

DECISION SUPPORT TOOLS AND TWO TYPES OF UNCERTAINTY REDUCTION

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REASONING AS REDUCTION OF TWO KINDS OF UNCERTAINTY

Grand Rationality is dead, long live Reason!

The 1960's saw the heydays of Grand Rationality in social decision-making. The planning ideal of that period has been termed "comprehensive rational approach" (Benveniste, 1989), "design school" (Mintzberg, 1994), or "technical rationality" (Schön, 1991). That ideal of rationality crumbled, much due to its inherent weaknesses.

Is there at present any hope for decision support tools that does not strand on the same reefs that the rationality movement of the 1960's? Yes, research about human knowledge, social reasoning processes, and software development has come a long way since then.

The cognitive sciences have parted ways with mathematics, logic, physics, and operational analysis that formed the basis for modelling rationality in the 1960's. Extrapolating from Herbert Simon's notion of "bounded rationality", the emphasis of research has shifted from mathematics to cognition. One direction focuses on the limitations of unaided human decision processes. For instance, research in heuristics and biases, clinical reasoning, and dynamic decision-making indicates that human reasoning normally falls far short of ideal standards (Dawes, 1988; Plous, 1993). Another direction focuses on possible shortcuts in reasoning that take us a long way towards ideal standards with very simple tricks, so-called "fast and frugal heuristics" (Gigerenzer, Todd et al., 1999).

An important conclusion on which these directions agree, is that human decision-making can improve via small, but well directed cognitive effort. We know so preciously little of many relevant aspects of the future that we do not have data to feed into the encompassing models that formed the rationalist ideals of the 1960's. But we can still have simple, robust decision procedures that will substantially improve on our decisions while feeding only on meagre or deficient data.

Since the 1960's, studies of social and political decision-making have informed us of the many factors and facets of real life decision-making. Decision-making is an integral part of ongoing processes, torn between power struggle, implementation agencies, and grassroots' interference. The grand master plans of the 1960's more or less took it for granted that planning could be an enterprise for staff functions, well isolated from the turmoil of ongoing organizational processes. Not so anymore.

The software revolution of the 1990's has turned the tables on the expert model of the 1960's. A minor factor is the computational power that shifts massive capacities for calculation from the Central Planning Staff to the roadside planner in the field. More important is the widened, common access to computerized means of representation, communication, and analysis. The GUI (Graphical User Interface), the widely spread computational literacy in a population and the lower costs of computation can bring simple, reasoning tools in the hands of experts and professional planners as well as politicians and public. A well-designed GUI can lower user threshold to provide sufficiently robust reasoning tools for structuring the limited knowledge that we actually have, or can come to share.

In designing reasoning procedures coupled to software support, it is important not to repeat the mistakes of the 1960's: costly decision support procedures with zero impact on real life. There are, as I have indicated, low budget tools with wide applicability that may

help us reduce the proportion of some obvious and, possibly costly or disastrous mistakes.

This gives the background of my argument: (1) Reasoning is important for decision-making. It can be applied to deliberations about past, present, and future. (2) Reasoning involves the reduction of uncertainty. This, we can divide into reduction of epistemic uncertainty and reduction of conceptual uncertainty. (3) Reasoning models for reducing epistemic uncertainty focus on inference procedures while the reduction of conceptual uncertainty focus on interpretational procedures. (4) There are sophisticated tools for dealing with epistemic uncertainty, e.g. the NEST software representing a causal model of the Baltic. However, such tools do not per se reduce conceptual uncertainty. (5) In deliberations about the Baltic, there is also considerable conceptual uncertainty. Such uncertainty is generally underestimated in decision-making. It cannot be reduced to sensitivity or fuzziness. (6) Some of the methods for dealing also with conceptual uncertainty are dialectics and negotiations. Software tools supporting such reasoning procedures are our packages Athena Standard and Athena Negotiator. (7) When software based models replace the Grand Rationalist models of the 1960's, one can focus also on conceptual uncertainty and frame new kinds of interaction between decision-makers and decision analysts.

Why be reasonable?

The semantics of “reasonable” indicates that reasonable decision-makers or reasonable processes of deliberation are better than unreasonable ones. But why should it be so?

Reasoning processes make a difference to the way we handle information. The symbolic nature of reasoning contrasts it with pure cases of animal perception. Reasoning processes are typical for humans even if they can, to some extent, also be found in higher primates. I hear a barking sound and infer that my neighbour has let his dog out. My cat hears the same sound and her brain builds complex patterns of expectations, associations, and behavioural tendencies. She has no need of reasoning involving conventional symbols or other representations. To some extent, humans can also manage without building symbolic representations or without processing them through inferences. But in general, most of our knowledge and decisions rely on our capacity for reasoning about matters not immediately present to our senses.

The power of reasoning derives from the fact that it feeds on symbols. Thus, it enables complex symbolizations of past, present and future. Learning from the past mistakes of others involves counterfactual analysis – what would have happened if the Swedish governments of the 1980's had deregulated the financial markets in another order? Projecting and selecting plans for the future involves the use of hypotheticals about means and ends.

Reasoning on a social scale can be focused towards past, present or future. It can refer to facts and values realized before, during or after decision-making and implementation. Typically, plans and decision refer to possible futures. If directed towards the future, reasoning, well performed, will reduce some uncertainties in decision-making. Therefore, in the long run, our balance of successes over failures will be improved. Acting for the future has in this respect analogies with betting. An actor paying no attention to odds will fail more often or more miserably than actors using proper procedures for grounding beliefs, decisions, and actions.

Reasoning can also be used contemporaneously where decision-making is distributed among a multitude of actors, grassroots or stakeholders. Reasoning can take a presentational and communicative role in proposing ideas for (partial) consensus. Without some reasonable guidance, decision processes of “muddling through”-type will be lost in the muddle. Participation in ideal speaker-hearers exchange will be less than ideal unless some conditions on the content of reasonable exchange takes place. The mere social processes of decision-making or communication themselves have no tendency towards quality, unless they are designed or selected to promote some logical or epistemological standard, i.e. standards of

reason. In well-conducted reasoning processes, the participants will tend to reach more robust agreements and disagreements. If they bring more facts and values to bear in a reasoning process, the outcomes of processes of decision or belief formation tend to be deeper entrenched in stable reasons rather than mere whims.

Focussing backwards is unavoidable if we want to draw any systematic lessons from the past. If directed towards the past, reasoning can analyze and evaluate what we then believed and wanted with our actual accomplishment. As part of the inventory of organizational learning, evaluations of past reasoning and decision-making may hold some of the keys to future wisdom.

There is a normative aspect in executing and evaluating reasoning. To be reasonable is to be able to reason well. Good reasoning will tend to draw the right conclusions from the right information more often than bad reasoning does. Reasoning, if well executed, relies on procedural knowledge. It involves being “properly” responsive to information. A decision-maker can overreact to new, worthless information. Or she can ignore strong indications. Both are errors of reasoning. Reasoning well involves taking the precautions to be “properly” responsive to “proper” information.

To sum up, if we wish decision-making to accomplish a better future than random decisions, to communicate, test, and entrench more stable views among present stakeholders and to learn from past successes and failures, reasoning is an inevitable part of such decision-making.

Reasoning deals with two kinds of uncertainty problems

Reasoning improves on our knowledge or on our clarity. It increases a decision maker’s certainty in her beliefs and judgement or in the certainty in her conceptualization.

Correspondingly, there are two sources of uncertainty, epistemic uncertainty and conceptual uncertainty. Epistemic uncertainty is due to incompleteness of knowledge, i.e. ignorance. Conceptual uncertainty is due to incompleteness of meaning, or intention. Even if you knew every single fact about a place – climate, vegetation or geology – you might still be uncertain whether it is “suitable for hiking”. The latter uncertainty can only be reduced if we clarify whose hiking we are discussing and the preferences and abilities of those persons.

By reducing epistemic uncertainty of beliefs, judgments, verdicts or decisions one improves on their justification. By supplying more and better evidence, one can improve on the accuracy and the legitimacy of beliefs and decisions.

By reducing conceptual uncertainty, one elaborates on the concepts by means of which we think and decide. Conceptual uncertainty and its effects on reasoning have long been studied in the forms of vagueness or ambiguity (Rolf, 1981). An updated survey is found in Smithson (2004).

Reduction of one kind of uncertainty does not automatically reduce that of the other. When science reduces our epistemic uncertainty about facts, new conceptual uncertainties can arise. For example, it seemed for many years that the answer to the following question was unproblematic:

How many planets are there in the solar system?

Recently, however, the traditional planet Pluto has been found in peculiar company. The Kuiper belt, of which Pluto is a part, contains some 100 000 other objects. Some of them have the size of Pluto and one is actually larger. Pluto is very different from the other planets of the solar system. One conceptual decision might be to define “planet” in a way that excludes Pluto and the rest of the objects in the Kuiper belt. Another conceptualization would include Pluto, but then it is problematic whether other objects of the Kuiper belt should be included as well.

The growth of knowledge in the sciences might reduce epistemic uncertainty and simultaneously increase conceptual uncertainty. When science discovers new facts, old concepts and terms no longer fit the facts. New conceptual definitions and delimitations need to be drawn in ways that seem consistent and coherent with the scientific enterprise.

Both kinds of uncertainty are also present in ordinary language and “common sense”, influenced also by experience, popularizations of older science, supposed facts, prejudices, myths, and political and commercial propaganda.

The two types of sources for uncertainty apply not only to cognition but also to values and norms. Administrative terminology draws on compromises between science, folk wisdom, supposedly moral and religious commands, legal considerations, and political expediency. Conceptual elaborations might be called for in order to treat proper things in a proper manner. An example is the legal concept of death. When medical technology enabled hospitals to keep a person’s blood circulating in spite of serious brain damage, legal decisions fixating the concept of death were called for.

We might be uncertain about the application of environmental regulation on both grounds. Epistemic uncertainty might prevent us from making up our minds, when our knowledge of laws and facts are insufficient. Conceptual uncertainty might prevent our decision, if the legal concepts and regulations are dim.

DECISION SUPPORT TOOLS FOR EPISTEMIC UNCERTAINTY

The MARE-project is a Swedish state financed R&D project running from 1999 to 2006 and involving more than forty researchers and technicians. Its objective is “to develop a user-friendly decision support system (NEST) in order to make estimations of cost-effective measures against eutrophication of the Baltic Sea possible”.

MARE is based on causal models, involving effects on seven sub basins of the Baltic by variations of 16 mitigation measures in 23 drainage regions. Parameters can be changed, one can exclude measures and countries, and the model permits sensitivity analysis. The causal model is coupled to various cost measures, enabling users to calculate cost efficiency of various types of interferences, conducted in different countries. The outcome of the MARE-project is the software package NEST. A rich set of user interfaces allows graphical representations of effects of various measures taken:

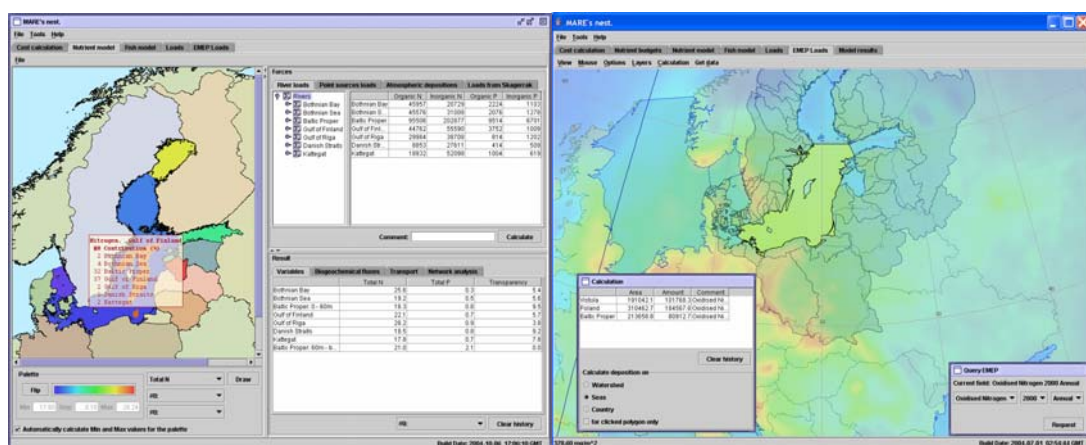


Fig. 1. Graphs of causal and economic modelling in NEST.

NEST is a very elegant way of coordinating available scientific knowledge, both as to causes and costs in order to present them to decision-makers. The project and its software product have a focus on validation of the scientific models and refinement of the input data.

There is no question about the importance of coordination of scientific and economic aspects. My point here is that even if NEST aims to reduce epistemic uncertainty, the conceptual uncertainty is not dealt with. This is admitted in the project description:

... there is a significant uncertainty in the future decision-making process for the Baltic Sea marine environment when Poland and the Baltic States will be members of EU. The relationship between EU, the member states and the international conventions have yet to be clarified. This means ... that MARE has a 'moving target group', and that the 'decision agenda' for the improvements of the Baltic Sea environment is unclear. This demands a large flexibility in our communication plan (MARE, Phase 2 A7 & A8, rev. 2003-02-20, p. 31).

The project has presumably proceeded under the strategy that, *first*, one has to get the facts, causes, and costs right, then, *second*, one has to place the decision support tool among a decision-makers with an agenda suitable to the tool, and with receptivity to sophisticated analyses provided by the NEST tool.

The approach is driven by a scientific desire to reduce epistemic uncertainty *in isolation* from the conceptual uncertainties facing decision-makers with an agenda relevant to the Baltic. I am not disputing that NEST can provide a reduction of epistemic uncertainty. In fact, it has already contributed to focussing the debate on the balance nitrogen-phosphorous.

But I wish to point out that in decision-making about the Baltic, there is *also* considerable epistemic uncertainty of a very elementary kind, blended with substantial conceptual uncertainty. Such sources of uncertainty are not addressed by MARE or NEST. Where MARE reduces one kind of uncertainty, another kind of uncertainty might come to the foreground.

CONCEPTUAL UNCERTAINTIES IN ENVIRONMENTAL DELIBERATION

Fact-value uncertainties

Swedish environmental policies towards the Baltic have come to focus recently. In 2005, a report by an international panel of experts concluded that the Swedish environmental policy, related to the purification of the Baltic, had targeted wrong problems. The decisions about purification taken 15 years ago were based on scientific majority view about the key role of nitrogen. Now, there is instead a widely spread disagreement about the relative importance of nitrogen versus phosphorus in purification. Roughly 10 billions SEK (roughly 1,1 billion Euro) have been invested towards the elimination of nitrogen with marginal, or perhaps even counterproductive effects.

In the Swedish Parliament, the failed investment has led to an interchange about "Prestige and serious confusions among researchers and authorities about cyanobacterial blooms in the Baltic Sea" (Interpellation 2005/06:83). Members of the Parliament referred to a conflict between two groups of Swedish scientists, identified as "the nitrogen group" and "the phosphorous group".

Among the researchers, a heated debate has ensued, reported in the largest newspapers and news agencies (TT, 2005; DN, 2005):

"Billion purification has missed phosphorous problem"
"Researcher brawl about the Baltic"

Scientific facts and models are highly contested among scientists. Such deep scientific disagreement would caution wise politicians, or civil servants, not to prompt more investments. Not so among the scientists interviewed. The researchers quarrelled over political recommendations concerning strategies and policies for dealing with

environmental problems of the Baltic. One issue of contention is whether purification should be where it is most cost efficient, i.e. in Poland, or whether it should take place where the Swedish tax-payers see effects.

None of the professors interviewed has any political mandate to set the goals or select strategies for environmental policies. Furthermore, the researches disagree about the very facts on which their policy recommendations are based. According to one school, the Baltic has undergone a “regime shift”, meaning that past tendencies cannot be extrapolated into the future. A regime shift would imply that the state of the Baltic cannot be reversed, or at least not by known means. At worst, its state of pollution might be irreversible, and investments for purification would have little or no effects.

The scientists involved have stepped into the role of politicians. Such transgression of role, responsibility, and competence is not uncommon. There is a tendency in inflamed debates, on the borderline between science and politics, that politicians act as incompetent researchers, misinterpreting facts, while researchers act as incompetent politicians, misconstruing the policy goals (Adelman, Stewart & Hammond, 1975; Hammond, 1996).

Uncertainty about boundaries of target and priorities

In a recent scientific study of the efficiency of purification, the authors note some peculiarities of the Swedish national environmental policy about the Baltic (Elofsson & Gren, 2004).

A peculiarity is that the goal statement does not make it clear whether nitrogen should be minimized in the worst polluted parts of the Baltic, or whether the contribution of nitrogen south of Åland should be minimized. Does the goal statement concern Swedish contribution south of Åland, or does it concern the outcome for the worst polluted parts? The uncertainty about the goals creates uncertainty about the means.

A second problem is that there is no priority or trade off between sub goals. Three sub goals are stated, two related to air emissions, one to water emissions. Motivations or clues towards implementation are lacking.

Third, the policy involves both ends and means and the means are not cost efficient in relation to some of the goals. If the goals are what they are said to be, it is hard to understand the means chosen at the political level (SOU, 2000).

Finally, the goal statements rest on a peculiar Swedish presupposition. The Baltic is, according to Swedish authorities, sensitive to nitrogen emissions only south of the Åland archipelago. In contrast, EU thinks that nitrogen emissions north of Åland can also contribute to eutrofication. It seems that the Swedish problem definition depends on the means available.

The importance of goal setting is well known. If we do not know the aim of our effort, there is no way of saying whether it was successful or not.

Uncertainties about real intentions

A particular heroic goal setting lends itself to our admiration:

If the Baltic has undergone a regime shift, it probably will not suffice with present measures or measures of the same kind. It is hard to say which extra measures will be needed, but in all likelihood, very extensive measures will be needed to bring back the Baltic to the condition it had in the 1940's. Such measures could involve decreasing emissions from all sources close to zero or perhaps to the level of the late 19th century.... We do not today know which measures would be needed or whether they are technically and economically realistic. Nor do we know which resources would be needed to bring about more extensive measures. In spite of the uncertainty about scenario (i.e. the possible regime shift), the government should now prepare to handle such a situation... (*Strategi för hav och kust utan övergödning*, 2005).

The lack of realism is striking. We do not know the causal processes that drive the change. If the Baltic has undergone a regime shift, measures against nitrogen emissions might have marginal effects, no effects, or possibly even counterproductive effects due to the

balance phosphorous-nitrogen. The medicine we would select, if we knew that no regime shift has taken place, might make the patient worse if there has been a regime shift.

In spite of our ignorance as to whether the goal can be achieved, this strategy calls for our preparation for the most extreme measures. Clearly, the strategists have forgotten the notion of adaptation, that is to recognize hard facts we cannot change, give up unrealistic goals and concentrate limited resources where they can produce any desired effects.

Heroic declarations about extreme measures cannot be made credible. As soon as the costs and effects can be estimated, unrealistic goals will be abandoned by any rational decision maker – hopefully before they have drawn any real costs. It is impossible to make a reasonable person believe in, or freely act towards, obviously unrealistic goals.

We might therefore retain reasonable doubt whether unrealistic goals are intended for implementation. Civil servants are handed two kinds of goals, those that are to be implemented and those that cannot be and probably are not even intended for implementation. Should civil servants focus on the realistic goals only, or are they also responsible for some symbolic manifestations of the unrealistic goals as well? At best, we land with an open, rhetorical agenda and a hidden, real agenda. At worst, rhetorical heroism can paralyze the mechanisms for decision-making and implementation, and commit the machinery to pay lip service to a symbolic manifest nobody believes in. False heroism on the political level gets embedded in double-thinking or in cynicism at the implementation level where real effects of real resources matter.

Uncertainties about priorities and conflicts

The interpretation of the notion “sustainability” is open to conceptual uncertainty due to lack of relative weights and priorities. In its normal use, the notion of sustainability contains three aspects: ecological, social, and economic aspects. When the notion is translated into legally binding regulations on a national level, uncertainty might arise from absence of priorities. (*Ingen övergödning*, 2003).

For instance, the Swedish law and legal processes are open to various interpretations about these three components. Is, for instance, the ecological aspect an absolute restriction on plans and projects, only permitting yes/no, or is it an aspect that can be traded off so that some ecological infringement can be compensated by high economic or social benefits?

The laws themselves are open to both interpretations. As a consequence, different parts of the national administration take different stances on the application of the law. While the environmental bureaucracy opts for a maximal interpretation of the ecological restrictions, the planning bureaucracy opts for milder interpretations trying to frame decision-making processes circumventing the environmental bureaucracy (Emmelin & Lerman, in press).

Uncertainty about framing

Framing uncertainty occurs where deductively equivalent descriptions give rise to different preferences or different epistemic foci. A well-known example is the “Asian disease” example, presented by Tversky and Kahneman (1981):

Imagine that the U.S. is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimate of the consequences of the programs are as follows:

- If Program A is adopted, 200 people will be saved.
- If Program B is adopted, there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved.

Which of the two programs would you favor?

Here, a majority (72%) preferred to save 200 lives for certain, rather than gamble on saving a

larger number. But a different framing of the consequences gave another result:

- If Program C is adopted, 400 people will die.
- If Program D is adopted, there is 1/3 probability that nobody will die, and 2/3 probability that 600 people will die.

Which of the two programs would you favor?

In this frame, a majority (78%) preferred to gamble, rather than accept a sure loss. However, the two frames are logically equivalent. By framing consequences in different ways, it has been proved possible to lead subjects into inconsistency. Even when the persons are made aware of their inconsistency, and offered to remove it by settling on one of the frames, many of them found it impossible to make up their minds.

We might expect framing effects in environmental decision-making as well. If decision-makers formulate regulations, prohibiting a certain substance in higher doses or levels than X, it logically follows that they allow it in lower doses or levels than X. We might suspect that deductive inconsistency will arise in such cases.

REASONING MODELS AND TWO KINDS OF PROCEDURES

Reasoning models involve two types of procedures

Reasoning is about inferences. I will here use “reasoning” to cover two types of procedures related to inferential activities. One is to interpret, formulate, or symbolize the informational stuff providing the input to inferences and to reinterpret, reformulate, or symbolize the information coming out from the inferences. The other type covers the handling of the complexes of inferences linking input with output.

In idealized cases, these two types of procedures can occur as separable activities. For instance, in lower school grades, children are presented with artificial problems like: “Eight men can dig 40 meters of ditches in five days. How much can 14 men dig in twelve days?” To solve such a problem, one first translates it into a suitable representation, e.g. in the form of equations, putting the x’s in the proper places. This is the *interpretation process*, taking us into a suitable symbolism. The *inferential process* applies algorithms to that symbolism, teasing out an identification of the unknown x. The latter is an inferential process, purified. Finally, one reinterprets the symbol x into an ordinary language answer to the teacher.

This idealized reasoning model enables us to illustrate two separable types of reasoning procedures and distinguish interpretational procedures from inferential procedures. As soon as we move beyond the simplest models and beyond schoolbooks, reasoning processes tend to merge interpretational and inferential procedures. The standard scientific answer to the lay folks is “It all depends on what you mean by so and so”. If the layperson meant A, then the answer is such but if she meant B, then the answer is otherwise.

In normal reasoning, interpretation and inference blend. To keep track of reasoning procedures, we have to pay attention to two dimensions: that we do not distort content and that we move in the right inferential direction without stepping too far beyond what the previous steps permit.

Inferential procedures, their theories and practice

We all recognize openly inferential activities, for instance when other persons say “hence”, “therefore”, or “firstly, secondly, and thirdly”. These phrases typically signal that a conclusion is inferred from something else. An “inference” is a structure, containing a conclusion and some premises, intended to underpin that conclusion. Both input and output of an inference are symbolic, e.g. the content of a decision, a proposal, a hypothesis, an explanation, a prediction, a diagnosis, or a statement of fact, or declarations of aims,

values, norms, and principles. Often, the symbols are clad in verbal forms, but we admit maps, diagrams, and other conventional representations as well.

Inferences can take place in the minds of persons, in publications, or in social arenas. There are no limitations to the content of inferences, other than that it be symbolic representations. By a “symbol” we here mean a representation, by convention or similarity connected to whatever it purports to stand for. Abstract pieces of mathematics and concrete events and processes may be the object of inferences. We can make inferences about past, present, and future, about good and bad courses of action, and about right or wrong policies, as long as they are symbolized.

Inferences can go very wrong and they often do. We need to distinguish good inferences from bad, or at the least, better from worse. Such distinctions will introduce standards of evaluation into the study of inferences. Such standards are, in a certain sense, normative or evaluative.

The normative element of reasoning skills does not imply that such norms are culturally or socially arbitrary, like table manners, or manners of greeting one another. As Bertrand Russell reminded us, if chickens had had access to more sophisticated inductive reasoning procedures, they would have played a less prominent role in human cooking.

Bad inductivists will tend to issue wrong predictions, wrong diagnoses, and mess things up more often than good inductivists, other things being equal. Reality, not primarily social sanctions, punishes bad reasoning. If social sanctions are directed against instances of bad reasoning, this has a justification beyond mere social conventions.

One distinguishes between deductive and inductive procedures and standards for constructing and evaluating inferences. In deductively valid reasoning, true premises force the truth of the conclusion. With true premises in a deductively valid inference, we can exclude the falsity of the conclusion. Even in inductively strong reasoning, falsity might slip into our conclusion, in spite of our true premises. In good inductive inferences, true premises improve on the probability or likelihood of the conclusion but are no full guarantee.

Standards of good inferences have, to some extent, been codified in the form of reasoning principles or reasoning paradigms. In deductive inferences, the syllogistic of Aristotle presented a set of principles for good syllogistic inferential schemata. Euclid’s elements provided an exemplary paradigm for the structure of scientific inference for schoolboys of two millennia. The formalization of predicate logic and the theorems of mathematical logic in the 20th century provided deep understanding of the nature of deductive inferences.

Human understanding of induction is far less advanced than that of deduction. Inductive methods for statistical testing were initially developed in the 1920’s and onwards. Then, a desire for scientific objectivism and purity severely restricted the interpretation of likelihoods. But, since the 1990’s, a revival of Bayesianism has moved inductive procedures beyond the limits of strict objectivism. The interpretation of the key concept of probability is still controversial among theoreticians of inductive inference. Discussions about confirmation, natural kinds, projectible predicates, and causality show that, at present, there is not a unique, well-defined collection of science-based principles of inductive inference.

There is a stark contrast between the well established metathory of deduction and the shifting or hazy metatheories of other forms of reasoning: induction, abduction, causal reasoning, legal reasoning, or moral reasoning. Underlying decision-making, there is a plethora of reasoning models. A basic difference extrapolates from the Weberian distinction between consequential rationality (Zweckrationalität) and deontological rationality (Wertrationalität). Consequential rationality is more prominent in models of economic decision-making; deontological rationality is based on the extension, articulation, and application of principles or prejudices, typical of legal reasoning. The role of cases and examples versus principles is still in the making. Deduction, and our thorough

understanding of its principles, is very untypical for the knowledge we have of reasoning.

A manifold of interpretational procedures

The intellectual arsenal proper for reasoning includes manoeuvres of interpretation. The legal professions have long found it necessary to develop conceptual techniques for pinning down the human limits of responsibility and public tolerance for deviant behaviour.

The toolbox of interpretation includes definitions and delimitations. Definitions replace highly ambiguous terms with terms that are made less ambiguous where ambiguity can do damage to overall reasoning. Take, for instance, notions like “risk”. Expertise need to be careful in keeping their various risk concepts apart in order to answer the right question and base it on the proper arguments.

Before one enters into reasoning processes, one has to tidy up some of the vocabulary. Take, for instance, the vicious question: “Can you guarantee that it is absolutely safe”. It is often fired at experts from self-appointed spokespersons for laypeople. If “safe” in that context means “probability of damage equals 0”, it is unsafe to sit in one’s backyard where meteors might fall. If a process of reasoning involves the undefined term “safe”, this process might go very wrong very soon in the sense that participants know less and feel more antagonistic at the end of the debate than when they started. One needs to settle some interesting upper level of probability as the bound of “safety”. But which level to choose can only be settled by further reasoning about tolerance and values.

Delimitation has to do with drawing spatial, temporal, and causal boundaries. Before deciding or drawing any conclusion, we may need to know where the spatial boundaries begin and end, which time frame is used and how far the effects are traced. The outcome of our scrutiny of a project or plan may depend on such delimitation. As we saw, the debate about the Baltic depends essentially on such delimitations.

Distinctions, i.e. making it explicit what one does not mean, is one way of eliminating confusion. In discussing responsibility, for instance, it may be a constructive move to exclude either moral or legal responsibility, depending on the concluding destination we wish to arrive at. Distinctions between facts and values might clarify reasoning about the Baltic.

Examples can often also be used to tie down the concepts we employ in our thought. For instance, in Anglo-Saxon common law, large parts of the intellectual edifice are carried by cases, rather than by explicitly defined principles. Principles and similarities come to surface only via the particular cases where they are brought to bear.

Indications of relative weight or priorities are needed for handling conflicts of goals or of principles. Executives can find themselves uncertain in a situation with conflicts between goals or between principles. A conflict of goals occurs when a decision-maker sets goals A and B and the executive finds herself in a situation where every action that leads towards A leads away from B. A conflict of principles P1 and P2 occurs in a situation where the executive finds that one and the same action is commanded by P1 but prohibited by P2.

Definitions, delimitations, distinctions, elaborative examples, and indications of relative weight or priorities demand conceptual labour. They consume time and effort, both to construct and to absorb. All our concepts are provisos – it is always possible to invest more labour into them. Normally, concepts and delimitations are chained to one another. In order to clarify one single point under discussion, we often need to clarify a number of related terms and issues. In order to clarify the term “murder”, one needs to clarify the notion “intention” and the premises for inferring the presence of intention behind an act. Even if definitions and delimitations seem to concern only an isolated building block, a wise reasoner will be cautious not to tie down any single item so hard that she loses the elasticity of the whole edifice of reasoning.

Decision-making needs to elaborate both dimensions of uncertainty

Normally, a decision-maker will be uncertain in both dimensions. Not being an expert, the decision-maker cannot be expected to frame an exact question in a terminology that best suits her interest. It is almost never sufficient for the expert to provide tools for reducing epistemic uncertainty, unless such reduction is coupled to tools for reducing conceptual uncertainty as well. As we saw in relation to the MARE-project and the example of the planet Pluto, a scientific reduction of epistemic uncertainty might even increase conceptual uncertainty.

Normally, decision-makers want to know whether facts and science are “favourable” for a plan, project, or course of action. Only under the most ideal conditions can a decision-maker provide an exhaustive definition of a goal or a set of preferences. The aims of decision-makers are often complex and involve negative, tacit aspects. In setting the Goal G, the decision-maker implicitly assumes that G can be obtained without considerable detrimental effects on A, B, C... where the negative goals have the form of an undefined, open-ended set that could not be specified by a decision-maker beforehand.

The decision-maker cannot always frame the proper questions in relations to her plans and projects. Decision-makers would often like to know about “facts and causes of relevance to my enterprise, plan, or project”, but expert knowledge normally cannot be classified that way. The facts, laws, and models, stored in scientific knowledge, only exceptionally carry tags: “relevant for the project X”.

Wise and helpful expertise will try to help conceptualize unexpressed intentions of their decision-making clients. A classical example of helpful expertise stems from the development of radar in the U.K., when Europe headed for the Second World War. Military experts of the 1920’s and 1930’s focused on the immense damage expected from bombing raids targeting civilians. Was there any way of preventing such attacks? For logistical reasons air patrols were not feasible. In Britain, the committee for Scientific Survey of Air Defence passed a question to scientific expertise about the possibility of a death ray. A short calculation showed the impossibility of generating sufficient amounts of energy to have any effects on incoming bombers. “Not possible”, was the scientists’ answer. But wisely, the scientists added the counter question: “But perhaps you would be interested in detection technology instead?” That wise counter question started a rapid, directed development of radar as part of a large-scale air defence system. It provided the narrow margin needed for the nation to prevail in the Battle of Britain during the critical months of 1940.

THE ROLE OF CONCEPTUAL UNCERTAINTY FOR MODELLING

Sensitivity and fuzziness overlook the depth of conceptual uncertainty

There are some commonly known ways of capturing conceptual uncertainty: sensitivity analysis, interval representations, and fuzzy logic. As we will see, none of them captures all aspects of conceptual uncertainty.

Sensitivity analysis and interval analysis are related. Instead of having a decision-maker settle for a point estimate of a probability or a preference, one can try to capture her uncertainty with an interval. Sensitivity analysis studies the effect on an outcome value by varying the input value over the interval of uncertainty. Interval analysis assigns to the outcome value an interval, depending on the input intervals.

While certain aspects of conceptual uncertainty can be handled in this manner, these methods carry a cost. There is a considerable risk of *dilution* in the sense that the more conceptually uncertain factors we add, the larger the outcome interval and the uncertainty indicated by it (Smithson, 2004). The more items of vague knowledge we add as input to our

reasoning, the more we would lose in precision of the output. This is unintuitive – adding new knowledge, although vague, should not automatically eradicate precision.

More gravely, intervals and sensitivity are limited to representing only one kind of conceptual uncertainty, pertaining to intervals. When we consider the uncertainties relating to fact vs. value, conflicts, and framing effects, it seems that intervals and sensitivity bear no relation to such uncertainty.

Fuzzy logic and fuzzy set theory are methods for representing the absence of a definite point value. Instead of insisting on a yes/no classification, into true/false, or member/non-member, fuzzy methods assign degrees of truth or degrees of membership. Instead of assigning a line between Sweden and Norway where each single point in the landscape belongs to Sweden or belongs to Norway, it might be that a point sometimes belongs to Sweden to 50% and to Norway to 50%. Again, this method cannot handle conceptual uncertainties relating to fact vs. value, conflicts, and framing effects.

Conceptual uncertainty is a deeper phenomenon than these three analyses assume. They all assume that *the model itself is determinate*. Therefore, they try to locate all uncertainty in the variables and parameters of the model. But conceptual uncertainty can concern the very choice of a unique model.

Conceptual uncertainty, malign (“wicked”) problems and essentially contested concepts
In the design sciences, one often draws a distinction between two types of problems. On the one hand, there are benign or “tame” problems, on the other malign or wicked problems. Benign problems can, in principle, be solved using known methods, and there are known principles for evaluating possible solutions. Benign problems can be highly complex and forbiddingly difficult, but there are ways of solving them, drawing on a rough consensus about relevant methods, if not always the results.

Malign or “wicked” problems do not have that character. The stakeholders might not agree about the conceptualization of the problem. Expertise cannot settle on what level of abstraction the problems are to be described or dealt with. There is no path to establish consensus behind a proposed solution, i.e. there are no “stopping rules” for deciding when a solution has been reached. The solutions tend to generate new problems of a similar kind, or the problems change when they are dealt with (Rittel, 1973).

At first, it might seem that the classification into benign or malign problems depends on the state of scientific or expert knowledge. If, and when, this is the case, research and expertise might transform malign problems into benign.

While it is true that research can lay bare some of the mechanisms underlying malign problems, often it cannot completely settle which model to choose. Different parties to the conflict conceptualize different aspects of a problem. The choice of one model or conceptualization over another will make the expert side with one party of a conflict. To Western specialists in epidemics, it may seem that HIV is to be modelled as an epidemic disease. To African politicians, it may seem that HIV is to be modelled as the aftermath of colonial exploitations of Black Africa. The choice of model is not always a purely cognitive choice.

Deep conflicts over wicked problems often involve conceptual uncertainty. Often attention and problem focus are fought over. Key terms of discourse function as strategic landmarks that attract intensive struggles between adversaries. Models and conceptualizations can become strategic assets in a conflict, a phenomenon described by Gallie as the use of “essentially contested concepts”. The proper use of such concepts, he claimed, “inevitably involves endless disputes about their proper uses on the part of their users.” (Gallie, 1956; Connolly, 1983).

Malign problems always involves some conceptual uncertainty. Conceptual uncertainty is a necessary condition for malign problems. When two stakeholders in a malign

problem conceptualize aspects of their conflicts by the same words, expressing different conceptualizations and the conceptualizations are strategic assets for the parties in conducting their conflict, an essentially contested concept arises. War, crime, religious conflicts, economic development, political failures, or growing environmental disasters include verbal phases with cognitive and strategic verbal elaborations. Different parties exploit conceptual uncertainty for gaining the upper hand in the conceptualizations of malign problems.

Reduction of conceptual uncertainty is more art than science

There are a number of procedures for reducing conceptual uncertainty, first articulated in Aristotle's *Organon* ("Tool") about 340 B.C. Such procedures have been taught in courses of informal reasoning for centuries, sometimes integrated with techniques of formalization, sometimes with techniques of concept formation in sciences and in law.

While the inferential procedures of deduction are largely open to formalization by algorithms, the interpretational procedures are far less so. First, interpretational procedures depend on real world knowledge. This becomes obvious where the real world knowledge or technology has been largely lost. Take, for instance, books drawing on the terminology of sailing technology of the 19th century, e.g. a novel by Joseph Conrad or the Hornblower books by C.S. Forester. It is impossible to understand the full content of the terms without having some knowledge about the structure and processes of handling large sailing ships.

Second, interpretation depends on knowing the intentions of the decision-maker, openly expressed or tacitly understood. To clarify the intentions, we need to settle spatial boundaries, temporal aspects and strength, and likelihood of causal effects on an indefinite range of objects. Often, several decision-makers are involved and they may be acting strategically, concealing their aims.

Third, good interpretation, as exemplified by the radar case mentioned above, presupposes that the experts try to match solutions that can be glanced within their epistemic horizon, with goals that can be glanced from within the decision-maker's horizon.

It does not seem possible to supply an effectively decidable, mechanical procedure for enumerating and testing relevance of real world knowledge; to inspect tacitly presupposed negative goals of decision-makers; or to survey valuable knowledge within reach. There is no software package that by itself can deliver solutions to known and common types of interpretation problems.

Reduction of conceptual uncertainty interacts with epistemic uncertainty. It is largely a matter of tact, related to the case at hand that determines which techniques reasoning would profit from, and which real world knowledge might be relevant.

Modelling wicked problems, or essentially contested concepts, is far beyond what can be accomplished by scientific methods designed to eliminate epistemic uncertainty. Customary applications of science based models and methods will not by themselves provide complete solutions, or management, of malign problems or conflicts, conducted with essentially contested concepts. They also need to be coupled with methods of another kind. Examples of such methods are dialectics and negotiations.

DECISION SUPPORT FOR CONCEPTUAL UNCERTAINTY: DIALECTICS AND NEGOTIATION

Dialectical Inquiry and Athena Standard

In a non-Hegelian, non-Marxian sense, dialectics has its root in the Socratic methods for conducting a dialogue. The Socratic dialogues relied on methods of definition and conceptual elaboration in order to test implications of definitions. The name "dialectics" was transferred to the medieval university to cover the use of logic. In the hands of Pierre Abelard,

dialectics was connected to pro-et-contra argumentation. It has been part of the university curriculum for centuries, often connected to courses in elementary reasoning.

Recent attempts to stabilize a core competence of dialectics have been done by the philosophers Arne Naess (1966) and Michael Scriven (1976). The art of reasoning pro and contra is connected to arts of interpretation and conceptual elaborations. In the 1960's a large number of argument analysis in political science arose from R. A. Levine *The Arms Debate* (1963). The application to environmental problems of a similar framework, based on Stephen Toulmin's argument theory, has been proposed by Parkin (1996; 2000). Argument graphs have been proposed for legal reasoning by Wigmore in the 1920's. The applicability of argumentation software to wicked problems has been proposed by Buckingham Shum (2003).

In the modern version of dialectics, two or several parties to a conflict may argue pro or con certain simple or complex issues. A clash of intellectual standpoints is divided into a number of main theses. Each of these is supported or undermined by set of nested premises, constituting a tree. Each premise can be evaluated as more or less *acceptable*. A subordinate premise can be evaluated as more or less *relevant* to a superior conclusion.

While ordinary spoken or written language is linear in time or in space, the structure of each argument is hierarchical and recursive. For instance, a state attorney may try to prove that J.D. committed the burglary by using testimonies from eyewitnesses as premises pro the guilt of J.D. The defence may argue against the reliability of the eyewitnesses and so forth.

The reconstruction and evaluation of argumentation is facilitated by tree graphs. There are a half a dozen internationally known software packages, suitable for constructing, representing, and elaborating on argument trees. Our package Athena Standard is one of these packages:

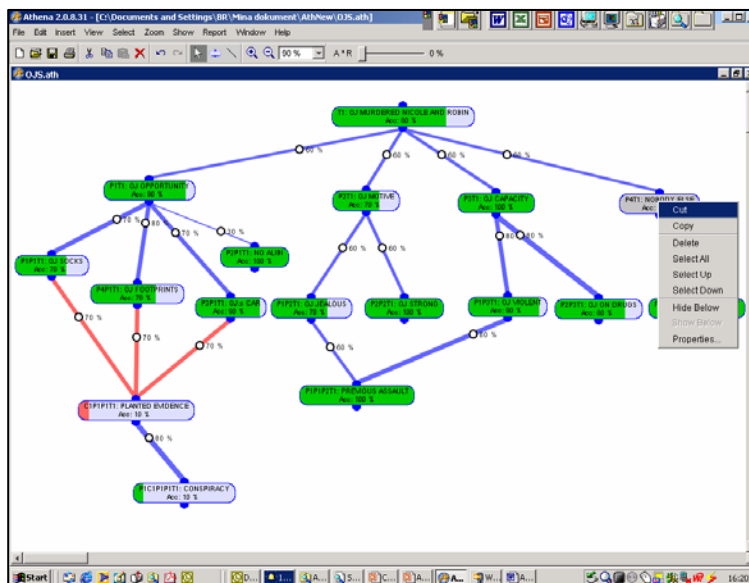


Fig. 2. Athena Standard, showing an argument tree with arguments pro (green) and con (red). Acceptability of premises and their relevance shown in tree.

Negotiation and Athena Negotiator

Negotiations have always been an option for coordinating interests between two or several parties. Negotiations may end with a settlement between parties involved where they agree on a common solution. If the parties interpret the solution in the same manner and stick to the agreement, they may succeed in benefiting from coordinated interests and putting aside conflicts of interest.

Negotiations involve a set of skills, partly drawing on science, partly on art. Analysis of negotiations rely on two different models that issue different recommendations. There is a

more legalistic model, based on Fisher & Ury's model (1983). According to this legalistic perspective, negotiations are seen as comprising two agreements. First the parties agree on principles for the settlement (*quid juris*), then they agree on facts determining the application of principles (*quid facti*).

Another, optimizing model for negotiations, is a natural extension of Howard Raiffa's opus on negotiation: *The Art and Science of Negotiation* (1982). It is based on Multicriteria Decision Analysis for multi-party actors. According to this theory, each issue can be evaluated on a number of dimensions, weighed by a linear function combining weights and values of negotiation outcomes. Linear models are general in application, well understood, and insensitive to small user errors in the selection of weights or values.

Multicriteria decision analysis has been used in planning and environmental decision-making (Dodgson et al., 2001). In a single user version, the theory lends itself to optimization. In multi-party negotiations, there is not a unique best solution but a spectrum of negotiation outcomes along an "efficient frontier", beyond which it is impossible for all parties to improve their lot. Our package for supporting negotiations is seen below:

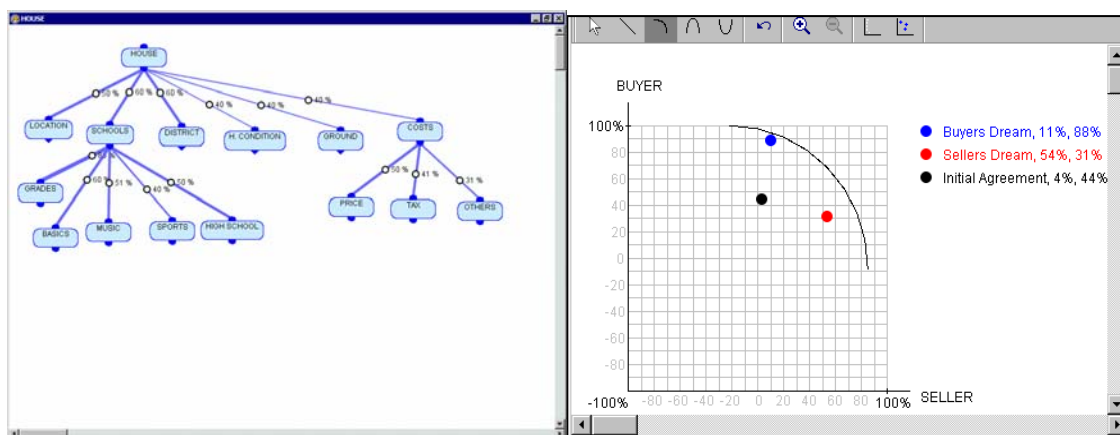


Fig. 3. Athena Negotiator, showing value analysis for one party (left) and outcome window for two parties (right), showing three possible negotiation outcomes and the efficient frontier.

While the evaluation of negotiation outcomes for each of the parties can be assessed with a rational model, the joint outcome cannot. Nor is there any known scientific way of optimizing the very process towards an agreement for any of the two parties. Furthermore, given the fact that there are two distinct models of negotiation, there are not unique models of best negotiation processes.

Some common features of Dialectic and Negotiation

Dialectic inquiry and negotiations share a number of features. First, in both kinds of reasoning, one employs procedures for managing conceptual uncertainty. It is common both in dialectic disputes and in negotiations that opponents do not share the same conceptualizations. Interpretations and delimitations are used to reduce the number of interpretations, or to coordinate the way they are handled.

Dialectics and negotiations cannot single out "the best solution", even if given all data. The quality of solutions depends on choice of conceptualization. One might hope for the elimination of some solutions, which are bad in all respects, or for all parties concerned. Reasoning may weed out the really bad alternatives without singling out any uniquely best solution.

In dialectics and negotiations, it is therefore necessary to deal with classes of models and solutions rather than single models or solutions. A class of models might be generated by a multiplicity of conceptualizations. For instance, in dialectics, the opponent and proponent

might not frame their standpoint using exactly the same concepts. Prosecutor and defence attorney might present deviating conceptualizations. In negotiations, the parties might differ about the boundaries of the object negotiated about.

Dialectics and negotiations are typically conducted between multi-party actors and representatives. Their interaction is regulated through assignment of social roles. Often, these roles are asymmetric and carry different epistemic obligations, for instance in the form of “burden of proof” (Eemeren et al., 1996).

Reasoning in dialectics and negotiations involve activities between actors. Hence, communication is essential for success. Such communication can, to some extent, be evaluated from a logical point of view, judging it from the stance of an idealized logical standpoint. To some extent, a strategic element enters, making it partly a power contest, measuring the communicative force and shrewdness of the actors.

Dialectics as well as negotiations are often conducted in multiple arenas, separated by time and space. The dialectician frames her standpoint against a background of standpoints by other dialecticians, presented elsewhere orally or in writing, but known to the recipients. The negotiating parties are often representatives with limited mandates, who have to secure their concessions elsewhere, in other negotiations.

Skills in reasoning in dialectics or negotiations, therefore, involve a blend of cognitive skills, pertaining to the reduction of both kinds of uncertainty, and social skills in handling the social interaction, making the best of the social role they have been assigned. Often this role is immersed in institutional frameworks, professional culture or ethos, and organizational procedures. The cognitive and social skills are interdependent: an argument of a scientist has some, but not all, features in common with a state attorney or a used-car dealer.

The cognitive skills of dialectics and negotiations are, at least partly, representable by an analysis of a complex cognitive issue into subcomponents, and relations among subcomponents. The only humanly feasible way of handling large complexities is via analysis and synthesis. Procedures of analysis and synthesis can be improved by software tools.

Software support for dialectics and negotiations

Why would software support improve on reasoning in dialectics and negotiations? First, there are some features of software that have potential for improvement on reasoning, and reasoning skills, over and above traditional methods.

First, software enables standardized and flexible visualization. Without a computer facilitates and constrains the use of symbolism, a multitude of actors will not be able to coordinate their representations. For group discussions in preplanning, or in post mortem analysis, there is hardly any other feasible way of presenting and comparing different conceptualizations.

Second, software enables more flexible interaction with the representations. Elementary operations like cut and paste, select and copy, save or undo, enable actors to experiment with intermediate conceptualizations before proceeding to the final one.

Third, input and output of complex computations can be tested and overviewed with no delay. By manipulating a graphical input and reading off its consequences on the output, users can gain insight into the dependencies of various factors for various parties.

Fourth, standard operations can be routinized. For instance, the software can eliminate one’s worst arguments before a presentation. It can produce output reports of various formats, based on the same reasoning structure.

Fifth, storage and retrieval of previous work are much simplified. In a computer, one might store templates, representing very general features of arguments, in classical argument theory called *topoi* or *loci*.

These features are common to any skilfully built Graphical User Interface. They largely extend the capacities of reasoners before, after, and, to some extent, also during

argumentation and reasoning.

Why would Athena software help improve environmental decision-making?

The decision support models from the 1960's focused on epistemic uncertainty, showing little or no concern for conceptual uncertainty. Our two Athena software models are designed to support reasoning also where both types of uncertainty occur. Methods for reducing conceptual uncertainty presuppose a mutual exchange between expert analysts and decision-makers. The reduction of conceptual uncertainty is like making up one's mind rather than finding out what is the case. The methods need be correspondingly different.

This is not to say that the reduction of epistemic uncertainty has a minor place in decision-making. Often, however, the issues for decision-making suffer from both kinds of uncertainty. Elaborate software tools aimed at a one-sided reduction of uncertainty will fail in such cases.

In reducing epistemic uncertainty, there are indications that very simple modelling might go far towards improving decision-making. Linear models with unit weights can improve decision-making beyond human expertise (Dawes, 1988). Heuristics based decisions, drawing on a single, dominating factor can, in many cases, produce better decisions than more sophisticated experts (Gigerenzer et al., 1999).

This is so, not because of the immense precision of simple and rough decision models, but because of their consistency, robustness, and the stochastic behaviour of the system whose behaviour we predict. The dependencies in the very systems themselves are so weak that we cannot reduce much of the epistemic uncertainty by increasing the precision of models or by collecting large sets of data.

There is room for a particular kind of decision support tools in situations where both kinds of uncertainty are vicious. In such situations, decision support tools need to promote consistency, robustness of analysis, flexibility of use, and a low user threshold to enable decision-makers to understand just enough for avoiding the worst.

Athena software tools deliver exactly that. They will not replace or compete with decision support tools for high precision modelling of complex causal interaction about which much is, or can be, known. But where data are rough, the underlying non-deterministic systems are largely unknown, or decision-makers are confused, Athena software tools need not lie idle.

HOW AND WHAT SHOULD DECISION AIDES SERVE?

The key idea in software support for decision analysis is to reduce uncertainty for decision-makers. The uncertainty can concern past, present, and future. It can be either epistemic, conceptual, or some mix of the two. The two kinds of uncertainty reductions can be interdependent. If we reduce uncertainty in one dimension, we might increase it in the other dimension. If we increase the sharpness of our conceptual system, our questions will be more precise, but we may lack sufficient knowledge to answer those questions. A reduction of conceptual uncertainty may increase epistemic uncertainty. On the other hand, we might increase conceptual uncertainties in ways that make our knowledge sufficient to answer our questions.

The Grand Rationalist ideals of the 1960's lay behind large scale planning and decision-making. Very little was known about conceptual uncertainty (Rolf, 1981). If there is considerable conceptual uncertainty involved in a matter for decision-making, a one-sided reduction of epistemic uncertainty may not help much. In such cases, it will help little if we cast models for decision support in software in order to reduce epistemic uncertainty, unless we also provide some means for reducing conceptual uncertainty.

Much effort in decision support has an unbalanced focus towards the reduction of epistemic uncertainty. From a theoretical point of view, there is a lot of science-based knowledge, ready for formalization and programming. Even though many such models were discovered to be almost useless for real life decision-making 30 years ago, it can still be an exciting and challenging task to develop PC software and textbooks, supporting and explaining the inferential procedures without help about interpretational procedures.

Unless we cling to a falsified epistemology of practical decision-making, we had better admit that there is not one type of decision support tools, but several. Which kind of tool is needed, depends on the type of uncertainty present, and on the types of known procedures to help reduce it. The design of decision support tools and user procedures needs to match needs of support with capacities for the right kind of uncertainty reduction. The tools will include both software-based methods and procedures for using them in attacking uncertainty problems.

In the construction of tools for decision aid, one should bear in mind relations between the decision-maker and her decision analyst expert. That relation bears similarity to that between the patron of a restaurant and the *maitre d'hôtel*.

During the days of Grand Rationalism in the 1960's, the relation between decision analyst and decision-maker was modelled on an Italian luxury restaurant of those days. The patron enters, and finds that there is no selection possible but for the wine – the whole menu is fixed. To the surprise of the patron, a large number of wonderful dishes will be served in due course. Per se, this is impressive, but perhaps not the way a tourist, trying to get a bite on her way between the Coliseum and the Forum, would want to spend a whole afternoon.

A pretentious grandeur accompanied Grand Rationalism. All the decision-maker would have to do was to throw in her preferences into the grand rationalist complete menu. The rest was prepared for her by the kitchen and served under fanciful names. However delicious under other circumstances, the meal was prepared in complete disregard of every other demand for attention by the hurried patron.

Another relation between decision-maker and decision expert might be analogous to that of an à la carte meal in an American diner. The patron is presented with a full and free choice, guided by a bewildering battery of questions about salads, dressings, kinds of meat, and preparation, plus a lot of bonus features at extra low prices. The confused patron selects at random and receives a gigantic portion of some non-descript food combination, everything formally in accordance with her expressed wishes.

An overly laissez-faire stance on tools for decision aid might land patrons in confused choices between options and combinations of which they are ignorant. The combinations might be ill suited for one another or for the problems at hand. The American diner model leaves the patron too ignorant of the best ways to fit her decision needs with the tools available.

A third relation can be illustrated by the Scandinavian Smorgasbord. The dishes are grouped partly depending on function, partly depending on similarity. Ham and roast beef at the one end, fish dishes at another end of the table. Cheese and sweets are found at separate tables. The patron can see for herself, get a general idea through sight and smell and pick minor nibbles for experimentation.

This is the kind of relation between decision-makers and decision experts that I would advocate. There are a large number of tools for decision support, and the choice of tools can neither completely lie on the decision analysis expert, nor on the decision-maker.

In a good choice of decision tools, one needs to know something about the tools and something about the kinds of problems and what aid the tools can bring. Decision experts often have deep knowledge about a few decision models but can be quite ignorant of a larger spectrum of decision support tools – not to mention the overall client situation.

While decision-makers generally recognize their decision problems when asked, they do not carry along lists of their needs of decision support tools. To elicit their needs is essential for good counselling. Decision-makers are often ignorant about decision tools.

Without good reasoning, there can be no decision-making, having better long-term effects on the environment, over and above decisions, drawn at random from a tombola. The failures of Grand Rationalist planning in the 1960's obscure that, today, it is possible to improve a lot on decisions with far less stultified means. The failure of the Grand Rationalist modelling of the 1960's depended on a too optimistic positivistic epistemology, dealing with epistemic uncertainty while ignoring a more pressing conceptual uncertainty. A sophisticated epistemology, with a firm basis in empirical research about environmental decision problems, can do better. This involves paying respect to both types of uncertainty, and forming decision support tools and procedures, suitable also for malign problems.

An updated, realistic epistemology, applied to tool making, stands a good chance of contributing to making decision processes and decision outcomes more reasonable.

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