A *Leidraad* for Uncertainty Scanning and Assessment at RIVM

Jeroen van der Sluijs[1], James Risbey[1], Penny Kloprogge[1], Jerry Ravetz[2]
Silvio Funtowicz[3], Serafin Corral Quintana[3], Ângela Guimarães Pereira[3]
Bruna De Marchi,[4] Arthur Petersen[5], Peter Janssen[5]
Rob Hoppe[6], Simone Huijs[6]

[1]Copernicus Institute for Sustainable Development and Innovation
Universiteit Utrecht, The Netherlands

[2]Research Methods Consultancy, London, UK

[3]Institute for the Protection and the Security of the Citizen, JRC, Italy

[4]Institute of International Sociology, Gorizia, Italy

[5]National Institute of Public Health and the Environment (RIVM)
The Netherlands

[6]Faculty of Public Administration and Public Policy
Universiteit Twente, The Netherlands

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Contents

Preface to Leidraad

I Introduction

This document provides an outline of a 'leidraad' for treatment of uncertainty in environmental assessments. We use the Dutch term leidraad to connote a form of guidance, offered if it can be of assistance, without expectation or obligation. The leidraad is oriented specifically toward the environmental assessment activities of the National Institute of Public Health and the Environment (RIVM). The leidraad is a tool which should provide assistance to RIVM in assessing and communicating uncertainties in, among other things, RIVM's Environmental Outlooks and Environmental Balances. The 'leidraad' is intended to provide assistance in this task, promoting self-education and good practice. However, the leidraad tool is only useful in so much as it does actually assist in assessing uncertainties. It should not hinder the job of the analyst or be used so rigidly that it begins to mislead or provide a false sense of security. Further, some comprehensiveness must be sacrificed in any tool of this sort, and there will inevitably be important issues that fall outside its scope.

This document is organized as follows. The rest of the preface provides a description of the background and goals of the leidraad, a brief outline of the components of the leidraad, and introduces an uncertainty typology to be used in the leidraad. The leidraad then follows, and has been organized into a series of steps corresponding to each section. At the end of each section there is a brief outline in shaded boxes of the outputs that can be expected from that part of the leidraad. In some parts of the text there are plain boxes that indicate the reasoning underlying responses to leidraad questions. In a future web version of the leidraad these elements will be incorporated into the leidraad architecture to provide direct feedback from responses.

I.1 Goals

The goals for development of the leidraad are as follows:

- Structure an approach to environmental assessment that facilitates an awareness, identification, and incorporation of uncertainty.
- Specifically address and relate the role of uncertainties in the context of policy advice
- May not *reduce* uncertainties, but provide means to assess their potential consequences and avoid pitfalls associated with ignoring or ignorance of uncertainties.
- Guidelines for use and help against misuse of uncertainty tools.

- Provide useful uncertainty assessments.
- Fit RIVM's specific role in the decision analytic cycle
- Promote the adoption of uncertainty awareness methods in common practice at RIVM
- Facilitate the design of effective strategies for communicating uncertainty.

Note that the leidraad uses 'uncertainty assessment' to aid in 'environmental assessment'. The former term refers to the set of methods and processes used to cope with uncertainty. This is one element of a larger process to assess an environmental problem, which goes by the term 'environmental assessment' here. The leidraad is not a guide to environmental assessment methods in general (which encompass more than just uncertainty assessment), but focuses on the intersection between uncertainty assessment and environmental assessment. The form of assessment intended in each case will be made clear throughout the leidraad.

I.2 Intended Users

The leidraad is intended for use in the environmental assessment process at RIVM. As such, it is pitched at project leaders and team members, but account managers, interfacers, theme coordinators, policy dossier keepers, and policy advisers can also benefit from parts of the leidraad. Users may place emphasis on different parts of the leidraad depending on their own roles and tasks, but it should be broadly accessible to all, and each part should be comprehensible to the project leaders. A shorter version of the leidraad is also provided here, and is denoted by the term 'quickscan'. The quickscan component of the leidraad provides a shorthand device for allowing different groups or individuals to set their own context for a problem. This in turn can facilitate comparison of quickscan results to reveal divergences of opinion or approach among team members early in the assessment process.

I.3 Existing Elements

Each environmental assessment project carried out by RIVM does not start with a blank slate. Further, many analyses are iterative, building on earlier work, rather than wholly novel. In every case, there is some set of existing resources and experience that can be brought to bear. These should be identified and utilized in the leidraad. In addition, the leidraad does not build from scratch either. There is by now a large body of uncertainty typologies, methodologies, and processes. Many of these have been identified and classified for use in the leidraad. A summary of some of these existing elements follows.

Tasks. In the process of carrying out environmental assessments at RIVM a common set of tasks tend to be encountered. These include monitoring-studies (emissions, concentrations), model- and data-based assessments, indicator-choices, scenario development and analysis, policy analysis and evaluation. A body of experience has already been developed in carrying out these various tasks. Further, each task tends to have characteristic methods that are used in solution. In turn, these methods have their own characteristic uncertainties.

Uncertainty types. The uncertainties characteristic of particular problems or methods should be organized in a form suitable for analysis. The organization of uncertainty types is described in the typology in section I.4. Different uncertainties have different properties, and a suite of uncertainty assessment methods have been developed to address them.

Uncertainty tools. A range of methods exist to address both quantitative and qualitative aspects of uncertainty. Examples of such methods are sensitivity analyses, NUSAP, PRIMA, and checklist approaches. Many of these methods have been drawn together in an uncertainty toolbox for the leidraad (see section C).

Processes. A focus on uncertainty tools alone is inadequate for capturing many of the qualitative dimensions of uncertainty. For this purpose a number of process based approaches have also developed. This set includes extension of peer communities, incorporation of stakeholders into the assessment process, problem framing from multiple perspectives, education, and communication.

I.4 Uncertainty Typology

A variety of different types of uncertainty have been defined and used in the literature and practice. For the purpose of the leidraad tool, it is important to agree upon a standard nomenclature and classification of uncertainties. There is no one particular uncertainty classification or typology that is universally agreed to be 'best' for all purposes. Thus, we had to be pragmatic and sought to compile a typology that makes reasonable sense for the kinds of tasks carried out by RIVM without claiming to be the only useful classification system. An uncertainty typology has been synthesized from a variety of pre-exiting typologies and tuned specifically for the leidraad. The uncertainty typology is included as appendix A. A shortened version of the typology is given in table 1 on page 8.

The typology classifies uncertainties according to the 'sort' of uncertainty and to their typical 'locations' (where they occur). The different sorts of uncertainty are those due to 'inexactness', 'unreliability', and 'ignorance'. *Inexactness* measures the spread in value of a quantity due to variability and heterogeneity in the underlying data used to represent the quantity. *Unreliability* refers to the quality of the inexactness estimate, and is typically influenced by the rigour and strength of the methods

location ↓ sort →	inexactness	unreliability	ignorance
sociopolitical and institutional context			
system boundary			
model or instrument			
inputs			

Table 1: Simplified uncertainty typology

used. Finally, there will inevitably be some aspects of the quantity in question which are not known or cannot be known, which fall under the category of *ignorance*. There are many different locations in which uncertainty is manifest. In table 1 we distinguish only four broad locations: the *sociopolitical and institutional* setting for the problem being analysed, the drawing of a *system boundary* around the problem being analysed (including some aspects of the problem and excluding others), the *instruments* used to analyse the problem, and the set of *inputs* to analysis.

The uncertainty typology provides a common language for viewing uncertainty in the leidraad. In the problem framing section of the leidraad, key uncertainties will be identified and related to the typology. In turn, each uncertainty in the typology is then related to the kinds of methods and tools which have been developed to deal with it. The typology thus becomes a focal point of the leidraad process.

I.5 Uncertainty Glossary

An extensive glossary of terms has been developed for the leidraad. The glossary is available in appendix B and online at http://www.nusap.net. The aim of the glossary is to provide clear definitions of the various terms used throughout the leidraad, or encountered in uncertainty assessment more generally. The glossary should also serve to minimize uncertainties due to linguistic imprecision or confusion about what particular terms are intended to convey.

I.6 Leidraad Steps

The steps in the leidraad are not necessarily made in a fixed sequence. While the quickscan and problem frame steps need to be taken first to initiate an assessment, the other steps may follow and recur in any order and/or simultaneously, and the whole sequence can be iterated.

Quickscan. A short broad checklist to provide a first indication of possible key issues and uncertainties. It should also orient analysis and provide *some* information prior to a full assessment. The quickscan can be used on its own for rapid scanning of problems.

Problem Framing. Identify the problem, context and history. For whom is it a problem and how is it framed? Provide an initial outline of the main issues and characteristics, interests, disputes, and possible solutions. Classify the problem type and structure, together with implications of these characteristics for uncertainty assessment. Provide an initial ranking of the salience of sociopolitical and institutional uncertainties.

Communication. Produce a map of the information flow at RIVM between analysts, project leaders, the media, ministry, and other outside institutions. Identify relevant communication pathways and points in the assessment process at which they need to be active. The role of stakeholders is also key for communication and is addressed in the next step.

Process Assessment. Given the characteristics of the problem (problem framing), what are the implications for process? Identify the different stakeholder groups and their characteristic values in regard to the problem. What are the appropriate roles for each of these groups? Where and when in the problem formulation and solution phases should they be involved and via what processes? Identify appropriate processes.

Environmental Assessment Methods. The environmental assessment process will entail use of various methods or tools to carry out the analysis. Such methods may include monitoring, modelling, scenario generation, policy exercises, focus groups, questionaires, and backcasting exercises for instance. Identify the methods used and characterize the uncertainties associated with these methods using the uncertainty typology.

Uncertainty Identification and Prioritization. For each step above (problem framing, process assessment, and environmental assessment methods), identify key uncertainties using the nomenclature in the uncertainty typology. Identify the best available method to approach each uncertainty, along with an indication of the strengths and limitations of the method. Identify any gaps between uncertainty methods required and those used or proposed. Describe potential consequences of gaps or weaknesses in uncertainty assessment. Make an initial prioritization of the potentially most important uncertainties.

Uncertainty Analysis. Carry out the prescribed set of uncertainty analyses for this problem. Checklists and other uncertainty methods will be used in the analysis as appropriate to the task and methods in question.

Review and Evaluation. Provide a review and summary of the analyses undertaken. Redo earlier steps or add steps if appropriate. Evaluate the robustness of results from the environmental assessment.

Reporting. Engage the identified audiences in a process of understanding results and their implications. Include dissenting or minority viewpoints. This may take the form of advice, a dialogue, or other, as appropriate to the context and processes identified (process assessment step). Note that though listed at the end here, the process assessment step may have identified communication and reporting efforts to occur throughout the assessment period.

II Quickscan

The uncertainty quickscan instrument for environmental assessment studies and policy evaluation is provided as as separate document.

III Leidraad

1 Problem Framing and Context

First, the broad context of the problem is set by identifying major issues, past work, the level of contention, and the role of assessment. The identification and role of stakeholders will be elaborated in section 2.

1.1 Problem Frames

A problem frame is literally a way of seeing or framing a problem. The following questions provide a problem frame scan to analyse a problem frame from any given perspective — that of the analyst or different stakeholder groups. The frame may be one that you use or that is used by someone with whom you have to communicate.

Since the problem frame section comes before the section on identification of stakeholders, the idea is that you will complete the problem frame section primarily from your own perspective the first time. After you have identified relevant stakeholders in section 2.1, you may wish to return to this section and redo it from the different stakeholder perspectives.

1. Describe the problem from your point of view.

   ¬

2. Describe the history of this problem in broader socio-political context.

   ¬

3. What boundary do we/they draw around the problem? In other words, what aspects of the problem situation do we/they leave out of scope?

   ¬

4. What criteria and benchmarks do we/they use to measure success in managing the problem?

   ¬

5. How is the burden of proof set?

   Choose one of the following:

   - ☐ this is a problem requiring action until proven otherwise
   - ☐ this is not a problem until proven otherwise
   - ☐ other (describe)

6. What metaphors or analogies do we/they use to think about this problem?

¬

7. What is being under- or over exposed in the problem frame we/they use?

¬

8. Can we summarize our/their problem frame in a single slogan?

¬

1.2 Problem Assessment

1. What is the role of analysis/assessment for this problem?

   Check all that apply:

   ◇ to evaluate existing policy

   ◇ to evaluate proposed policy

   ◇ to foster recognition of a problem

   ◇ to aid in the management of a transition

   ◇ to suggest possible solutions

   ◇ to provide contra-expertise

   ◇ other (describe)

2. How urgent is the problem? What is the time frame for analysis?

days	months	years
☐	☐	☐

3. Describe the results of any previous studies on this problem.

¬

4. For whom is this a problem: Who loses? Who gains?

¬

5. Identify key public interests at stake.

¬

6. Identify key private interests at stake.

¬

7. Describe any solutions that have been put forward for this problem. Comment on the feasability, acceptability, and effectiveness of each proposed solution.

¬

8. Describe any key disputed facts

¬

9. Describe key value issues.

¬

10. What are the key inputs to assessment?

¬

11. What are the key outputs or indicators from the assessment process?

¬

12. How well do the key outputs or indicators address the problem?

scarcely	moderately	adequately
☐	☐	☐

13. For some environmental assessments there may be specific indicators that have been declared in advance that must be monitored. Are there (legal) norms or policy targets to which any of the key outputs from the assessment must comply?

no targets	general policy targets	legally binding targets
☐	☐	☐

If so, specify them.

14. When estimates for a particular indicator are close to a legal norm or target, then estimates of uncertainty are particularly critical. How close are current estimates of any indicators to these norms or targets?

well below	just around	well above
☐	☐	☐

15. What roles do models play in the assessment?

Check all that apply:

◇ to provide a structured knowledge archive

◇ for communication of knowledge and educating

- ◇ for building community and shared understanding
- ◇ for exploration and discovery
- ◇ to provide predictive information to policy
- ◇ other (describe)

16. How is the problem reflected in the 'model'?

scarcely	moderately	adequately
▭	▭	▭

17. List any key aspects of the problem that are not reflected (or poorly reflected) in the 'model'.

18. What methods will be used in assessment?

    Check all that apply:

- ◇ modelling
- ◇ scenario generation or use
- ◇ focus groups
- ◇ stakeholder participation
- ◇ expert elicitation
- ◇ sensitivity analyses
- ◇ qualitative uncertainty methods
- ◇ other (describe)

1.3 Problem Structure

This section is intended to help draw out the broad structure of the problem to place it on a spectrum from more structured technical problems to more unstructured post-normal science problems. The degree of structure of the problem will have implications for the kinds of uncertainties and approaches to use as well as for the involvement of stakeholder groups. Note that different stakeholders may have different views of the problem structure from one another and from the analysts. In that event it may be useful to redo this section from the point of view of each of the relevant stakeholders.

Implications from structure diagram

1. Score the problem according to the level of agreement about what kind of knowledge is needed to solve the problem

low	high
☐	☐

2. Score the problem according to the level of consent on norms and values

low	high
☐	☐

If agreement on what kind of knowledge is needed is low and consent on norms and values is low, then the problem is unstructured. Highlight uncertainties of type ignorance and value loading. Typically requires public debate, conflict management, and reflexive science.

If agreement on what kind of knowledge is needed is high and consent on norms and values is high, then the problem is well structured. Typically requires normal scientific procedures.

If agreement on what kind of knowledge is needed is low and consent on norms and values is high, then the problem is moderately structured. Highlight uncertainties involving unreliability and ignorance. Typically requires mutual partisan adjustment, stakeholder involvement, and extended peer acceptance.

If agreement on what kind of knowledge is needed is high and consent on norms and values is low, then the problem is moderately structured. Highlight uncertainties involving value loading, particularly related to knowledge utilization. Typically requires accomodationist policy and reflexive science.

Implications from Post-normal science

3. Score the problem according to the level of decision stakes

low	high
☐	☐

4. Score the problem according to the level of systems uncertainty

low	high
☐	☐

If the decision stakes are low and system uncertainty is low, then the problem is mostly in the technical domain. Highlight uncertainties involving inexactness and unreliability only. Stakeholder involvement is not so key.

If the decision stakes are high and system uncertainty is high, then the problem is one of post-normal science. Highlight uncertainties involving value loading and ignorance. Typically require extended peer communities in working the problem and close stakeholder involvement.

If the decision stakes are high and system uncertainty is low, then the problem is still post-normal, but with less emphasis on scientific uncertainty. Explore instead legal, moral, societal, institutional, proprietary, and situational uncertainties. Typically requires efforts to bring stakeholders together in the solution phase.

If the decision stakes are low and system uncertainty is high, then the problem may be subject to changes in its structure. Highlight uncertainties involving unreliability and ignorance. While the low decision stakes may imply a diminished role for stakeholders, they should be involved as a precaution since the system uncertainty is high.

1.4 Problem Lifecycle

The lifecycles of environmental problems do not readily conform to idealized models. Nonetheless, it is useful to speak of problems as being in certain phases, such as recognition, active debate, implementation, monitoring, and so on. In practice a problem may move back and forth between various stages as new information comes to light. In this section we try to determine the current phase of the problem, if such exists. This can be useful to gauge the level and stage of involvement of different groups on this issue.

1. Is the issue recognized as a problem among the following groups:

	hardly	partially	mostly
scientists	☐	☐	☐
those directly affected	☐	☐	☐
media	☐	☐	☐
research organizations	☐	☐	☐
NGO's	☐	☐	☐
community groups	☐	☐	☐
advisory bodies	☐	☐	☐
political actors	☐	☐	☐
legal actors	☐	☐	☐

2. Have solutions been actively discussed and debated?

hardly	moderately	intensively
☐	☐	☐

3. Have efforts at implementation of solutions begun?

hardly	moderately	intensively
☐	☐	☐

4. To what extent will current efforts (if any) at implementing solutions likely solve the problem?

hardly	moderately	mostly
☐	☐	☐

5. Has monitoring of policies been put into effect?

none	partial	intensive
☐	☐	☐

6. Are there any indications that this problem has been under or overestimated so far? By whom?

underestimated	well estimated	overestimated
☐	☐	☐

7. Based on your answers to the previous questions, how would you rate this problem overall?

immature	active	mature
☐	☐	☐

Implications for methods and uncertainty types

if problem phase immature — important to identify stakeholders if problem structure indicates values important, then the stakeholders should be involved early in the project. if problem phase active — work with existing stakeholders if problem phase mature — less critical to engage stakeholders

1.5 Uncertainty in Socio-political Context

The uncertainty typology shown in table 1 provides most detail on scientific uncertainty and less detail on sociopolitical and institutional uncertainties. This section provides more detail on the latter uncertainties to address their implications for the assessment process. De Marchi et al. (1994) have outlined seven distinct types of uncertainty, which are defined in the glossary (appendix B). In the left hand column of the table below, rank the uncertainties in terms of their relative salience to the problem, from '1' (most salient uncertainty type) to '3' (third most salient uncertainty type). Independent of the relative salience of each uncertainty, you should also provide a judgement on the severity of each type of uncertainty by selecting one of the boxes to the right. Some examples may illustrate the point. It is possible that scientific uncertainty could by severe (high), but the scientific uncertainties may not be important to the policy process — in which case the salience of scientific uncertainty would be ranked low relative to the other uncertainties. Conversely, scientific uncertainties could be relatively mild, but still dominate a problem that was relatively technical and devoid of salience in the other uncertainty dimensions.

1. Rank the salience and severity of the different types of uncertainty for this problem:

salience rank		*severity* low	medium	high
☐	scientific	☐	☐	☐
☐	legal	☐	☐	☐
☐	moral	☐	☐	☐
☐	societal	☐	☐	☐
☐	institutional	☐	☐	☐
☐	proprietary	☐	☐	☐
	situational	☐	☐	☐

IMPLICATIONS FOR METHODS AND UNCERTAINTY TYPES

if scientific uncertainty salient and severe, highlight inexactness, unreliability and ignorance uncertainties as appropriate

if legal uncertainty salient and severe, the assessment process should involve legal analysts

if moral uncertainty salient and severe, highlight value loading uncertainties and involve stakeholders with different views of problem frame

if societal uncertainty salient and severe, involve stakeholders representative of different social views of the problem and decision process

if institutional uncertainty salient and severe, highlight communication between RIVM and other institutions that may reduce this

if proprietary uncertainty salient and severe, identify inequity in access to knowledge and highlight communication steps or empowerment issues to address this

if situational uncertainty salient and severe, describe the decision process and highlight communication steps within RIVM or with outside people that may reduce this

Outputs from section 1

→A description of the problem.
→A gauge of how well assessment tools address the problem.
→A list of which uncertainties are salient on the basis of problem structure.
→An indication of the relevance of uncertainty for the policy problem at hand.
→An indication of whether to involve stakeholders or not.
→A scoring of the maturity of the problem in the policy process.
→A relative ranking of scientific and socio-political uncertainties.

2 Process Assessment

The assessment of problem frames, structure, lifecycle, history, conflict, and values has implications for the set of stakeholders who ought reasonably to be involved, how they should be involved, and when they might be involved in the assessment process. This step of the leidraad aims to help identify appropriate sets of stakeholders, together with something about their positions, their values, and their possible roles.

2.1 Stakeholder Identification

The identification of stakeholders on any given problem is an art in itself, and there is no single way to do this that avoids all forms of selection bias. Thus, the best approach is to use several different methods. The leidraad provides a couple of different methods, though they need not both be used in all cases.

In identifying stakeholders from different segments of society it is useful to classify them in some form. The classification scheme can then provide a form of checklist to go back and see if relevant members from each group have been identified or not. Of course, not all groups are actively involved in all issues, and so they may not all provide stakeholders. The following classification scheme is offered as a loose checklist in identifying stakeholders:

Cabinet and ministries (national)	
Parliament (national)	
Other governmental actors (local/international)	
Other planning offices (economic/social/cultural)	
Research and advisory organizations	
Scientists and universities	
Sector-specific actors/stakeholders	
Enterprise (industries, firms)	
Cross-sectoral special interest groups	e.g. VNO
Environmental and consumer organizations	
Media	
Other	

Stakeholder and client groups

2.1.1 Knipselkrant Method

We assume that in the RIVM a dossier of newspaper clippings (knipselkrant) has been compiled on the problem. The identification of stakeholders proceeds by scanning the knipselkrant and identifying stakeholder groups and the frequency with which they are mentioned. The frequency with which members of each stakeholder type are mentioned in the knipselkrant can be catalogued as in table 2.

name of stakeholder group	frequency

Table 2: Stakeholder frequency in the knipselkrant.

The main stakeholder groups can be identified from the knipselkrant analysis. This method falls short when an issue has not been well covered in the media, or when some stakeholders have been excluded from debate or media coverage. Since this is often the case, we recommend supplementing this method with scans of the issue in historical and legal records, on the web, and via consultation with experts.

2.1.2 Snowball Method

Another method to find out who are the actors involved in a problem is the snow ball method which can be done by telephone interview. The snowball method asks persons involved in the problem at hand to name others who are involved in or have a stake in the problem at hand. To increase the probability that one covers the full spectrum of value orientations and dissent one can specifically ask stakeholders to mention names of others with whom they disagree. The groups named by the respondent are then contacted and asked the same question. The procedure is repeated and a graph is made with on the X-axis the number of actors asked to mention names and on the Y-axis the cumulative number of unique names mentioned. One can stop the snowball if the curve flattens out (no new names being mentioned). One can also make a frequency count indicating how often each actor was mentioned. Frequently mentioned names are assumed to be formal or informal leading actors in the problem. Note that the snowball method is also biased, as it is not likely to capture unorganised interests.

2.2 Value mapping and Argumentative Analysis

This section provides a means to map out key value positions held by the respective stakeholder groups. In societal debates on policy problems, different levels of argumentation can be distinguished (Fischer, 1995). These are:

Ideological view. This is the deepest level of disagreement and can lead to very different views of whether there is a problem or what it is. One can hold the view that a radically different ideological starting point is required. Ideological argumentation focuses typically on ideology and alternative societal orders.

Problem setting and goal searching. Groups may agree on the existence of a problem, but not on identifying precisely what the problem is, how to formulate it, and what the end goal or solution point should be.

Problem solving. Groups may agree on the existence of a problem and further agree on policy goals but disagree on the strategies and instruments required to reach the goal. Problem solving argumentation typically focus on effectiveness, side effects, and efficiency of methods.

Outcomes and fairness. Groups often care about the fairness of solutions to problems, but can hold different views on what constitutes fair outcomes. For example, one can hold the view that the policy at hand does not serve the public interest or public wellbeing. Fairness argumentation focuses typically on public interest, unexpected societal side effects, and distributive justice.

As part of the context analysis, it is useful to map what level of arguments are put forward by what actors. Ideological argumentation reflects deeper value conflicts amongst actors than problem solving argumentation for instance. A simple way to do the mapping is to extend the knipselkrant actor analysis by classifying arguments put forward by each of the actors identified according to the classification given above. Write down all arguments found in table 3 on page 24. When finished, scan each row and flag areas of agreement and disagreement. Note that table 3 provides space for only five different stakeholder groups, and so we recommend selecting five representative groups for this exercise.

Level of argumentation	Stakeholder 1	Stakeholder 2	Stakeholder 3	Stakeholder 4	Stakeholder 5	Agreement	Disagreement
Ideological view							
Problem setting and goal searching							
Problem solving							
Outcomes and fairness							

Table 3: Stakeholder argumentation table.

2.3 Communication and Engagement

Communication concerning the assessment process and the role of uncertainty in it occurs at several levels. In this section the role of communication within RIVM as it relates to project management, and externally with clients and stakeholders is addressed.

2.3.1 Client/Customer Level

It is important to obtain general agreement on the main issues to be addressed in the assessment; moreover the potential role and influence of uncertainty should be explicitly addressed.

1. What are the clients minimal requirements with respect to uncertainty management?

   Check all that apply:

   ◇ Uncertainty is not an issue
   ◇ The robustness of the conclusions w.r.t. uncertainty should be assessed
   ◇ Uncertainty in the major outcomes should be indicated
   ◇ The major causes of the uncertainty should be determined
   ◇ The effects of uncertainty on policy-level should be indicated
   ◇ Other (specify)

2. What level of detail is requested by the client in this uncertainty assessment?

qualitative indication	quantitative indication
▭	▭

3. Explain why this is the (minimal) requirement w.r.t. uncertainty management.

   ↵

4. Describe any further requirements by the client about the form in which uncertainty should be presented?

   ↵

2.3.2 Stakeholder Level

One should gauge here how important it will be to engage stakeholders actively in the assessment process (why, who, when and how). If stakeholders will be involved, mutual agreement on roles, tasks, form of interaction etc. is important.

1. At what stage should primary stakeholders first be engaged in the assessment for this problem?

as soon as possible	during the assessment	after the assessment
☐	☐	☐

2. Describe the forms this engagement should take for each of the identified stakeholder groups (using table 4). The forms of engagement could include written or verbal communication, presentations, site visits, focus groups, meetings, requests for feedback or participation, research partnerships, and so on.

name of stakeholder group	forms of engagement

Table 4: Stakeholder engagement forms.

2.3.3 Project Management Level

For project management purposes, various groupings within RIVM can be identified:

- Advisory and Steering group (klankbordgroep).
- Other project teams.
- Suppliers/producers of information (data, model results, expertise) and facilities (software, hardware) in the assessment process. This applies to internal as well as external groups (sub-contractors).
- Members of the project team.

Bear these groups in mind in answering the following:

1. Identify in an early stage on the basis of consultation of experts and subcontractors involved (information/knowledge suppliers) what is achievable for this project given the available resources (information-base, expertise, time, budget). Briefly summarize your view in this regard.

   ⇁

2. Identify any critical pathways, bottle-necks and break-down risks in performing the assessment. List them.

   ⇁

3. Assess and describe their potential consequences for the results. These issues should be communicated to the persons involved (on the various levels given above).

   ⇁

4. Identify any requirements or boundary conditions with which one has to account in performing the assessment process (e.g. the use of a quality system), and describe what this means for internal and external communication with respect to line-, project and team-management, and external contacts.

   ⇁

Outputs from section 2

→A list of relevant stakeholders.
→An identification of areas of agreement and disagreement among stakeholders on value dimensions of the problem.
→Recommendations on when and how to involve different stakeholders in the assessment process.
→Guidance on internal management of the assessment process

3 Environmental Assessment Methods

The environmental assessment process will entail use of various methods or tools to carry out the analysis. Such methods may include monitoring, modelling, and scenario generation for instance. The methods used for this assessment were identified in section 1.2.

1. Write down the methods used in table 5 and characterize the uncertainties associated with these methods using the uncertainty typology.

List of methods to be used	List of associated uncertainties

Table 5: Assessment methods used and associated uncertainties

Outputs from section 3

→A list of uncertainties associated with the environment assessment tools.

4 Uncertainty Identification and Prioritization

Central in this step is highlighting areas on the uncertainty map (appendix A) that need attention in the problem at hand. The map is spanned by a table distinguishing sort of uncertainty and location of uncertainty. The main sorts distinguished are inexactness, unreliability and ignorance. The location scale goes from socio-political context, problem framing, system boundary down to the more technical levels such as indicators chosen to assess the problem, model structure (with a broad interpretation of 'models' to include all calculation schemes, including for instance $Emission = Activity \times EmissionFactor$), parameters, input scenarios, and input data.

In a separate document (uncertainty toolbox) that goes with this leidraad, we have compiled a description of available tools for addressing uncertainty. The uncertainty toolbox provides a description of each uncertainty tool, and provides information on:

- The sorts and locations of uncertainty that the tool addresses
- The resources required to use the tool
- Strengths and limitations of each tool
- Some guidance on the application of the tools and on their complementarity with other tools
- Pitfalls of each tool

- References to handbooks, user-guides, case studies, websites, and experts

Once uncertainties have been identified, the uncertainty tool(s) best suited to cope with them are selected from the uncertainty toolbox.

1. Work through the uncertainty typology (appendix A) to identify uncertainties. List the uncertainties indicated from the typology and from table 5 in the left column of table 6. Next, identify the tools best suited for addressing each uncertainty in the right column in table 6.

Type of uncertainty	Method/tool for addressing

Table 6: Uncertainties and tools to address them

Outputs from section 4

→A prioritized list of uncertainties.
→For each uncertainty, a recommendation for what tool to use to address it.

5 Uncertainty Analysis

Carry out analyses for this problem, including both uncertainty analyses and the environmental assessment. The uncertainty toolbox provides further guidance on the application of the uncertainty assessment tools selected. Take particular care to avoid the pitfalls listed for each tool in the toolbox.

Outputs from section 5

→The set of outputs from this section depend on the methods used from the methods toolbox, and will correspond to the outputs from each method described there. Examples of such outputs are diagnostic diagrams, error bars from sensitivity runs, multiple perspective views, and so on.

6 Review and Evaluation

This step of the leidraad provides an opportunity to review results of the environmental assessment and check on the robustness of results obtained.

6.1 Revisit the Problem and Assessment Steps

At various points in the assessment process it may be useful to review the progress to date and to reassess the appropriateness of earlier steps. Some reanalysis or new analysis may be warranted to keep abreast of any new information, new directives, or changes in the problem being considered. Such a review and reanalysis should be undertaken if it has not already been done so.

6.2 Robustness of Results

Before proceeding to the reporting of results, some checks on the robustness of the environmental assessment may be in order. The following questions are designed to aid that process.

1. Describe the main results of the environmental assessment.

   ¬

2. What is new from the last time an assessment on this problem took place?

   ¬

3. If some results have changed, what explains the difference?

   ¬

4. Given your assessment of the most critical assumptions underlying the results, your assessment process has encompassed and tested:

few of the major assumptions	some of the major assumptions	most of the major assumptions
☐	☐	☐

5. Can you imagine a scenario by which it turned out that the main results were substantially incorrect or not valid?

not imagineable	conceivable	quite possible
☐	☐	☐

If so, describe such a scenario.

6. Would results come out differently if the burden of proof were reversed?

   no ☐ yes ☐

7. How certain are you about the main results? How would you rate your confidence in them?

   low ☐ medium ☐ high ☐

8. Who might/would disagree with the main results and why?

   ¬

9. Could any disagreement be reconciled by:

   Check all that apply:

   ◇ Further research
   ◇ New information
   ◇ Better measurements
   ◇ Better models
   ◇ Better dialogue
   ◇ Convergence on values
   ◇ Other (specify)
   ◇ None of the above

10. From the perspective of the policy process, do the results matter?

    hardly ☐ somewhat ☐ critical ☐

11. If so (critical), why? And if not (hardly), why not?

    ¬

12. Is RIVM devoting the right amount of attention to this problem?

    not enough ☐ about right ☐ too much ☐

13. If too little or too much, why is that?

→

Outputs from section 6

→An assessment of the robustness of results (low, medium, high)
→An indication of what it might take to make results more robust.
→An assessment of the relevance of results to the problem.

7 Reporting

The purpose of this section is to help engage the identified audiences in a process of understanding results and their implications (including dissenting or minority viewpoints). This may take the form of advice, a dialogue, or other as appropriate to the context and processes identified (process assessment step). Note that though listed at the end here, the process assessment step may have identified communication and reporting efforts to occur throughout the assessment period/process.

Communicating and reporting uncertainty entails a number of issues that should be taken into consideration. These issues are outlined in the following subsections.

7.1 Context of Communication of Uncertainty

1. Why is uncertainty being reported?

   Check all that apply:

   ♢ To serve a political purpose

   ♢ To conform to good scientific practice (for scientific purposes)

   ♢ Practice of the institution that carries out the environmental assessment

   ♢ Required by legislation

   ♢ Requested by stakeholders involved in the process

2. At which stage is uncertainty being reported? Check all that apply:

   ♢ During the environmental assessment process

   ♢ Delivered with final report/delivery of the environmental assessment process

   ♢ Some time after the final report

3. What is the context of reporting/communicating uncertainty? Check all that apply:

- ♢ Active involvement of audiences requiring setting up of participatory processes (e.g. debate, deliberative process, policy making, extended peer review)
- ♢ Unilateral information supply
- ♢ Other?

4. What is the setting in which communication/reporting takes place? Check all that apply:

   - ♢ report
   - ♢ meeting
   - ♢ focus group
   - ♢ press articles
   - ♢ public session
   - ♢ scientific journal
   - ♢ internet
   - ♢ other

7.2 Who are the Target Audiences?

The target audience may correspond to the stakeholders identified for the problematique of concern. It might not correspond to the whole set of stakeholders but it is surely a subset of those. The type of audience will determine amongst other things the 'language' of the communication/report and its content. Note that because the reporting of uncertainty within the scientific community has a reasonably well established protocol, the remainder of this section addresses mainly non-scientific audiences. It should also be pointed out that non-scientific audiences possess resources and knowledge that can enrich debates about uncertainty. In fact, the engagement of non-scientific audiences is often critical for the overall success of the assessment.

1. Who are your target audiences ? (list according to your stakeholder list)

$\neg$

7.3 Language

The language used in the communication and reporting of uncertainty is one of the most important issues. Careful design of communication and reporting should be done in order to avoid information divide, misunderstandings, and misinterpretations.

1. Is the communication of uncertainty (scientific) jargon free?

jargon free	some jargon	jargon loaded
☐	☐	☐

2. If there is some jargon in the reporting document, are there guidelines to facilitate clear and consistent use of terms provided?

no guidelines	some guidelines	clear guidelines
☐	☐	☐

3. Are values made explicit in the reporting process?

value explicit	mixed	values implicit
☐	☐	☐

4. What it the potential for ambiguity in the wording of the report or in use of metaphor?

low	medium	high
☐	☐	☐

7.4 Method

The method used to manage uncertainty and hence, the types of information generated, is a crucial aspect of communicating and reporting uncertainty.

1. What methods were used to address uncertainty management?

   Check all that apply

   ◇ Uncertainty analysis (e.g. statistical analysis)

   ◇ Quality assurance (e.g. NUSAP, Pedigree)

   ◇ Explanatory frameworks (e.g. cultural theory)

   ◇ Other - specify

   Uncertainty methods can operate in the *foreground* when applied explicitly to produce information on uncertainty (e.g. written material, graphs), or in the *background* as when run behind a model and results are embedded in the output (e.g. model outputs, scenarios).

2. Are the methods used primarily:

background	mixed	foreground
☐	☐	☐

7.5 Style

A variety of different reporting formats and media can be used (numbers, words, narratives, graphs, pictures, multimedia). No one format is more valid than others. The choice of format depends on communication settings, type of audience, and uncertainty management methods.

1. What is the format and style of reporting/ communicating uncertainty?

   Check all that apply:

   Written material:

   - ◇ A section of the environmental assessment report
   - ◇ Press articles
   - ◇ Scientific journal papers
   - ◇ Internet publication
   - ◇ Supporting resources for internet material

   Models:

   - ◇ Model results in the form of graphs, tables, ...
   - ◇ Model runs (by the audience)

   Scenarios:

   - ◇ Narratives
   - ◇ Graphs, tables
   - ◇ Pictures, collages
   - ◇ Animations
   - ◇ Other

   Multi-media material:

   - ◇ Internet based, CD-ROM

   Audiences of reporting documents will have varying amounts of resources and time to digest any information that is presented. The following tips may be useful:

   Policymakers typically have time to read an A4 sheet of paper

   Focus groups require at least two and a half hours and are good settings to make oral presentations

   Information on the internet allows access to those with internet resources (not always all groups) whenever the audience has time

2. Was the availability of each of the audiences considered in packaging uncertainty information?

barely	somewhat	extensively
☐	☐	☐

3. Can the target audiences with fewest resources likely access reported information on uncertainty?

not readily accessible	with some effort	readily accessible
☐	☐	☐

4. Rehearsing communication is important to achieve effective dialogue on uncertainty with audiences. Have efforts at rehearsing communication been made?

no	yes
☐	☐

7.6 Content

1. Have implications for policy and for social context been stated?

not stated	some attention	explicitly stated
☐	☐	☐

2. Were uncertainty relations with risk (namely consequences for different risk management strategies) stated?

not stated	some attention	explicitly stated
☐	☐	☐

3. Have areas of ignorance (what we don't know) been acknowledged where they are relevant to results?

not acknowledged	partially acknowledged	fully acknowledged
☐	☐	☐

4. To what extent does the report reflect engagement or dialogue with the intended audiences?

barely	partially	extensively
☐	☐	☐

5. Are there many examples of scientific arbitrariness ('abracadabra') in the report? That is, steps where the underlying reasoning is not supplied?

none	some	many
☐	☐	☐

6. Is citation of other similar studies done?

no	yes
☐	☐

7. Does the report offer pedigree of results?

   Check all that apply:

   ◊ references

   ◊ background documents

   ◊ other

Outputs from section 7

→A set of guidelines and tips for reporting results.

A Uncertainty Typology

B Glossary

The latest version of this glossary can be found at www.nusap.net

Aggregation Aggregation is the joining of more or less equivalent elements. Aggregation can take place across different scale-dimensions, leading to different resolutions on these scales. The most relevant scale dimensions in environmental assessment are: temporal scale (e.g. diurnal; seasonal; annual; century), spatial scale (e.g. local; regional; continental; global), and systemic scales (e.g. individual plants; ecosystems; terrestrial biosphere).

Aggregation error Aggregation error arises from the scaling up or scaling down of variables to meet a required aggregation level. In cases of non-additive variables the scaling-up or scaling-down relations are always to a certain degree arbitrary.

Assessment Assessment is a process that connects knowledge and action (both directions) regarding a problem. Assessment comprises the analysis and review of knowledge for the purpose of helping someone in a position of responsibility to evaluate possible actions or think about a problem. Assessment usually does not mean doing new research. Assessment means assembling, summarizing, organizing, interpreting, and possibly reconciling pieces of existing knowledge, and communicating them so that they are relevant and helpful to an intelligent but inexpert policy-maker or other actor involved in the problem at hand.

Behavioural variability One of the sources of variability distinguished in the PRIMA typology (Van Asselt, 2000). It refers to 'non-rational' behaviour, discrepancies between what people say and what they actually do, or deviations of 'standard' behavioural patterns (micro-level behaviour).

Bias A constant or systematic deviation as opposed to a random error. It appears as a persistent over- or under-estimation of the quantity measured, calculated or estimated. See also expert bias and value loading.

Bias: Anchoring Assessments are often unduly weighted toward the conventional value, or first value given, or to the findings of previous assessments in making an assessment. Thus, they are said to be 'anchored' to this value.

Bias: Availability his bias refers to the tendency to give too much weight to readily available data or recent experience (which may not be representative of the required data) in making assessments.

Bias: Coherence Events are considered more likely when many scenarios can be created that lead to the event, or if some scenarios are particularly coherent. Conversely, events are considered unlikely when scenarios can not be imagined. Thus, probabilities tend to be assigned more on the basis of one's ability to tell coherent stories than on the basis of intrinsic probability of occurrence.

Bias: Overconfidence Experts tend to over-estimate their ability to make quantitative judgements. This is often manifest with an estimate of a quantity and its uncertainty range that does not even encompass the true value of the quantity. This is difficult for an individual to guard against; but a general awareness of the tendency can be important.

Bias: Representativeness This is the tendency to place more confidence in a single piece of information that is considered representative of a process than in a larger body of more generalized information.

Bias: Satisficing This refers to the tendency to search through a limited number of solution options and to pick from among them. Comprehensiveness is sacrificed for expediency in this case.

Bias: Unstated assumptions A subject's responses are typically conditional on various unstated assumptions. The effect of these assumptions is often to constrain the degree of uncertainty reflected in the resulting estimate of a quantity. Stating assumptions explicitly can help reflect more of a subject's total uncertainty.

Conflicting evidence One of the categories on the continuum of uncertainty due to lack of knowledge distinguished in the PRIMA typology (Van Asselt, 2000). Conflicting evidence occurs if different data sets/observations are available, but allow room for competing interpretations. 'We don't know what we know'.

Context validation Context validity refers to the probability that an estimate has approximated the true but unknown range of causally relevant aspects and rival hypotheses present in a particular policy context. Context validation thus is minimizing the probability that you overlook something of relevance. Context validation can be performed by a participatory bottom-up process to elicit from stakeholders aspects considered relevant and rival hypotheses on causal relations underlying a problem and rival problem definitions and problem framings. See Dunn,1998, 2000.

Cultural theory cultural theory also known as "group grid theory". An explanatory scheme created by Mary Douglas and applied by herself and colleagues as Michael Thompson. It assumes two axes for describing social formations, "group" and "grid"; when these are at "high" and "low", they yield types described as "hierarchist", "egalitarian", " fatalist" and "individualist". Michael Thompson has added a fifth type, residing in the middle, called "hermit". In recent applications the "fatalist" has been eliminated from the scheme. Recently Ravetz (2001) proposed a modification of the scheme using as dimensions of social variation: Style of action (isolated / collective) and location (insider / outsider), yielding the types: "Administrator", "Business man", "Campaigner", and "Survivor" (ABCS).

Disciplinary bias Science tends to be organized into different disciplines. Disciplines develop somewhat distintive cultures over time. That is, they tend to develop their own character, manner of viewing problems, manner of drawing problem boundaries and selecting the objects of inquiry, and so on. These differences in perspective will translate into forms of bias in viewing problems.

Epistemology The theory of knowledge.

Expert bias (cognitive bias) Experts and lay people alike are subject to a variety of sources of cognitive bias in making assessments. Some of these sources of bias are as follows: overconfidence, anchoring, availability, representativeness, satisficing, unstated assumptions, coherence. A fuller description of sources of cognitive bias in expert and lay elicitation processes is available in Dawes (1988).

Extended facts Knowledge from other sources than science, including local knowledge, citizens' surveys, anecdotal information, and the results of investigative journalism. Inclusion of extended facts in environmental assessment is one of the key principles of Post-Normal Science.

Extended peer communities Participants in the quality assurance processes of knowledge production and assessment in Post-Normal Science, including all stakeholders engaged in the management of the problem at hand.

Extrapolation The inference of unknown data from known data, for instance future data from past data, by analyzing trends and making assumptions.

Facilitator A person who has the role to facilitate a structured group process (for instance participatory integrated assessment) in such a way that the aim of that group process will be met.

Focus group Well established research technique applied since the 1940's in the social sciences, marketing fields, evaluation and decision research. Generally, a group of 5 to 12 people are interviewed by a moderator on a specific focused subject. With the focus group technique the researcher can obtain at the same time information from various individuals together with the interactions amongst them. To a certain extent such artificial settings simulate real situations where people communicate among each other.

Functional error Functional error arises from uncertainty about the nature of the process represented by the model. Uncertainty about model structure frequently reflects disagreement between experts about the underlying causal mechanisms.

GIGO Literally, Garbage In, Garbage Out, typically referring to the fact that outputs from models are only as good as the inputs. Ravetz (following Andy Stirling) has formulated gigo as: Do the uncertainties in the inputs need to be suppressed lest the outputs become indeterminate? Ravetz notes that a symptom of gigo is that as the precision of numerical outputs goes up, the accuracy of quantitative inputs goes down. A variant formulation is "Garbage In, Gospel Out" referring to a tendency to put faith in computer outputs regardless of the quality of the inputs.

Global sensitivity analysis Global sensitivity analysis is a combination of sensitivity and uncertainty analysis in which "a neighbourhood of alternative assumptions is selected and the corresponding interval of inferences is identified. Conclusions are judged to be sturdy only if the neighbourhood of assumptions is wide enough to be credible and the corresponding interval of inferences is narrow enough to be useful". Leamer (1990) quoted in Saltelli (2001).

Hardware error Hardware errors in model outcomes arise from bugs in hardware. An obvious example is the bug in the early version of the Pentium processor for personal computers, which gave rise to numerical error in a broad range of floating-point calculations performed on that processor. The processor had already been widely used worldwide for quite some time, when the bug was discovered. It cannot be ruled out that hardware used for environmental models contains undiscovered bugs that might affect the outcomes, although it is unlikely that they will have a significant influence on the models' performance. To secure against hardware error, one can test critical model output for reproducibility on a computer with a different processor before the critical output enters the policy debate.

Hedging Hedging is a quantitative technique for the iterative handling of uncertainties in decision making. It is used, for instance, to deal with risks in finance and in corporate R&D decisions. For example, a given future scenario may be considered so probable that all decisions which are made assume that the forecast is correct. However, if these assumptions are wrong, there may be no flexibility to meet other outcomes. Thus, rather than solely developing a course of action for one particular future scenario, business strategic planners prefer to tailor a hedging strategy that will allow adaptation to a number of possible outcomes. Applied to climate change, it could for example be used by stakeholders from industry to reduce the risks of investing in energy technology, pending governmental measures on ecotax. Anticipating a range of measures from government to reduce greenhouse gases emissions, a branch of industry or a company could estimate the cost-effectiveness of investing or delaying investments in more advanced energy technology.

Ignorance The deepest of the three sorts of uncertainty distinguished by Funtowicz and Ravetz (1990): Inexactness, unreliability and border with ignorance. Our knowledge of the behavior of the data gives us the spread, and knowledge of the process gives us the assessment, but there is still something more. No process in the field or laboratory is completely known. Even physical constants may vary unpredictably. This is the realm of our ignorance: it includes all the different sorts of gaps in our knowledge not encompassed in the previous sorts of uncertainty. This ignorance may merely be of what is significant, such as when anomalies in experiments are discounted or neglected, or it may be deeper, as is appreciated retrospectively when revolutionary new advances are made. Thus, space-time and matter-energy were both beyond the bounds of physical imagination, and hence of scientific knowledge, before they were discovered. Can we say anything useful about that of which we are ignorant? It would seem by the very definition of ignorance that we cannot, but the boundless sea of ignorance has shores, which we can stand on and map. The Pedigree qualifier in the NUSAP system maps this border with ignorance in knowledge production. In this way it goes beyond what statistics has provided in its mathematical approach to the management of uncertainty.One of the categories on the continuum of uncertainty due to lack of knowledge distinguished in the PRIMA typology (Van Asselt, 2000). The PRIMA typology distinguishes between: reducible ignorance and irreducible ignorance.

Reducible ignorance 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'. Irreducible ignorance there may be processes and interactions between processes that cannot, or not unambiguously, be determined by human capacities and capabilities. 'We cannot know'.

Indeterminacy Inderterminacy is a category of uncertainty which refers to the open-endedness (both social and natural) in the processes of environmental damage caused by human intervention. It applies to processes where the outcome cannot (or only partly) be determined from the input. Indeterminacy introduces the idea that contingent social behavior also has to be included in the analytical and prescriptive framework. It acknowledges the fact that many knowledge claims are not fully determined by empirical observations but are based on a mixture of observation and interpretation. The latter implies that scientific knowledge depends not only on its degree of fit with nature (the observation part), but also on its correspondence with the social world (the interpretation part) and on its success in building and negotiating trust and credibility for the way science deals with the 'interpretive space'. One of the categories on the continuum of uncertainty due to lack of knowledge distinguished in the PRIMA typology (Van Asselt, 2000). Indeterminacy occurs in case of processes of which we understand the principles and laws, but which can never be fully predicted or determined. 'We will never know'.

Inexactness One of the three sorts of uncertainty distinguished by Funtowicz and Ravetz (1990): Inexactness, unreliability and border with ignorance. Quantitative (numerical) inexactness is the simplest sort of uncertainty; it is usually expressed by significant digits and error bars. Every set of data has a spread, which may be considered in some contexts as a tolerance or a random error in a calculated measurement. It is the kind of uncertainty that relates most directly to the stated quantity, and is most familiar to student of physics and even the general public. Next to quantitative inexactness one can also distinguish qualitative inexactness which occurs if qualitative knowledge is not exact but comprises a range.One of the categories on the continuum of uncertainty due to lack of knowledge distinguished in the PRIMA typology (Van Asselt, 2000). Inexactness, also referred to as lack of precision, inaccuracy, metrical uncertainty, measurement errors, or precise uncertainties. 'We roughly know'.

Institutional uncertainty One of the seven types of uncertainty distinguished by De Marchi (1994) in her checklist for characterizing uncertainty in environmental emergencies: institutional, legal, moral, proprietary, scientific, situational, and societal uncertainty. Institutional uncertainty is in some sense a subset of societal uncertainty, and refers more specifically to the role and actions of institutions and their members. Institutional uncertainty stems from the "diverse cultures and traditions, divergent missions and values, different structures, and work styles among personnel of different agencies" (De Marchi, 1994). High institutional uncertainty can hinder collaboration or understanding among agencies, and can make the actions of institutions difficult to predict.

Lack of observations/measurements One of the categories on the continuum of uncertainty due to lack of knowledge distinguished in the PRIMA typology (Van Asselt, 2000). Lack of observations/measurements refers to lacking data that could have been collected, but haven't been. 'We could have known'.

Legal uncertainty One of the seven types of uncertainty distinguished by De Marchi et al. in their checklist for characterizing uncertainty in environmental emergencies: institutional, legal, moral, proprietary, scientific, situational, and societal uncertainty. Legal uncertainty is relevant "wherever agents must consider future contingencies of personal liability for their actions (or inactions)". High legal uncertainty can result in defensive responses in regard to both decision making and release of information. Legal uncertainty may also play a role where actions are conditioned on the clarity or otherwise of a legal framework in allowing one to predict the consequences of particular actions.

Leidraad Leidraad is a Dutch word and has no satisfactory English equivalent. It constitutes an offering of guidance which can be taken up if it helps or discarded if not.

Limited knowledge One of the sources of uncertainty distinguished in the PRIMA typology (Van Asselt, 2000). Limited knowledge is a property of the analysts performing the study and/or of our state of knowledge. Also referred to as 'subjective uncertainty', 'incompleteness of the information', 'informative uncertainty', 'secondary uncertainty', or 'internal uncertainty'. 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 unreliability to structural uncertainty.

Model-fix error Model-fix errors are those errors that arise from the introduction of non-existent phenomena in the model. These phenomena are introduced in the model for a variety of reasons. They can be included to make the model computable with today's computer technology, or to allow simplification, or to allow modelling at a higher aggregation level, or to bridge the mismatch between model behaviour and observation and or expectation. An example of the latter is the flux adjustment in many coupled Atmosphere Ocean General Circulation Models used for climate projection. The effect of such model fixes on the reliability of the model outcome will be bigger if the simulated state of the system is further removed from the (range of) state(s) to which the model was calibrated. It is useful to distinguish between (A) model fixes to account for well understood limitations of a model and (B) model fixes or to account for a mismatch between model and observation that is not understood.

Monte Carlo Simulation Monte Carlo Simulation is a statistical technique for stochastic model-calculations and analysis of error propagation in calculations. It's purpose is to trace out the structure of the distributions of model output. In it's simplest form this distribution is mapped by calculating the deterministic results (realizations) for a large number of random draws from the individual distribution functions of input data and parameters of the model. To reduce the required number of model runs needed to get sufficient information about the distribution in the outcome (mainly to save computation time), advanced sampling methods have been designed such as Latin Hyper Cube sampling. The latter makes use of stratification in the sampling of individual parameters and pre-existing information about correlations between input variables.

Moral uncertainty One of the seven types of uncertainty distinguished by De Marchi et al. in their checklist for characterizing uncertainty in environmental emergencies: institutional, legal, moral, proprietary, scientific, situational, and societal uncertainty. Moral uncertainty stems from the underlying moral issues related to action and inaction in any given case. De Marchi notes that, though similar to legal responsibility, moral guilt may occur absent legal responsibility when negative consequences might have been limited by the dissemination of prior information or more effective management for example. "Moral uncertainty is linked to the ethical tradition of a given country be it or not enacted in legislation (juridical and societal norms, shared moral values, mores), as well as the psychological characteristics of persons in charge, their social status and professional roles" (De Marchi, 1994). Moral uncertainty would typically be high when moral and ethical dimensions of an issue are central and participants have a range of understandings of the moral imperatives at stake.

Motivational bias Motivational bias occurs when people have an incentive to reach a certain conclusion or see things a certain way. It is a pitfall in expert elicitation. Reasons for occurrence of motivational bias include: a) a person may want to influence a decision to go a certain way; b) the person may perceive that he will be evaluated based on the outcome and might tend to be conservative in his estimates; c) the person may want to suppress uncertainty that he actually believes is present in order to appear knowledgeable or authoritative; and d) the expert has taken a strong stand in the past and does not want to appear to contradict himself by producing a distribution that lends credence to alternative views.

Multi-criteria decision analysis A method of formalising issues for decision, using both "hard" and "soft" indicators, not intended to yield an optimum solution but rather to clarify positions and coalitions.

Natural randomness One of the sources of variability distinguished in the PRIMA typology (Van Asselt, 2000). It refers to the non-linear, chaotic and unpredictable nature of natural processes.

Normal science Normal science and post-normal science are terms coined by Funtowicz and Ravetz (1990). In their words: "By 'normality' we mean two things. One is the picture of research science as 'normally' consisting of puzzle solving within an unquestioned and unquestionable 'paradigm', in the theory of T.S. Kuhn (Kuhn 1962). Another is the assumption that the policy environment is still 'normal', in that such routine puzzle solving by experts provides an adequate knowledge base for policy decisions. Of course researchers and experts must do routine work on small-scale problems; the question is how the framework is set, by whom, and with whose awareness of the process. In 'normality', either science or policy, the process is managed largely implicitly, and is accepted unwittingly by all who wish to join in."

Numerical error Numerical error arises from approximations in numerical solution, rounding of numbers and numerical precision (number of digits) of the represented numbers. Complex models include a large number of linkages and feedbacks which enhances the chance that unnoticed numerical artifacts co-shape the model behaviour to a significant extent. The systematic search for artifacts in model behaviour which are caused by numerical error, requires a mathematical 'tour de force' for which no standard recipe can be given. It will depend on the model at hand how one should set up the analysis. To secure against error due to rounding of numbers, one can test the sensitivity of the results to the number of digits accounted for in floating-point operations in model calculations. A pitfall here is pseudo precision.

NUSAP Acronym for Numeral Unit Spread Assessment Pedigree Notational system developed by Silvio Funtowicz and Jerry Ravetz to better manage and communicate uncertainty in science for policy.

Parameter A quantity related to one or more variables in such a way that it remains constant for any specified set of values of the variable or variables.

Pedigree Pedigree conveys an evaluative account of the production process of information (e.g. a number) on a quantity or phenomenon, and indicates different aspects of the underpinning of the numbers and scientific status of the knowledge used. Pedigree is expressed by means of a set of pedigree criteria to assess these different aspects. Examples of such criteria are empirical basis or degree of validation. These criteria are in fact yardsticks for strength. Many of these criteria are hard to measure in an objective way. Assessment of pedigree involves qualitative expert judgement. To minimise arbitrariness and subjectivity in measuring strength a pedigree matrix is used to code qualitative expert judgements for each criterion into a discrete numeral scale from 0 (weak) to 4 (strong) with linguistic descriptions (modes) of each level on the scale. Note that these linguistic descriptions are mainly meant to provide guidance in attributing scores to each of the criteria. It is not possible to capture all aspects that an expert may consider in scoring a pedigree in a single phrase. Therefore a pedigree matrix should be applied with some flexibility and creativity. Examples of pedigree matrices can be found in the Pedigree matrices section of this website.

Pitfall A pitfall is a characteristic error that commonly occurs in assessing a problem. Such errors are typically associated with a lack of knowledge or experience, and thus may be reduced by experience, by consultation with others, or by following procedures designed to highlight and avoid pitfalls. In particularly complex problems we sometimes say that pitfalls are "dense", meaning that there are an unusual variety and number of pitfalls. See Ravetz (1971).

Post-Normal Science Post-Normal Science is the methodology that is appropriate when "facts are uncertain, values in dispute, stakes high and decisions urgent". It is appropriate when either "systems uncertainties" or "decision stakes" are high. Click here for a tutorial.

Practically immeasurable One of the categories on the continuum of uncertainty due to lack of knowledge distinguished in the PRIMA typology (Van Asselt, 2000). Practically immeasurable refers to 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'.

Precautionary principle The principle is roughly that "when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically" (Wingspread conference, Wisconsin, 1998). Note that this would apply to most environmental assessments since cause-effect statements can rarely be fully established on any issue. If the burden of proof were set such that one must demonstrate a completely unequivocal cause-effect relationship before taking action, then it would not be possible to take action on any meaningful environmental issue. The precautionary principle thus relates to the setting of burden of proof.

PRIMA approach Acronym for Pluralistic fRamework of Integrated uncertainty Management and risk Analysis (Van Asselt, 2000). The guiding principle 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 'coulored' 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.

Probabilistic Based on the notion of probabilities.

Probability density function (PDF) The probability density function of a continuous random variable represents the probability that an infinitely small variable interval will fall at a given value. The probability density function can be integrated to obtain the probability that the random variable takes a value in a given interval.

Problem structuring An approach to analysis and decision making which assumes that participants do not have clarity on their ends and means, and provides appropriate conceptual structures. It is a part of "soft systems methodology".

Process error Process error arises from the fact that a model is by definition a simplification of the real system represented by the model. Examples of such simplifications are the use of constant values for entities that are functions in reality, or focusing on key processes that affect the modelled variables by omitting processes that play a minor role or are considered not significant.

Proprietary uncertainty One of the seven types of uncertainty distinguished by De Marchi et al. in their checklist for characterizing uncertainty in environmental emergencies: institutional, legal, moral, proprietary, scientific, situational, and societal uncertainty. Proprietary uncertainty occurs due to the fact that information and knowledge about an issue are not uniformly shared among all those who could potentially use it. That is, some people or groups have information that others don't and may assert ownership or control over it. "Proprietary uncertainty becomes most salient when it is necessary to reconcile the general needs for safety, health, and environment protection with more sectorial needs pertaining, for instance, to industrial production and process, or to licensing and control procedures" (De Marchi, 1994). De Marchi notes that 'whistle blowing' is another source of proprietary uncertainty in that there is a need for protection of those who act in sharing information for the public good. Proprietary uncertainty would typically be high when knowledge plays a key role in assessment, but is not widely shared among participants. An example of such would be the case of external safety of military nuclear production facilities.

Proxy Sometimes it is not possible to represent directly the quantity or phenomenon we are interested in by a parameter so some form of proxy measure is used. A proxy can be better or worse depending on how closely it is related to the actual quantity we intend to represent. Think of first order approximations, over-simplifications, idealisations, gaps in aggregation levels, differences in definitions etc..

Pseudo-imprecision Pseudo-imprecision occurs when results have been expressed so vaguely that they are effectively immune from refutation and criticism.

Pseudo-precision Pseudo-precision is false precision that occurs when the precision associated with the representation of a number or finding grossly exceeds the precision that is warranted by closer inspection of the underlying uncertainties.

Resolution error Resolution error arises from the spatial and temporal resolution in measurement, datasets or models. The possible error introduced by the chosen spatial and temporal resolutions can be assessed by analyzing how sensitive results are to changes in the resolution. However, this is not as straightforward as it looks, since the change in spatial and temporal scales in a model might require significant changes in model structure or parameterizations. For instance, going from annual time steps to monthly time steps in a climate model requires the inclusion of the seasonal cycle of insolation. Another problem can be that data are not available at a higher resolution.

Robust finding A robust finding is "one that holds under a variety of approaches, methods, models, and assumptions and one that is expected to be relatively unaffected by uncertainties" (IPCC, 2001). Robust findings should be insensitive to most known uncertainties, but may break down in the presence of surprises.

Robust policy A robust policy should be relatively insensitive to over- or underestimates of risk. That is, should the problem turn out to be much better or much worse than expected, the policy would still provide a reasonable way to proceed.

Scenario A plausible description of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces (e.g., rate of technology changes, prices). Note that scenarios are neither predictions nor forecasts. The results of scenarios (unlike forecasts) depend on the boundary conditions of the scenario.

Scientific uncertainty One of the seven types of uncertainty distinguished by De Marchi et al. in their checklist for characterizing uncertainty in environmental emergencies: institutional, legal, moral, proprietary, scientific, situational, and societal uncertainty. Scientific uncertainty refers to uncertainty which emanates from the scientific and technical dimensions of a problem as opposed to the legal, moral, societal, institutional, proprietary, and situational dimensions outlined by De Marchi et al. Scientific uncertainty is intrinsic to the processes of risk assessment and forecasting.

Sensitivity analysis Sensitivity analysis is the study of how the uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input. From Saltelli (2001).

Situational uncertainty One of the seven types of uncertainty distinguished by De Marchi et al. in their checklist for characterizing uncertainty in environmental emergencies: institutional, legal, moral, proprietary, scientific, situational, and societal uncertainty. Situational uncertainty relates to "the predicament of the person responsible for a crisis, either in the phase of preparation and planning, or of actual emergency. It refers to individual behaviours or personal interventions in crisis situations" (De Marchi, 1994) and as such represents a form of integration over the other six types of uncertainty. That is, it tends to combine the uncertainties one has to face in a given situation or on a particular issue. High situational uncertainty would be characterized by situations where individual decisions play a substantial role and there is uncertainty about the nature of those decisions.

Societal randomness One of the sources of variability distinguished in the PRIMA typology (Van Asselt, 2000). It refers to social, economic and cultural dynamics; the non-linear, chaotic and unpredictable nature of societal processes (macro-level behaviour).

Societal uncertainty One of the seven types of uncertainty distinguished by De Marchi et al in their checklist for characterizing uncertainty in environmental emergencies: institutional, legal, moral, proprietary, scientific, situational, and societal uncertainty. Communities from one region to another may differ in the set of norms, values, and manner of relating characteristic of their societies. This in turn can result in differences in approach to decision making and assessment. Some salient characteristics of these differences will be different views about the role of consensus versus conflict, on locating responsibility between individuals and larger groups, on views about the legitimacy and role of social and private institutions, and on attitudes to authority and expertise. From

De Marchi (1994). Societal uncertainty would typically be high when decisions involve substantial collaboration among groups characterized by divergent decision making styles.

Software error Software error arises from bugs in software, design errors in algorithms, type-errors in model source code, etc. Here we encounter the problem of code verification which is defined as: examination of the numerical technique in the computer code to ascertain that it truly represents the conceptual model and that there are no inherent numerical problems in obtaining a solution (ASTM E 978-84, cited in Beck et al., 1996). If one realizes that some environmental models have hundreds of thousands of lines of source code, errors in it cannot easily be excluded and code verification is difficult to carry out in a systematic manner.

Stakeholders Stakeholders are those actors who are directly or indirectly affected by a issue and who could affect the outcome of a decision making process regarding that issue or are affected by it.

Stochastic In stochastic models (as opposed to deterministic models), the parameters and variables are represented by probability distribution functions. Consequently, the model behavior, performance, or operation is probabilistic.

Structural uncertainty Uncertainty about what the appropriate equations are to correctly represent a given causal relationship.In a different meaning structural uncertainty refers to the lower half of the continuum of uncertainty due to lack of knowledge distinguished in the PRIMA typology (Van Asselt, 2000), also referred to as radical, or systematic uncertainty. It comprises conflicting evidence, reducible ignorance, indeterminacy, and irreducible ignorance.

Structured problems Hoppe and Hisschemller have defined structured problems as those for which there is a high level of agreement on the relevant knowledge base and a high level of consent on the norms and values associated with the problem. Such problems are thus typically of a more purely technical nature and fall within the category of 'normal' science.

Surprise Surprise occurs when actual outcomes differ sharply from expected ones. However, surprise is a relative term. An event will be surprising or not depending on the expectations and hence point of view of the person considering the event. Surprise is also inevitable if we accept that the world is complex and partially unpredictable, and that individuals, society, and institutions are limited in their cognitive capacities, and possess limited tools and information.

Sustainable development "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of "needs", in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs." (Brundtland Commission, 1987)

Technological surprise One of the sources of variability distinguished in the PRIMA typology (Van Asselt, 2000). It refers to unexpected developments or breakthroughs in technology or unexpected consequences of technologies.

Transparency The degree to which a model is transparent. A model is said to be transparent if its pedigree is well documented and all key assumptions that underlie the model are accessible and understandable for the users.

Type I error also: Error of the first kind. In hypothesis testing, this error is caused by incorrect rejection of the hypothesis when it is true. Any test is at risk of being too selective and too sensitive. The design of the test, especially confidence limits, aims at reducing the likelihood of one type of error at the price of increasing the other. Thus, all such statistical tests are value laden.

Type II error also: Error of the second kind. In hypothesis testing this error is caused by not rejecting the hypothesis when it is false.

Type III error also: Error of the third kind. Assessing or solving the wrong problem by incorrectly accepting the false meta-hypothesis that there is no difference between the boundaries of a problem, as defined by the analyst, and the actual boundaries of that problem (Raifa, 1968, redefined by Dunn, 1997, 2000).

Unreliability One of the three sorts of uncertainty distinguished by Funtowicz and Ravetz (1990): Inexactness, unreliability and border with ignorance. Unreliability relates to the level of confidence to be placed in a quantitative statement, usually represented by the confidence level (at say 95 % or 99 %). In practice, such judgements are quite diverse; thus estimates of safety and reliability may be given as "conservative by a factor of n". In risk analyses and futures scenarios estimates are qualified as "optimistic" or "pessimistic". In laboratory practice, the systematic error in physical quantities, as distinct from the random error or spread, is estimated on an historic basis. Thus it provides a kind of assessment (the A in the NUSAP acronym) to act as a qualifier on the number together with its spread (the S in the NUSAP acronym).The upper half of the continuum of uncertainty due to lack of knowledge distinguished in the PRIMA typology (Van Asselt, 2000), comprising inexactness, lack of observations/measurements and practical immeasurable.

Unstructured problems Hoppe and Hisschemller have defined unstructured problems as those for which there is a low level of agreement on the relevant knowledge base and a low level on consent on norms and values related to the problem.

Compare with structured problems. Unstructured problems have similar characteristics to post-normal science problems.

Validation Validation is the process of comparing model output with observations of the 'real world'. Validation can not 'validate' a model as true or correct, but can help establish confidence in a model's utility in cases where the samples of model output and real world samples are at least not inconsistent. For a fuller discussion of issues in validation, see Oreskes et al., (1994).

Value diversity One of the sources of variability distinguished in the PRIMA typology (Van Asselt, 2000). It refers to the differences in people's mental maps, world views and norms and values due to which problem perceptions and definitions differ.

Value-ladenness Value-ladenness refers to the notion that value orientations and biases of an analyst, an institute, a discipline or a culture can co-shape the way scientific questions are framed, data are selected, interpreted, and rejected, methodologies are devised, explanations are formulated and conclusions are formulated. Since theories are always underdetermined by observation, the analysts' biases will fill the epistemic gap which makes any assessment to a certain degree value-laden.

Variability In one meaning of the word, variability refers to the observable variations (e.g. noise) in a quantity that result from randomness in nature (as in 'natural variability of climate') and society. In a slightly different meaning, variability refers to heterogeneity across space, time or members of a population. Variability can be expressed in terms of the extent to which the scores in a distribution of a quantity differ from each other. Statistical measures for variability include the range, mean deviation from the mean, variance, and standard deviation.One of the sources of uncertainty distinguished in the PRIMA typology (Van Asselt, 2000). The system/process under consideration can behave in different ways or is valued differently. Variability is an attribute of reality. Also referred to as 'objective uncertainty', 'stochastic uncertainty', 'primary uncertainty', 'external uncertainty' or 'random uncertainty'. The PRIMA typology distinguishes as sources of variability: natural randomness, value diversity, behavioral variability, societal randomness, and technological surprise.

C Uncertainty Toolbox