid to give the experts a broader vision than their own, but it has not been used as input, clearly not.'

Partly because of the variety in uncertainty treatment and the lack of an overall strategy, and partly due to less than optimal communication between the various laboratories due to the sectoral set-up of the assessment process and time pressure, uncertainty information gained with regard to a component of the analysis got lost in the transfer of knowledge, model results and quantitative estimates from one analyst or department to the other:

- 'We adopted the central estimate and took along our knowledge of the range around it.'
- 'I did not even pass on the ranges, I just gave the figures; I could have done it, but I did not.'
- 'The processing of uncertainty in the follow-up phases is not operationalised.'
- 'My experience with the MV-5: they also do their best; they also try to list all the uncertainties, yet they do not really take up the ranges that were delivered by others. Concerning uncertainty, RIVM tends to work a bit compartmentalised.'
- 'LLO (RIVM Laboratory for Air Research – ed.) states: The uncertainty of the deposition is 30%. But that applies to the estimations they make, for those 5 x 5 km grids. How to interpret uncertainty if you work with depositions at another level?'

It is unclear how the 'ifs and buts' associated with the input received from others in the assessment chain have been processed. The majority of the respondents suggested that there should be a more open and transparent communication between the different departments, which could improve the interdisciplinary process of uncertainty management on the level of the MV-5 as a whole.

As a consequence of the above, the respondents agreed that it is difficult to judge the degree of uncertainty associated with the conclusions, as the following quotes illustrate:

- 'There is hardly anything said in an integrated manner about uncertainty. We do not have a closing chapter on uncertainty. We did pay attention to it, in different ways, throughout the MV. Yet an integral conclusion about the extent of uncertainty at the end of the chain is lacking. That is something we can only start to do when we analyse from the fact sheets what factors have played a role in each step of the chain. This kind of post-analysis is planned for the coming period.'
- 'There is not only uncertainty in emissions but also in the way these affect climate change, which, in turn, affects sea-level rise, health, nature and environmental diversity. This whole area is filled with uncertainty, and requires another way of dealing with it. Right now we miss a translation of uncertainty from the beginning of the chain to the uncertainties at the end.'
- 'A problem is the cumulation of uncertainties, for example, from acid emissions to fine dust and other aspects of large-scale air pollution, I think the range presented is pretty narrow. This does not mean that the conclusions are affected in such a way that they need to be changed, but is does affect the picture.'
- 'Who can oversee the whole MV process? I have a reasonably good idea of the uncertainty within my own area. Given the input I received, I can reason about the uncertainty and the solidity of my output but that is it.'

The respondents seemed to agree that for the 5th Environmental Outlook, an integrated assessment of uncertainty over the whole chain was simply beyond reach.

From the interviews some more obstacles to systematic uncertainty management can be deduced:

- 'Due to lack of time we were not always able to focus on aspects of uncertainty in our work, other issues got more priority.'
- 'Lack of time was an important factor of uncertainty within the MV-5: for example, due to lack of time we could not determine whether variability is an important factor of uncertainty, or whether the choice of species is important for the results.'
- 'We face a dilemma: we want to produce reports that matter to the Cabinet. Given this context, the documents have a certain size. At the same time we want to give them thorough, science-based, as-objective-as-possible documents. (..) There is a big dilemma about the degree of nuance.'

The interview data seem to suggest that the way uncertainty was dealt with on the level of the MV-5 assessment can be described as an internal informal intuitive process of expert judgement and peer review that was not completely transparent or fully documented. Some examples of quotes illustrating this picture:

- 'We need a checklist for our activities, so that we know what to do first.'
- 'Those who work with data and interpret them, are continuously critical. If something seems wrong, people go back and check. But it is a very hazy procedure. '
- 'If uncertainty was dealt with in an adequate manner, this is usually done by a very informal process; if you are not certain about something you consult each other.'
- 'But time was still too short, and effort too limited: predominantly individuals have done it'

The lack of transparency is illustrated by some respondents' criticism with regard to the editing, and thus, integration process. From quotes like the ones below it can be concluded that the process of processing uncertainty information delivered by analysts or departments was not fully transparent to practitioners involved in the MV-5 process:

- 'Every time they come up with another version that you are expected to agree with, but they do not tell you what has changed compared to the previous versions. That means that you either read through it very carefully, keeping the old version next to it, or that you say at a certain point that you have other things to do, and I tend to choose the latter option. Does this mean that I put my signature to the last version? This remains the question, since the person directing the process has the final responsibility over it. I am pushed into a situation over which I have no control.'
- 'Some of the figures that we handed in – emissions for CO_2 and greenhouse gases – were rounded differently than we had delivered them. We had rounded them off to tens, which is a very rough by which we showed that the forecasts were very uncertain. They used techniques based on the MB, with the result that they used units. Techniques used for the MB were used for the MV, while I think that the MV faces very different types of uncertainty. It deals with estimates and not with solid figures; it is a different type of uncertainty that you take into consideration.'
- 'We know that figures might be uncertain, but I believe they are presented more certain, more certain than intended at least. Anyway, it will definitely be read more certain than we intended, I think. We produce results that we complement with nuances, but these disappear during the final editing. People are tempted to formulate their results in a clear manner, as they want the outlook to be legible for policymakers.'

Notwithstanding the observed constructivist attitude, it can be concluded from the interviews that uncertainty in actual practice was occasionally still perceived as an obstacle, and dealt with in a positivist manner, as the following quotes illustrate:

- 'Then (if it is uncertain, MvA) we do not present the results.'
- 'If you make a major point of it (uncertainty, MvA), that you have to state for all numbers and models you use 'this is its status', this will dominate the Environmental Outlook. I don't believe that this the intention of the Outlook.'
- 'If we produce our results with nuances – which the scientist does by nature – this is ' edited out in the final editing process. We want to produce a report which is readable to policy-makers and the Dutch Cabinet, 'on the one side – on the other' does not satisfy such an aim?'

The following discussion also illustrates the tension between ideal and common practice:

- P1: 'The train just keeps on running'.
- P2: 'Obviously, we consider other tasks more important (than addressing uncertainty, MvA)'
- P3: 'We choose to work on other tasks because they are considered more urgent, because the boss asked you to and because those tasks are maybe easier……'

On the other hand, it can be argued that inadequate treatment of uncertainty is not only a question of time and priority, but also that more learning and training is needed:

- 'Uncertainty is dealt with in a fragmentary manner, not systematically. There is an improvement compared to the MV4, as uncertainty is on the agenda and people want to deal with it, yet they do not know how to do so.'
- 'Uncertainty is still very much a bottom-up process; awareness is growing, individually or with a small group people try to implement it, but there is no strategy saying: 'this is how it needs to be done'. There is a need for a top-down strategy, for a systematic approach (ed.).'
- 'Taking the circumstances into account, we handled uncertainty rather well, but it is also a learning process. To give it explicit attention means that new facts may come to the surface, and then you want to do it increasingly better. We tried to do it the best we could within the time we had, and throughout the process we learned that it could be done better.'
- 'By the way, I learned a lot from the interview about uncertainty. I came in quite blank and I returned much 'richer'. On the basis of the discussions during the interview, we tried to perform an uncertainty analysis in line with your ideas, the effort of which will be reported in the background report. Thanks for this basis.' *(submitted per email by one of the respondents)*

6.4 Learning process

From the interview data we conclude that the 5th Environmental Outlook can be considered as a learning process, in which practitioners have attempted to address uncertainty in their contribution to the MV-5. From the interviews, it can be observed that awareness of uncertainty does not automatically imply that uncertainty is systematically addressed in the assessment.

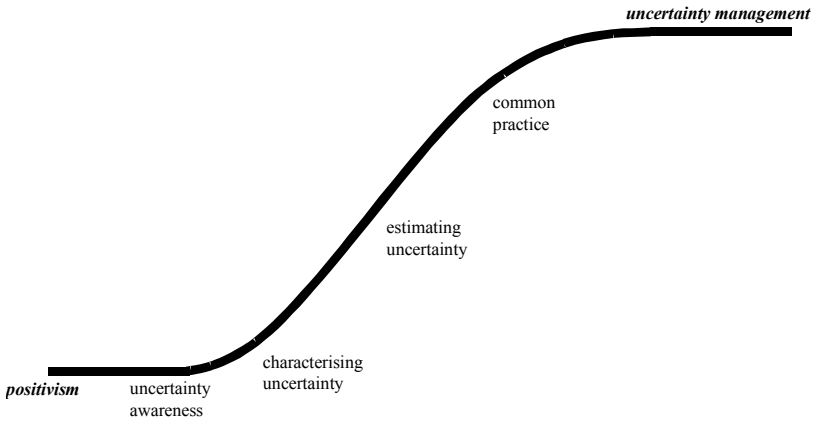

Figure 17 – *Learning transition.*

This is due to the fact that uncertainty management involves a transition from assessment in a positivist mood towards uncertainty management as central to the assessment (Figure 17)[228]:

[228] This ideas builds on Langendonck (1999).

Positivism implies that uncertainty is qualified as 'bad work', which in turn implies that uncertainty reduction is the key task. Awareness of uncertainty implies that uncertainty becomes a theme on the assessment agenda, but is not systematically addressed. In the next phase, uncertainty receives more systematic attention. Instead of treating it as a black box, it is specified in terms of types and sources, which allows a more targeted use of available methods for uncertainty management. The following phase features the stage in the learning process in which the degree of uncertainty will be systematically assessed, where possible, 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 partial analysis, but of the full assessment. Building on the previous phases, the policy relevance of specific uncertainties in the following phase is no longer assessed intuitively but in a systematic manner sufficiently supported by the underlying assessment. Ultimately, uncertainty management will be fully integrated into the assessment methodology.

To understand the S-curve shape of the learning process, the analogy of behavioural change of an individual may provide an illustration. At a certain point, specific behaviour becomes problematic. Others are signalling this, or the person him/herself concludes without feedback from others that 'this is a problem'(phase 2). Therapy can be used as a way to analyse the problem; this involves making the problem tangible, understanding why and exploring alternatives. This process of realisation and confrontation (phase 3) is accompanied by stress and uncertainty, as the old frame of reference is being undermined and an alternative has not yet emerged and crystallised. Whether behaviour will change structurally depends on internalisation (phase 4), which is a difficult and time-consuming process. The transition from the 3rd to the 4th phase is a critical and crucial phase in the process of learning and change. To stimulate this transformation, it is vital that progress is rewarded and that stimuli are given continuously. The transition towards uncertainty management thus implies a change in culture.

With information from our study, we tried to characterise RIVM's state of affairs in view of the transition from positivism to an uncertainty management process. The expression of attitude encountered during our research implies that RIVM is definitely beyond positivism. Uncertainty is acknowledged but not yet thoroughly and systematically treated in the assessment. The practitioners were able to articulate and prioritise uncertainty and address them in terms of sources. However, the empirical evidence discussed in the current report indicates that the analysts are uncertain about how to deal with uncertainty. It can be argued that RIVM finds itself currently in the middle of a learning process: on the one hand, the MV-5 process was a natural successor in the series of Environmental Outlooks, while on the other, beneath the surface a fundamentally different approach to environmental assessment was being explored through an emerging interplay of a number of relatively small activities and initiatives. So we can conclude that RIVM finds itself in the transition from phase 3 (characterising uncertainty) to phase 4 (estimating uncertainty).

It is important to realise that this is not an easy phase in the learning process. The more so, because RIVM's change does not take place in isolation, but in an environment where positivist expectations are still relevant in shaping science–policy–society interactions. This paradigm-maintaining circle can be described as follows: society still primarily expects science to solve uncertainty, or at least to diminish it - an attitude that inhibits positivist thinking. At the same time, policy demands scientific advice on short notice, asking for

answers that cannot always be supported by credible scientific evidence. An intricate process of power and interaction seduces, or even forces, scientists to provide 'pseudo-certainties' when confronted with socially undesired uncertainty. Although it is considered among scientists as a value to be knowledgeable about uncertainties in the field of expertise, scientists are in a way not trained to deal with uncertainty in a manner that enables them to address society's need. Due to unmanaged uncertainty, different scientists present different recommendations and results, which in turn fuels social distrust and further increases the pressure on the scientists. The status of science then comes into question, which in the extreme case may even force scientists to 'prove' what society wants. This may ultimately lead to a kind of lock-in situation: in a certain way, social pressure generates 'poor' science, which generates, as response, more social pressure, as science is no longer taken seriously. On the other hand, it may lead to a situation in which scientists find themselves caught in a conflict between constructivist ambitions and a social world that gives preference to a positivist approach. This implies that the RIVM's transition has not only implications for RIVM itself, but also requires a constructive attitude and change among both partner institutes and policy-makers.

Thus RIVM finds itself in a crucial phase: internally, the old frame of reference is being questioned, but is still dominant in science–policy–society dynamics. The group interviews, as well as the response to the uncertainty-related activities discussed in Chapter 5, demonstrate a will to change, as is further illustrated in the following statements:

- 'I think it is very important that we communicate to the NMP4 team that everything that we explain is immersed in uncertainty. By now The Hague (seat of government –ed.)is no longer as naïve as to think that this will not be the case. We try to formulate our recommendations in a robust manner. Another aspect is that we need to bring the organisation a step further; we should not remain stuck in a discussion about the past, but find out how we can function as a policy assessment office in a world of uncertain information.'
- 'If we are able to demonstrate the relevance of a firm knowledge of uncertainty for policy-making, we will be a step further. Then they can do something with uncertainty. I think that if you build aspects into your scenarios that determine emissions, and put a range to it, you create something which is useful for policy-makers.'
- 'The context has changed at DGM: we can now claim space for uncertainty, there is momentum for it. For example, for the 4th National Environmental Programme (NMP4) we wrote an interactive report; this means that we delivered input in a working group that prepared the NMP4 for energy and mobility. It was not so much a session of asking RIVM or CPB to come up with all the answers, but rather to point out possibilities, to explore why things could work. Within this process, it was the policy group that made the decisions. So one can indeed advise policy-makers while managing uncertainty, without being forced to make a choice. During these interactive processes we claimed the space to point out uncertainties; sometimes they were huge, with cost ranges for things we had no idea of. Maybe two years ago this would have tempted us to provide averages; now we indicate the whole range. And next, policy concludes that we cannot utter preferences based on costs. This is a big difference to how things used to be, where you were tempted to give policy-makers the solid aspects they wanted.'

In conclusion, there is momentum for experiments and change, which is only partly in reaction to the 'De Kwaadsteniet affair'. The conviction is growing that innovation in addressing uncertainty in the assessment endeavours is definitely needed. If the MV-5 process is primarily considered as a learning process, the challenge now is to use the lessons learned and build on first innovative steps in upcoming assessment processes. To facilitate such learning the above findings have shown that substantial time, effort and expertise will be needed for this endeavour. This implies that uncertainty management should be a strategic priority for RIVM as a whole, not one to which only lip service is paid, but one

which guides action. Furthermore, RIVM needs to pay serious attention to communication on uncertainty with its clients and the partner institutes, so as to stimulate and facilitate a broad transition process in thinking about uncertainty in relation to decision-making. In the next chapter, we will share our ideas about the following steps in this challenging endeavour.

7 LOOKING AHEAD

This Chapter summarises the major lessons learned in relation to the scenarios employed, the models and data applied, the expert judgement involved and the reporting style. We will also share our ideas about the next steps in this challenging transition process.

Notwithstanding RIVM's early efforts to address the issue of uncertainty analysis, uncertainty was not systematically addressed in the series of Environmental Outlooks from 'Concern for Tomorrow' up to the 4th Environmental Outlook. The 'DeKwaadsteniet affair' illustrated the resulting vulnerability for criticism on the quality of assessments in relation to uncertainty. The current document reports RIVM's learning process associated with the 5th Environmental Outlook. From the analysis it can be concluded that uncertainty management plays a role at various levels in the 5th Environmental Outlook:

- The ***scenarios*** used: the scope of the 'what if' perspective of the CPB scenarios does not encompass the complete range of relevant possible futures. As a consequence, uncertainty captured by the scenarios used is necessarily limited. The conclusions associated with the applied scenario-based assessment should therefore be interpreted in a restricted, conditional sense.
- The applied ***models and data***, comprising the cause–effect chains: the degree of uncertainty and the dominant source(s) of uncertainty depend on the level of knowledge and information in the areas under study and the amount of variability on the scales of interest. How uncertainty is addressed in the quantitative assessments turned out to be very issue-dependent and contextual. A general framework or strategy to address uncertainty was lacking, with the consequence that the researchers dealt with uncertainty in the way they considered adequate, given the available amount of time, data, knowledge and expertise. Typically, this information on uncertainty referred only to a specific part of the cause–effect chain, generally using central/nominal values as input and because of scale inconsistencies between different partial analyses. A complete uncertainty assessment that includes uncertainty propagation over the whole chain is currently beyond reach.
- The ***expert judgement*** involved: in interpreting and assessing information and results from data analysis and model experiments expert judgement plays a role. Furthermore, in cases where adequate information is lacking, expertise and judgement are used to arrive at insights relevant for the question at hand. In the MV-5 assessment process forms of expert judgement have been used explicitly - through expert workshops, counter-expertise/'second opinion', consensus formation and peer review - to address and assess uncertain issues.
- The ***reporting style***: more than in the previous Environmental Outlooks, the awareness of uncertainty has been an important theme during the MV-5 process: the initial shared ambition was to make uncertainty explicit, both in the background documents and in the main report. How uncertainty is managed is generally reflected in the background documents and the associated fact sheets. With regard to the main report, some analysts expressed their opinion that the main MV-5 'audience' (especially policy-makers) could not handle uncertainty adequately. Based on this conviction, it was decided not to discuss uncertainty systematically, but only to touch upon it explicitly in cases where RIVM considered it crucial in view of its recommendations. Textboxes were used in these cases to present background information on computational methods, assumptions and uncertainties in a narrative, qualitative or (semi-) quantitative manner.

Notwithstanding the decision to be selective with presenting uncertainty in the main report, stating results and conclusions was attempted in such a way as to take account of underlying uncertainties. In the final editing process, it was attempted to strike an often delicate balance between presenting clear and relevant information for policy, while doing justice to the uncertainties involved. It is too early yet to judge whether this strategy was adequate in view of the aims of an assessment. Although the background documents discuss, in principle, associated uncertainties and how they were assessed, the consequence of the adopted strategy is that readers cannot develop an informed judgement on uncertainty and robustness of the conclusions and recommendations directly from the main report unless there is at least a clear reference to the relevant background document.

The aim is to learn from this experience on how to move forward with uncertainty management in RIVM's assessment activities. From the interviews with practitioners the following suggestions can be derived for future assessment activities:

- There is a clear and broadly shared need for ***scenarios*** that offer a broader perspective than the CPB scenarios. Because of this, groups working on different topics (tend to) develop their own assumptions for the same parameters. It was suggested that RIVM could develop its own scenarios, but it was broadly shared by the respondents that such an exercise should preferably be done in co-operation with other institutes such as CPB, Social Cultural Planning Office (SCP), Netherlands Energy Research foundation (ECN) and universities.
- One of the main problems is that uncertainty information gets lost over the course of the ***model chain***. Uncertainty is, generally speaking, addressed within a department responsible for a specific part of the chain, but the next group of researchers usually does not further process this uncertainty information. This implies a need for more focus on communication between departments. These issues partly related to the general difficulties associated with interdisciplinary research. Time pressure also plays a role here.
- The majority of the respondents felt uneasy about how their work was processed in the ***final report***. Because of legibility, nuances were left out, with the risk that, notwithstanding the attention to formulation, the results are perceived more 'certain' than intended. It was suggested to pay more structured attention to internal review of the main report, especially with regard to the final editing phase. Uncertainty information can be argued to be found in the background documents, but these are published later in time and are therefore viewed, both internally and externally, as arriving too late 'in the day' to fill this need. Another issue is that the integrated assessment ('the bridge' between the referred background reports and the main report) is not fully documented. The respondents shared the idea of the MV as consisting of two equally assessed documents, i.e. (1) a comprehensive assessment report in which uncertainty is consistently addressed and (2) a brief policy summary with relevant points for governmental consideration. The first can be viewed as a scientific compendium to the policy report that enables understanding of the assessment and logic. Background reports, which discuss particular topics in detail, form the ingredients for the integrated assessment reflected in the scientific compendium. It is also important that such basic documents are produced on a continuous basis so that they can actually be used in the assessment process, instead of being produced too late in the day as in current common practice.

In sum, the general conclusion is that RIVM needs a protocol or at least a guideline or a 'style guide' that describes which uncertainty management steps need to be taken in which phase of the assessment process. It should furthermore contain criteria that enable practitioners to decide on which type of assessment uncertainty management is essential and whether a recognised level of uncertainty is critical to the assessment. Besides this, it should involve guidelines for practitioners about how to report and communicate on uncertainty among colleagues, and with the clients and stakeholders. These guidelines for uncertainty management should then be tested in integrative studies to evaluate its feasibility in practice, as well as the practical consequences. Such a guide for uncertainty management could take the form of an Internet document to make it easy for the policy analysts to use the ideas and concepts in their own work.

Time, effort and expertise should be devoted to the development of such a framework and strategy for uncertainty management. It is clear from the current report that learning to manage uncertainty is a process that needs time. To this end, the challenge for RIVM is to create that time by starting as soon as possible. This implies that uncertainty management should be a strategic priority for the whole RIVM, which is not only given lip service, but which guides action. It was a commonly shared fact that RIVM should start **today** with the 6th Environmental Outlook. It was argued that all project plans need to indicate uncertainty management, also in terms of necessary time, effort and expertise. To this end, it may be useful to explicitly name interested and experienced practitioners as 'uncertainty analysts', and in doing this, provide assistance to those struggling with uncertainty-related questions.

Furthermore, RIVM will need to pay serious attention to communication on uncertainty with clients and the partner institutes so as to stimulate and facilitate a broad transition process in thinking about uncertainty in relation to decision-making. One step could be to organise a workshop with colleague researchers from other policy assessment agencies to share and discuss the lessons learned. ECN has expressed an explicit interest in learning from RIVM endeavours[229], but also the other agencies have realised, through the 'DeKwaadsteniet affair', that they are in the same boat when it comes to uncertainty management in assessment endeavours. RIVM has to chance to play a pivotal role in this learning processes. One way to stimulate communication with the clients is to prepare an addendum to the 5th Environmental Outlook and/or a specific publication, in which explicit attention is paid to uncertainty. It is further advised to hook up with current discussions on the role of knowledge in policy as organised by other agencies, such as the RMNO (Dutch Advisory Council for Research on Nature and Environment).

Our analysis indicates that RIVM scientists are more than willing to embark on an endeavour in the direction of uncertainty management. It should be realised that this will involve a lengthy common query of apparently small steps forward. It is not wise to have unrealistic expectations; this may even frustrate the learning process. RIVM must dare to be consistent in its uncertainty management ambition so that we can conclude that only the

[229] A research proposal has been submitted in which a retrospective study similar to the one reported on the Environmental Outlooks will be performed for the ECN series of National Energy Outlooks (NEV). The PRIMA approach will be explored in the context of the next NEV.

future will teach us whether the 5th Environmental Outlook process can be considered a milestone in RIVM's assessment practice.

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Appendix 1 : Track record of media facts

(national newspapers and national radio & TV)

items* in chronological order
(covering January 1999 – September 1999)

Lagendijk, A. Politically correct. *De Volkskrant*, 23 May 1998.

Trouw. Environmental institute lies and deceives. *Trouw*, 20 January 1999.

De Kwaadsteniet, J.W. The society has a right to honest information. *Trouw,* 20 January 1999.

Engels, J. Then the truth is less important. *Trouw*, 20 January 1999.

RIVM. RIVM distances itself from assertions that environmental results would be dishonest. RIVM, 20 January 1999.

Rijswijk, C. Conversation with Director Van Egmond of the RIVM. Tijdsein (EO radio programme), 20 January 1999.

De Volkskrant. Parliament shocked by criticism on reports RIVM. *De Volkskrant*, 21 January 1999.

Reijnders. L. Publish RIVM report together with criticism. *Trouw*, 21 January 1999.

Telegraaf. Parliament wants inquiry into RIVM. *Telegraaf*, 21 January 1999.

Trouw. RIVM has to highlight uncertainties in reports. *Trouw*, 21 January 1999.

Trouw. The Schiphol- and ammonia- figures of the RIVM. *Trouw*, 21 January 1999.

Trouw (comment). Environment, science and politics. *Trouw*, 21 January 1999.

Trouw (Editorship Science). Fuss in Parliament after criticism of environmental figures. *Trouw*, 21 January 1999.

Trouw (Editorship Science). RIVM: no malicious intent. *Trouw*, 21 January 1999.

Borgman, W. Conversation with Minister of Environment Jan Pronk about the RIVM. Tijdsein (EO radio programme), 20 January 1999.

Trouw (Editorship Politics). Parliament asks Pronk for elucidation. *Trouw*, 22 January 1999.

* Dutch-language titles freely translated

Trouw (Editorship Politics). Pronk rejects criticism on environmental institute. *Trouw*, 22 January 1999.

Van Cooten, A. Accusation against reliability of RIVM hits agricultural sector directly. *Agrarisch Dagblad*, 22 January 1999.

Van Houten, M. Unassailable figures in environmental research. *Trouw*, 22 January 1999.

Verhoeven, R. Computer-models and the inflow of asylum seekers. *Trouw*, 22 January 1999.

De Volkskrant. Monopoly position makes accused RIVM vulnerable. *De Volkskrant*, 23 January 1999.

Trouw. Suspended official summons RIVM. (court of justice). *Trouw*, 23 January 1999.

Trouw (Editorship Politics). VVD: Pronk too laconic about criticism of RIVM. *Trouw*, 23 January 1999.

Buitenhof – Discussion with DeKwaadsteniet – Nederland 1 (TV), 24 January 1999.

RIVM. Irresponsible accusations not only harmful for RIVM. RIVM, 24 January 1999.

ANP. RIVM-co-worker ignores ban on public pronouncement. *De Volkskrant*, 25 January, 1999.

De Volkskrant. Political science. *De Volkskrant*, 25 January 1999.

EO. Conversation with Director Van Egmond and Professor Lucas Reijnders. Tijdsein (EO radio programme), 25 January 1999.

Eindhovens Dagblad. Parliament: clarification on environmental institute. *Eindhovens Dagblad*, 26 January 1999.

NRC-Handelsblad. RIVM blames criticism on co-workers. *NRC-Handelsblad*, 16 January 1999.

Rijswijk, T. Conversation with Director Van Noort of the RIVM. Tijdsein (EO radio programme), 26 January 1999.

Wams, T. RIVM operates in a minefield. *De Volkskrant*, 26 January 1999.

Breedveld, W. The bankruptcy of the figures. *Trouw*, 27 January 1999.

De Volkskrant. RIVM angry about accusations of co-workers. *De Volkskrant*, 27 January 1999.

Trouw (Editorship Science). Fierce criticism of RIVM on accusation deceit. *Trouw*, 27 January 1999.

Bomhoff, E.J. RIVM has to provoke competition. *Trouw*, 27 January 1999.

Trouw. Chamber/Parliament wants to question Pronk about the RIVM. *Trouw*, 27 January 1999.

Rotmans, J., van Asselt, M. Measurement is not beneficial for RIVM inquiry. *Trouw*, 28 January 1999.

Pulles, T. Not everything can be scientifically sound. *Trouw*, 29 January 1999.

Van Dobben, H., Verboom, J. en Wamelink, W. A calculation model is always better than a crystall ball. *De Volkskrant*, 29 January 1999.

Aarden, M., Trommelen, J. Kafka and the environment figures. *De Volkskrant*, 30 January 1999.

Bomhoff, E.J. Badly organised research. *NRC-Handelsblad*, 30 January 1999.

Hulsbosch, J.K. How controllable is scientific research? *De Volkskrant*, 30 January 1999.

Van Dommelen, A., Van der Schot, J. Not method but model determines outcome. *Trouw*, 2 February 1999.

Van Egmond, N.D. Models give measurement results meaning. *Trouw*, 3 February 1999.

Didde, R. en Mieras, M. Accurate figures: ten years after the environmental alarm. *Intermediair*, 4 February 1999.

De Berg, J. (*Trouw* Editorship). Question also the other party. *Trouw*, 5 February 1999.

Van de Sluijs, J., Schulte Fischedick, K. Crisis about authority on environmental figures. *Trouw*, 6 February 1999.

Quak, A. Government bases policy too often only on models. *Trouw*, 9 February 1999.

Van Staalduinen, M. Wageningen tests unscientifically. *Trouw*, 10 February 1999.

Trouw (Editorship Politics). Parliament: RIVM tested externally. *Trouw*, 11 February 1999.

Engels, J. Would competition not be better for RIVM? *Trouw*, 11 February 1999.

Klein Molenkamp, J.H. Independent testing of environmental figures necessary. *Trouw*, 11 February 1999.

Van der Steenhoven, J., Rabbae, M. Desired outcomes are easily bought. *Trouw*, 11 February 1999.

Van der Burg, T. CPB has the wrong conclusions. *Trouw*, 12 February 1999.

Trouw. Homage to the whistle-blower. *Trouw*, 12 February 1999.

Trouw. (Editorship Politics). Work of RIVM more precisely reviewed. *Trouw*, 12 February 1999.

Trouw. De Kwaadsteniet disappointed in Parliament. *Trouw*, 12 February 1999.

De Volkskrant. Suspended RIVM co-worker wants to go back to work. *De Volkskrant*, 19 February 1999.

Trouw. RIVM wants to get rid of scientist De Kwaadsteniet. *Trouw*, 19 February 1999.

De Volkskrant. Judge declares that civil servant is right. *De Volkskrant*, 25 February 1999.

Schoonen, W. De Kwaadsteniet has the wind behind him. *Trouw*, 25 February 1999.

De Volkskrant. RIVM appoints a confidant for co-workers. *De Volkskrant*, 26 February 1999.

Trouw. RIVM punishes critical co-worker after all. *Trouw*, 26 February 1999.

Trouw. (Editorship Politics) RIVM examined on quality of data. *Trouw*, 10 March 1999.

Engels, J. The balance is missing. *Trouw*, 29 April 1999.

Schoonen, W. The 'Djöficering' of the Netherlands. *Trouw*, 29 April 1999.

De Volkskrant. RIVM has to dispose of tasks due to less subsidy. *De Volkskrant*, 7 May 1999.

Trouw. (Editorship Politics). To economise RIVM has to dispose of research. *Trouw*, 7 May 1999.

Van Dommelen, A., Van der Schot, J. RIVM retrains to be an environmental detective. *Intermediair*, 9 September 1999.

Appendix 2: Research reports on uncertainty assessment

Research reports:

- Van Asselt, M.B.A. (2000). 'Perspectives on Uncertainty and Risk: The PRIMA approach to decision support,' Kluwer, Dordrecht, The Netherlands.
- Langendonck, R., Van Asselt, M.B.A., (1999). 'Searching for Uncertainty. A case-study on the Dutch National Environmental Outlooks', Maastricht, The Netherlands.
- Van Asten, F., (2000). 'Onzekerheid in de praktijk: Een toepassing van de PRIMA-aanpak op Milieuverkenningen 5,' Maastricht, The Netherlands.
- Van Asselt, M.B.A., Van Asten, F., (2000). 'Onzekerheid & Milieuverkenningen 5.' Workshop-rapport. Maastricht, The Netherlands.
- Van Asselt, M.B.A., van Asten, F., Langendonck, R., Rotmans, J. (1999). 'Uncertainty at Risk. Learning from the Dutch Environmental Outlooks'. Paper presented at the 1999 Open Meeting of the Human Dimensions of Global Environmental Change Research Community, Japan, 24-26 June 1999, Maastricht, The Netherlands.
- Van Asselt, M.B.A. (1999). 'Improving decision-making under uncertainty. An integrated approach to strategic risk analysis'. Paper prepared for the 9th Annual Conference of the Society for Risk Analysis 'facing the New Millenium', Rotterdam, the Netherlands, 10-13 October 1999, Maastricht, The Netherlands.

Appendix 3: Results of Post-Its sessions

The results of the Post-Its session are summarized in the following tables. In the far-right column (#) the number of Post-Its addressing a particular uncertainty is given. The source of the uncertainty is also given for 46 uncertainties. On 29 Post-Its, an accompanying uncertainty-range was (roughly) indicated. The numbers shown in superscript in the second column, indicate to which uncertainty source (see the corresponding first column) the mentioned uncertainty range refers. The clustered uncertainties (i.e. the rows) are rank-ordered according to the number of times the particular uncertainty-cluster was mentioned on the Post-Its.

Table 27 – Institutional uncertainties

Institutional			
Uncertainty	**Range**	**Source**	**#**
Effect and implementation of measures, degree of implementation / effectiveness of measures[1] / effectiveness of policy / degree of enforcement		Conflicting evidence[1], Lack of measurements[1]	5
The role of the state (who makes decisions)[1] / degree of influence on politics / rulers/ translation of policy from national government to local councils[2]/ institutional developments[3]	Large: much 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 and 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	Increasingly more considerations	Policy/behaviour	1

Table 28 – Socio-cultural uncertainties

Socio-cultural			
Uncertainty	**Range**	**Source**	**#**
Behaviour[1] / behavioural changes / interaction: 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 of actors to policy and the instruments [4]	50%[2]	Human actions[1], Lack of knowledge[2], 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

Socio-cultural			
Uncertainty	**Range**	**Source**	**#**
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 several million for the Netherlands[1]		2
Inner-city traffic problems			1

Table 29 – Nature and environmental 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 with or uncertainty of functions of ecosystems[2]/ environmental pressure → ecosystems	30%[2]	Unpredictability of nature[1], lack of knowledge of long-term developments in 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	Depends on who asks	System knowledge/ translation between scale levels (variability)	1

Table 30 – Economic uncertainties

Note: Empty boxes indicate that no remarks were made on the Post-Its regarding range and source.

Economy			
Uncertainty	**Range**	**Source**	**#**
Technology[1] / technological development[2] / technological innovation (speed & extent)[3]/ technological developments in relation to behaviour[4]	Large potential effect, large uncertainty[2]	Variability[1], technology[3] indeterminacy [4]	6
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

Appendix 4: Overview of perspective-based interpretations

The tables below summarise the perspective-based interpretations per category. Empty cells indicate that the working group did not address that particular uncertainty in terms of a perspective-based interpretation or evaluation.

Table 31 – Perspective-based interpretation of institutional uncertainties

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

Table 32 – Perspective-based interpretation of socio-cultural uncertainties

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			

Table 33 – Perspective-based interpretation of nature and environmental 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 there is a good chance that the Netherlands will be flooded	Global problem
Emissions	Strongly regulated, thus predictable		Will increase if economy continues to grow
Dose-effects	On the safe side	Emphasis on local, human problems	Worried about unknown artefacts in 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

Table 34 – Perspective-based interpretation of economic 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 from consumer pressure	Problems cannot be solved by technology; eco-technology is a necessary evil; integrated process technology
Behaviour of economic sectors	Regulation of economic sectors and consumption patterns by levies and covenants	Role of multinationals; environmental programmes initiated by companies	Steady-state economy; economy is not an aim
Structure and size of Dutch industry			
Global recession	*Risky uncertainty*	*Risky uncertainty*	

The policy options that may be derived from the output of the working groups are summarised in Table 35.

Table 35 – Policy options per perspective (derived from workshop output)

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 for new environmental risks
		Closing of cycles
		Integrated process technology

It should be noted that articulation of management style was not an explicit exercise in this workshop. The above enumeration shows the management style aspects that can be derived from this workshop and used as input to follow-up steps.

Appendix 5: Preparation of MV-5 uncertainty interviews

Preparation for interviews

Within the framework of the international review of the MV-5 and with a view to the development of uncertainty methodology within the framework of MAP-Environment and MAP-SOR, staff members will be interviewed in pairs about the handling of uncertainty in MV-5. This evaluation will focus on the topics of consumption (including mobility) and technology; uncertainty in the 'source-effect' causality chain will also be carefully evaluated. You belong to the group of people who will be interviewed. It is important that you prepare yourself in such a way for the interview that it will result in a realistic overview of the actual course of events in the MV-5. As an aid to preparation, we are asking you to answer some questions below. During the interview you will have the opportunity to further explain your answers. We would also like to ask you to consider in advance what you would like bring up about 'uncertainty' in the MV-5.

Questions to complete:
Give your opinion on the following statements:

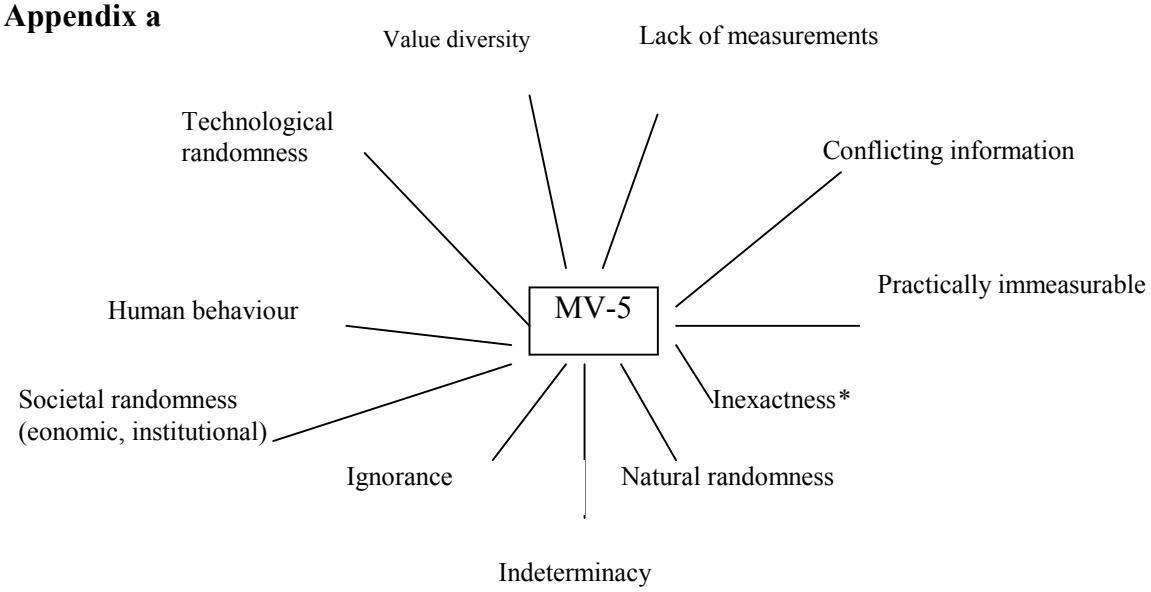
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Knowledge is not the same as truth and certainty					
Science is solving uncertainties					
More knowledge implies less uncertainty					
Uncertainty is poor science					
Measuring means knowing					
Uncertainty can be captured in numbers					

1. Delete in attachment 1 those sources of uncertainty that play no role in the MV-5 in your opinion. Subsequently, classify by means of numbers, which sources of uncertainty you consider most important for the MV-5 (from1 for the most important, 2 for the next important, 3 for the next, etc.).
2. Attachment 2 reports the uncertainties arising from the uncertainty workshop (June 1999). Delete the uncertainties that you consider irrelevant for the MV-5. Indicate per cluster the two least important uncertainties (by means of – and --) and the two most important uncertainties (by means of + and ++).
3. Do you miss any uncertainties in this overview; is, what is the source of these uncertainties? Indicate the relevance of these uncertainties.
4. Within MV-5 you are responsible for ……..? What relations exist between this topic, consumption (including mobility) and technology? Could you delineate this in a causal diagram? (see attachment 3 for an example) What relations are taken into consideration in the MV-5?
5. On the basis of your expertise, which uncertainties play a role in this combination?

6. Can you estimate the order of magnitude of these uncertainties[230], use of attachment 4 to do this. About which uncertainty is more information urgently needed, and which information involves this?
7. Check the mentioned uncertainties one-by-one with the question: Is this uncertainty included in the MV-5, and if so, how?

Annotations – remarks you would like to make about uncertainty during the interview

Appendix a



** Including approaches and simplifications; this category relates to data as well as models.*

Clarification

Uncertainty is a vague concept; it has meaning, but no content. This makes it a very difficult topic to communicate on. To understand the concept of uncertainty better, we made a taxonomy of sources of uncertainty, built on the scientific literature on uncertainty. On the highest level of aggregation, 'lack of knowledge' and 'variability' are the two most important sources of uncertainty.

'Lack of knowledge' is a quality of analysts who do the research and/or of the current level of knowledge. There are different degrees of lack of knowledge:

- *Inexactness* (we roughly know)
- *Lack of measurements* (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.)

[230] *Specify exactly where the uncertainties are located and how prominent and on how they make themselves felt. Keep in mind that the uncertainties might be considerable re. (sub)divisions, but that their effect on, for example, end results and conclusion might be limited. In other words, this is clearly a matter of a combination of uncertainty and sensitivity.*

- *Conflicting evidence*: different data sets are available and can be interpreted in a competing manner. (We do not know what we do not know.)
- *Ignorance*: 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 will in the future. (We do not know what we do not know.)
- *Indeterminacy*: there may be processes of which we understand the principles and laws, but which can never be fully predicted. (We will never know.)
- The first three degrees of 'lack of knowledge' are also referred to as 'unreliability' and the latter three are also referred to as 'structural uncertainty' or 'systematic uncertainty'.

Variability is defined as uncertainty because a system can behave in different ways or is valued differently. Variability is connected to different sources:

- Natural randomness
- Value diversity
- Behavioural variability
- Societal randomness
- Technological randomness

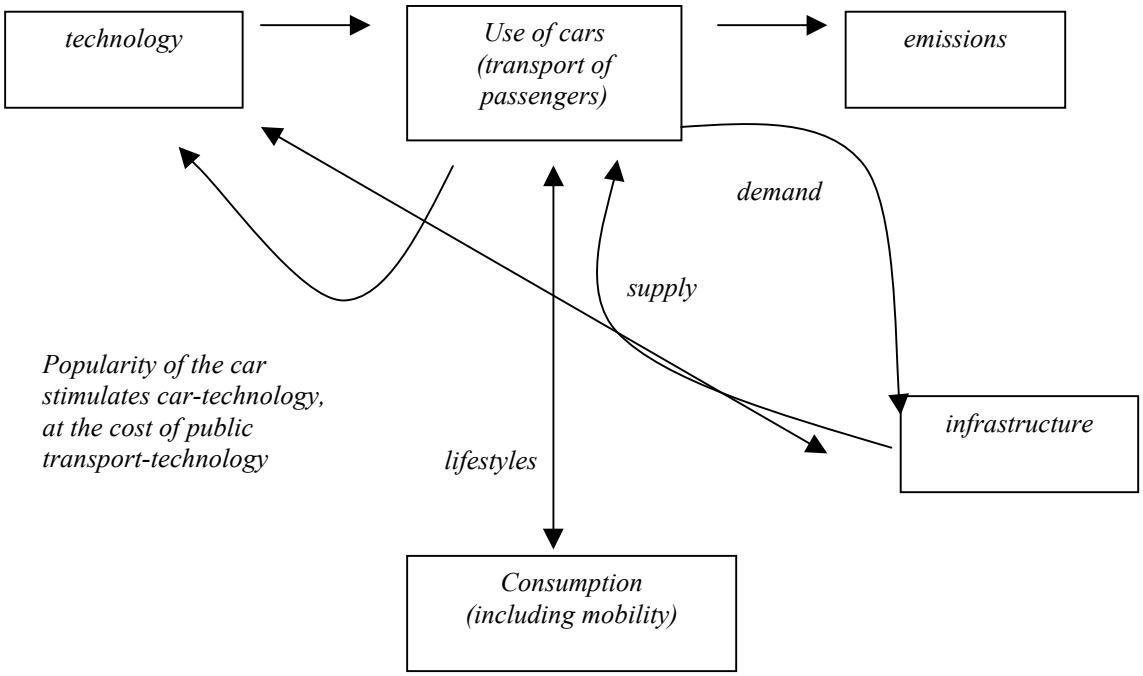
Appendix b: Overview of uncertainties relevant for the RIVM based on the workshop 'uncertainty and environmental outlook'

(See also Van Asselt and Van Asten – 'uncertainty and MV-5: workshop report')

Institutional	
Effect and implementation of measures, degree of implementation / effectiveness of measures / effectiveness of policy / degree of enforcement	
The role of the state (who makes decisions) / degree of influence on politics / rulers/ translation of policy from national government to local councils / institutional developments	
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 / Influence of foreign environmental policy and behaviour	
Escalation of conflicts in the Third World / instability (war) / discrete, once-only changes 'disasters' / Discontinuity of social developments	
Policy objectives: Prevention versus broad considerations	
Social-cultural	
Behaviour / behavioural changes / interaction with technology – behaviour / realisation of desired behaviour / Human factor (policy, behaviour) / Human actions (whether or not according to the rules) / Reaction of society to the policy / Reaction actors to policy and the instruments	
Attitude of citizens to improvements in the quality of the environment / response of people to the decline of the environment (+ eco) policy / Social preferences	
Consumer behaviour / pattern of consumption 2030 / reaction of producers and consumers to the consumption pattern (+ consumption of nature)	
Social development	
Demography / Migration	
Inner city traffic problems	

Environment and nature	
Climate variability / climate system variability / occurrence of climate changes / Long term (100 – 1000 years) fluctuations in the climate and ecosystems	
Collective (basic) emission (ERC) / predictability of emissions / emissions, in particular spatial differentiation / air emissions / emission information, e.g. fine dust, ammonium	
Human + ecological effects / Effects on humans and ecosystem / Dose-effect relations	
Response of ecosystem (fauna + flora) to the decline of quality of the environment / Unfamiliarity of uncertainty of functions of ecosystems/ Environmental pressure → ecosystems	
Speed of change of ecosystems to climate changes / feedback mechanisms climate-hydrology-ecology	
Relation of CO2 and threats via weather/climate, influences of weather	
Global supplies, water, energy, food production	
Natural variability (in contrast to highly authorised indicators)	
Economy	
Technology / technological development / technological innovation (speed & extent) / Technological developments in relation to behaviour	
Economy, behaviour of the economic sectors	
Structure + size of Dutch industry	
Occurrence of global economic recession	

Appendix c – fictitious example of a relationship diagram



Appendix d – Quantifying uncertainty ranges

Uncertainty	**small medium large** *definition*	**quantitative range**	**remarks**

First, the respondent needs to define what he/she means by small/medium/large to be able to promote the comparability of the answers

APPENDIX 6: Interview guide of MV-5 uncertainty interviews

Interview guide

The following questions will be used as a basis; they are not necessarily posed in the following order and wording.

Questions:

Part 1 – Introduction

Target: to gain insight into the background, environmental outlook experience and expertise of the respondents.

1. What is your scientific background and expertise?
2. Since when did you work for RIVM? Since when were you involved in the environmental outlooks and in what function?
3. What is your role in the MV-5? In what topics are you involved?

Part 2 – Attitude uncertainty

Target: to gain insight into the attitude of the respondents to supply information for understanding / explaining specific choices later on.

1. What is your opinion about the 'DeKwaadsteniet affair'? Did De Kwaadsteniet have a point or not, why/why not?
2. How important do you consider uncertainty in relationship in your own work?

Statements on a five-point scale:

- Knowledge is not the same as truth and certainty.
- Science is solving uncertainties.
- More knowledge implies less uncertainty.
- Uncertainty is poor science.
- Measuring means knowing.
- Uncertainty can be captured in numbers.

Part 3 – MV-5 and uncertainty

Target: To gain global insight into how, according to the respondents, uncertainty was handeled in the MV-5.

1. How was uncertainty 'managed' in the assessment process and why in this manner? Which methods and approaches were used?
2. Do you think that uncertainty was dealt with adequately in the MV-5? If so, how does this show? If not, what should have been done better?

Part 4 – Uncertainties in MV-5 – in general

Target: To gather information as an aid to a thorough overview of the uncertainties relevant for the MV-5.

1. Delete in attachment 1 those sources of uncertainty that you consider unimportant for the MV-5. Subsequently, classify by means of numbers, which sources of uncertainty you consider most important for the MV-5. Explain why.
2. Attachment 2 reports the uncertainties taken from the uncertainty workshop (June 1999). Delete those uncertainties that you consider irrelevant for the MV-5. Indicate per cluster the two least important uncertainties (by means of + and ++) and the two most important uncertainties (by means – and --).
3. Do you miss any uncertainties in this overview, and what is the source of these uncertainties?

Part 5 – uncertainties in MV-5 - specific

1. Within MV-5 you are responsible for …….? What relations exist between this topic, consumption (including mobility) and technology? What relations are taken into consideration in MV-5? *(delineate in a causal diagram)*

2. Based on your expertise, which uncertainties play a role in this combination? *(if necessary use the overview of sources and lists of the workshop; use questions in the previous part to stimulate the respondent)*

3. Can you estimate the order of magnitude of these uncertainties, and on what do you base these estimations? *(make use of attachment 3)*

4. Check the uncertainties mentioned one by one with the question: Is this uncertainty included in the MV-5, and if so, how? *(make use of the inventory of uncertainty techniques derived from PhD, see attachment 4)*

5. Are you satisfied with the manner in which the uncertainties mentioned are managed? If so, indicate why you did it this way? If not, what should have – ideally – been done differently and why?

6. Why are the uncertainties not included? What is the consequence of this for the robustness of the conclusions of the MV-5 in the area of consumption (including mobility) and technology?

7. How could relevant uncertainties, which are not included this time in your opinion, be included in the assessment process?

APPENDIX 7: Respondents' judgements on uncertainty

The full overview of the rankings in terms of ++ (very important), + (important), - (of minor importance) and – (unimportant) is provided in Table 36. Empty cells indicate that this cluster of uncertainty was not relevant to a respondent's field of expertise.

Table 36 – Respondents' judgements on importance of uncertainties

Classification per respondent Uncertainties	***1 A***	***2 A***	***3 T***	***4 T***	***5 S***	***6 N***	***7 N***	***8 N***	***9 N***	***10 E***	***11 G***	***12 C***	***13 O***
Institutional													
Effect and implementation of measures, degree of implementation / effectiveness of measures / effectiveness of policy / degree of enforcement	--			+	++			+		+	+		+
The role of the state (who makes decisions) / degree of influence on politics / rulers/ translation of policy from national government to local councils / institutional developments	++			-				-		++			-
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 / Influence of foreign environmental policy and behaviour	++	+	+	+	+			-		+	+		
Escalation of conflicts in the Third World / instability (war) / discrete, once-only changes 'disasters' / Discontinuity of social developments				-	-			-		+/-	-		-
Policy objectives: Prevention versus broad considerations	--				--			-		-	-		
Social-cultural													
Behaviour / behavioural changes / interaction with technology – behaviour / realisation of desired behaviour / Human factor (policy, behaviour) / Human actions (whether or not according to the rules) / Reaction of society to the policy / Reaction actors to policy and the instruments		+	+	+	+			-		+	-	+	+
Attitude of citizens to improvements in the quality of the environment / response of people to the decline of the environment (+ eco) policy / Social preferences								+		++		+	-
Consumer behaviour / pattern of consumption 2030 / reaction of producers and consumers to the consumption pattern (+ consumption of nature)		+	++	+	++			-			+	++	-
Social development				-	--			-			+	+	-
Demography / Migration			-	-	-			-		-	+	+	-
Inner city traffic problems		-	--					-		+	+	+	-
Environment and nature													
Climate variability / climate system variability / occurrence of climate changes / Long term (100 – 1000 years) fluctuations in the climate and ecosystems	+	+					-	-	++	++	+		-

Collective (basic) emission (ERC) / predictability of emissions / emissions, in particular spatial differentiation / air emissions / emission information, e.g. fine dust, ammonium	+					--	+	++	+	-	+		+
Human + ecological effects / Effects on humans and ecosystem / Dose-effect relations	++	+				+	+	+	+	++	+		
Response of ecosystem (fauna + flora) to the decline of quality of the environment / Unfamiliarity of uncertainty of functions of ecosystems/ Environmental pressure → ecosystems	++	+				++	+	+	++	+	+		
Speed of change of ecosystems to climate changes / feedback mechanisms climate-hydrology-ecology	+						-	-	+	+	+		
Relation of CO2 and threats via weather/climate, influences of weather	+						-	-	-	+	+		-
Global supplies, water, energy, food production	+						-	-	-	+	+	++	-
Natural variability (in contrast to highly authorised indicators)	+	+				-	+	-	+	-	-		+
Economy													
Technology / technological development / technological innovation (speed & extent) / Technological developments in relation to behaviour		+	++	+	++			-		++	-		+
Economy, behaviour of the economic sectors		+	+	+				-		+	-	+	+
Structure + size of Dutch industry	--				+			-		-	-	--	-
Occurrence of global economic recession		-	--	-				-		+		+	

Legend

A: Air Pollution; T: Technology; S: Scenarios; N: Nature; E: Energy; G: General; C: Consumption; O: Overfertilisation and desiccation