



CONCEPTUALISATION OF THE GAP BETWEEN MANAGERIAL DECISION-MAKING AND THE USE OF DECISION ANALYTIC TOOLS

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Abstract

Numerous software tools aimed at supporting the analysis of decisions under risk have been developed during the latter years. One purpose of these softwares is that they are not only to be used by experts within the field of decision analysis, but also by managers in public or private organisations, hence acting as a facilitator for the theory of rational choice on behalf of decision-makers. Although we share the view that the potential impact of decision analysis software on improving managerial decision-making is high, usage of such software in real-life decision situations is not as widespread as was predicted twenty years ago. One reason for this is that the softwares and their underlying models place too high demands upon the decision-makers in a variety of ways. Thus, there exists a gap between the decision-making managers and the tool supposed to support them. In this paper, we propose a conceptualisation of this gap, identifying seven gap component types and relating these gap components to the collaborating objects (decision-maker, decision model, and decision tool) and the interfaces between them. These gap components are then bundled into a set of three explicit issues: 1) Applicability issues, 2) Representation issues, and 3) Elicitation issues, which together constitute main research issues for additional development and further work in order to reduce the gap.

Keywords: *Decision Making, Decision model and tools, applicability issues, representation issues, elicitation issues*

1 Introduction

Uncertainty regarding future states, risks, probabilities, and consequences of alternatives has meant that decision-making at the managerial level has become one of the major concerns for most types of modern organisations, whether public or private. It is thus reasonable for outsiders to believe that important and high-impact decisions have actually been conducted in a rational manner within these professional organisations. It is also reasonable to assume that the majority of the relevant facts have been taken into account and that several possibilities have been thoroughly analysed with a view to achieving the organisation's long-term objectives. This is, however, far from the reality in many

present day organisations, not least public, despite this condition having been known for decades and despite managers' access to large amounts of information through a multitude of information systems. This state of affairs has attracted a great deal of attention within business administration, particularly within organisational theory, cf., e.g., [Simon, 1956; March and Simon, 1958; Cyert and March, 1963; Simon, 1976].

Research has shown that it is common for relevant information and interactions between different objectives and values to be ignored when attempting to simplify decision situations in order to cope with large and complex problems. Further, research has also shown that the human mind is incapable of analysing complex decision situations where uncertainty prevails, cf., e.g., [Simon, 1976;



March, 1994]. In order to circumvent this incapability, a widespread suggestion has been to take advantage of decision support, for example in the form of decision analytic tools based on normative decision theory and utility theory. By using normative decision theory as a core, systematic procedures and guidelines have been devised in order to employ normative rules. These procedures and guidelines commonly referred to as decision analytic processes, aim, when followed, to produce a rational decision process where reason prevails. Brown [1970] poses the question whether “*decision analysis will be to the executive as the slide rule is to the engineer*” due to the potential impact of decision analytic techniques for assisting business decisions. More than thirty years later, the same question may still be posed. At present, these decision analysis techniques are readily available in the form of decision analytic computer software. Although many are convinced of the potential of decision analysis and related software tools, several writers, e.g., [Shapira, 1995; March, 1994; Riabacke, 2007] have concluded that such tools are, almost without exception, not employed in managerial decision-making. It appears that one reason for this situation is that the demands of these tools placed upon the decision-makers are too high in a variety of ways.

Nevertheless, there have been very few investigations performed regarding the borders between the making of real decisions and the use of computer-based decision aids. In addition, a general lack of both methods and guidelines exists regarding the means to merge these two spheres. Several attempts have been made to provide guidelines with regards to how to teach people to make better decisions in general, cf., e.g., [Clemen, 1996; Hammond et al., 1999; Keeney, 2004]. However, a gulf still exists between the worlds of managerial decision-making and the use of decision analytic tools. This is rather disheartening, as the promises made for these tools have not yet been fulfilled to any great extent.

One hypothesis is the existence of a conceptual gap between the managers and the tools. If this gap could be described, a remedy would be to bridge the gap by addressing the conceptual differences between the worlds. On one side we have decision-makers, occupied

with a large number of (unaided) decisions every day, and on the other side, we have the available computer-based decision analytic tools. However, between these two sides, a gap exists where there is little discernible interaction present, and the overall focus of this paper is on characterising this gap. The aim is to identify problem areas and specific problems where the major impediments, regarding the intellectual interaction between the decision-makers and the decision analytic tools, occur. In addition, the aim is to propose concrete suggestions regarding the alleviation of the identified problems, and to point out directions for future work within this area.

As a complement to the literature, a larger empirical study of managers was carried out [Riabacke, 2007]. The purpose of the study was to fill in knowledge gaps found during literature studies for the paper. The study will be referred to throughout the paper.

The paper does not deal with general decision support systems (DSS) which focus on delivering up-to-date figures and then structuring the figures into more useful information for the decision-makers, but rather with the use of (normative) decision theory as a means of decision support. Hence, the focus will be on tools derived from decision theory, which use inputs such as probabilities and utilities. The tools will not be discussed in detail, but some of the key features of tools aimed at decisions under risk will be highlighted.

Further, the paper deals with single objective managerial decision-making under risk. Hence, there is no explicit discussion regarding either tools or methods to support decisions with multiple objectives such as multi-criteria decision analysis (MCDA, [Roy, 1996; Vincke, 1992]) or the analytic hierarchy process (AHP, [Saaty, 1980]). This simplifies the presentation but does not incur any substantial limitations to the conclusions drawn since the paper mainly deals with higher levels of managerial decision-making.

In this paper, the generic term *decision-maker* refers to individual managers and other decision-makers within organisations, public and private, and, in addition, to groups of decision-makers. The paper is organised as follows. Section 2 outlines some properties of managerial decision-making. Section 3 deals with available decision tools. Section 4



discusses how decision analysis can be useful in managerial decision-making and points out some problems related to such approaches. These findings are analysed in Section 5. In Section 6, we present a discussion and put forward a number of suggestions in order to reduce the conceptual gap between managerial decision-making and the use of decision analytic tools. Section 7 concludes the paper.

2 Managerial Decision-Making

The human tendency to simplify complex problems has been a well-known fact within the field of business administration since the work of Simon in 1955. He argued that people do attempt to be rational, but since they have a limited capacity to process information they cannot be completely rational, see also [Lindblom, 1959]. How individuals process information, in order to provide meaning to decision-making, has been a key issue in the research within behavioural decision theory for many years [March and Sevon, 1988]. This research has shown, among other things, that people tend to simplify and edit situations and that the tendency is to ignore some information and focus, instead, on other information. According to March and Sevon [1988], humans frequently try to decompose decision problems into smaller sub-problems, and thus more complex phenomena will, in many cases, be modelled by (a set of) single numerical values, values which must then be considered equitable representations of a complex reality. Furthermore, the number of alternatives under consideration will usually be severely limited with respect to the set of (theoretically) possible alternatives, and the accuracy is thus likely to be distorted and the extent of processed information available reduced. Simon [1955, 1976] labelled this behaviour *bounded rationality*, emphasising the difficulties involved in anticipating or taking into account all possible alternatives and all information, cf. e.g., [March and Simon, 1958; Lindblom, 1959; Radner, 1975].

Furthermore, according to Slovic [2000], *“people systematically violate the principles of rational decision making when judging probabilities, making predictions or otherwise attempting to cope with probabilistic tasks. Frequently, these violations can be traced to*

the use of judgemental heuristics or simplification strategies.” Hogart [1980] gives a practical overview of the problems related to the above discussion. He labels it people’s *limited processing capacity* and describes it as follows:

- Perception of information is not comprehensive but *selective*. *Anticipations* therefore play a large part in what we actually do see. Physical as well as motivational reasons account for why “people only see what they want to see”.
- Since people cannot simultaneously integrate a great deal of information, processing is mainly done in a *sequential manner*.
- People do not possess intuitive “calculators” that allow them to make what one might call “optimal” calculations. Rather, they use relatively simple procedures, rules, or “tricks” (sometimes called “heuristics”) in order to reduce the mental effort required.
- People have limited memory capacity. Although there is considerable uncertainty as to how memory processes actually work, current theories support the view that memory works by a process of associations that reconstructs past events.

Only a few empirical studies have been carried out in the field of managerial decision-making and risk taking [Shapira, 1995]. Some deal with the decision context and a number of writers stress the fact that since the decision context affects the decision-making in several respects, it is of great importance to pay attention to the context in which the decisions are made, see, e.g., [French and Liang, 1993; House and Singh, 1987; Lee et al., 1999; Simon, 1976]. As stated by French and Rios Insua: *“No decision takes place in vacuo: there is always a context”* [French and Rios Insua, 2000, p.7]. In order to obtain more data



and identify problems that decision-makers perceive when making decisions, a larger study within major Swedish forest companies, which is one of the backbones of Swedish industry, was carried out [Riabacke, 2007]. In the study, a set of problematic issues regarding decision-making was identified by the decision-makers and, following on from this, prescriptive decision analytic support was perceived to be a promising route to take in order to increase the quality of their decision-making processes.

Additionally, a majority of the decision-makers in [Riabacke, 2007] stressed that there are many unwritten rules built into the organisational culture, and that the culture and structure of the organisation guide people in the way they make their decisions. As Lee et al. [1999, p.10] stated: *“One key aspect of organisational structure is the way in which it should outline and facilitate decision making”*. The structure will therefore determine the way in which people should make decisions. The structure will furthermore set, or create, the boundaries within which people are expected to act, i.e. make their decisions.

As a further example, one of the decision-makers in the study also said that many of his co-workers had become disciplined and the reason was, according to him, that they could choose to either “adapt to the style” or leave/lose their jobs. He also added *“We are free, to a large extent, to perform our jobs as we want – as long as it fits to the built in norms.”* Therefore, if the portrayal of culture is that this is the “correct way to perceive, think, and feel”, then the implication is that it will indeed influence the way people perceive their roles in decision-making processes. Since the working norms are defined by the organisational culture, the culture can include or exclude individuals from decision-making processes [Lee et al., 1999]. Schein [1992] provides a definition of culture, which is able to serve as a basis for a discussion on the link between organisational culture and decision-making. According to Schein, decision-making is *“A pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, and that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems.”*

Several of the decision-makers in [Riabacke, 2007] also stressed the importance of avoiding decisions in which there were risks that they could not afford or the possibility of a “catastrophic” outcome. Furthermore, the decision-makers explicitly expressed fears of doing something wrong, i.e. making “poor” decisions. An interesting conclusion of the study was that when the decision-makers were made aware of the normative rules, they actually showed a desire to act in accordance with them when making decisions in their professional lives.

3 Decision Analytic Tools

Most decision analytic tools available supporting decisions under risk rely on graph decision models, e.g., commercial software such as TreeAge’s *TreeAge Pro* (www.treeage.com), Palisade’s *PrecisionTree* (www.palisade.com), Syncopation’s *DPL* (www.syncopation.com), Vanguard’s *DecisionPro* (www.vanguardsw.com), and Preference’s *DecideIT* (www.preference.bz) among others. Clearly, the target groups of such decision software are both decision experts and decision-makers in business organisations in order to assist them in their evaluations of risky decision alternatives. For a survey of tools, see [Maxwell, 2002, Maxwell, 2004].

Although a large set of computer-based tools exist, their philosophical core remains the same in that decision evaluations are primarily being made with respect to the expected utility principle. The major differences between these tools involve neither their interpretation of the role of decision analysis nor the stage in the decision process at which it is possible to employ them, but rather lie in the variety of ways that different user inputs, with respect to setting risk attitudes and beliefs in order to assign probabilities and utilities, are enabled. In addition, different evaluation principles, generally based on the expected utility, are employed [Danielson, 2005]. Other differences between the tools involve the different means of support provided for performing sensitivity analyses and identifying the most critical variables in a decision situation. The tools may also differ in the provision available for studying the risk profiles of the different

alternatives in the decision situation. However, in this case, the fundamental meaning of such profiles will remain the same, as they are probability distributions over the potential outcomes of a given alternative.

Usage of the tools depends on a set of mutually exclusive alternatives (as well as for each alternative, a set of exhaustive and mutually exclusive consequences) being modelled by the decision-maker. To assist in the formulation of the problem, the tools employ graphic decision models such as decision trees [Raiffa, 1968] or influence diagrams [Howard and Matheson, 1984]. In brief, a decision tree is a graph in the form of a rooted tree with decision nodes, chance nodes,

and consequence nodes constructed in order to enable a probability distribution over the set of mutually exclusive consequences and their utility values, see Figure 1. An influence diagram is a directed acyclic graph which also contains decision nodes, chance nodes, and a value node, and may be seen as a compact representation of a decision tree explicitly showing “influences” (such as probabilistic dependence) between parameters in the decision situation, see Figure 2. As the same underlying theory is employed for the evaluation, any influence diagram can be converted into a corresponding (symmetric) decision tree and vice versa.

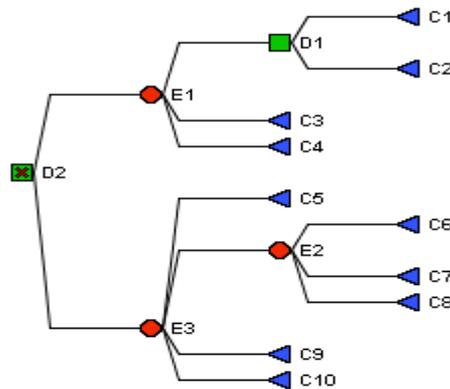


Figure 1. A small decision tree. Decision-makers are to assign to each consequence node (C_i) a utility value and to each emanating path from all event nodes (E_j) a probability. Decision nodes (D_k) represent the decisions to be made. For example, if selecting the upper alternative in D2, the outcome of E1 may lead to either a new decision D1 to be made, the consequence C3, or the consequence C4.

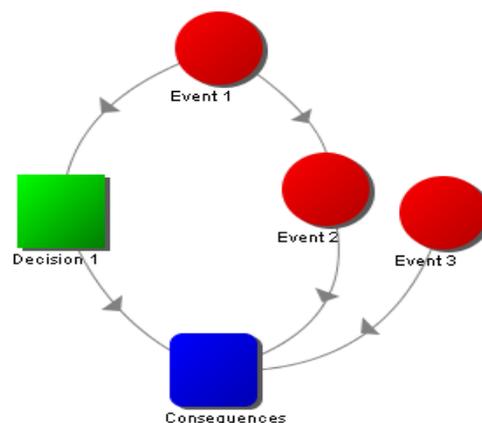


Figure 2. A small influence diagram.



Decision-makers are to assign to each outcome of an event (chance) node a probability (and possibly also a value) conditional on outcomes or alternatives in the direct predecessor nodes.

Among the benefits associated with structuring decisions in decision graph models is that probabilities are assessed locally, i.e., in the case of several uncertain future events which may affect the outcome of a decision alternative, the decision-maker may assess probabilities of one event conditional on other events. In addition, these graph models are a well-defined carrier of information and are possible to utilise during communication with experts.

Thus, the types of generic input required by tools in order to produce valuable output are:

- 1) A model of the structure of the decision situation showing the relationships between decision parameters
- 2) Probability distributions of uncertainties
- 3) A preference order of the consequence set by means of utility assignments

When complemented with various evaluation functions, this is the type of support provided by the current tools. From a conceptual point of view, there is generally good support for the model by the tool. Most tools implement a model clearly articulated by its documentation and with a foundation in expected utility theory.

Roles That Tools Can Play in Managerial Decision-Making

Computer-based decision tools can be useful during structured analyses of decision situations in ranking alternatives, performing sensitivity analyses, and assessing risk estimates but, additionally, in clarifying the most important outcomes of different courses of action. The use of computer-based decision aids could also assist in circumventing the traditional, well-established ways of thinking and acting [Schein, 1992]. Keeney and Raiffa [1976] also state that using computer-based

decision aids can be one way of legitimising and justifying decisions based on vague information and intuition, which is the case in many real-life decision situations. Computer-based decision analytic tools could furthermore provide valuable support for decision-makers since many explicitly express fears of making poor decisions, see, e.g., [Riabacke, 2007].

Clemen [1996] discusses decision-making in terms of decisions being “hard”, i.e. hard to make or hard to comprehend. They can be hard for many different reasons such as complexity due to many parameters, uncertainty of the consequence of a given alternative, or because the situation contains conflicting objectives. Moreover, Clemen [1996] states that computer-based decision analytic tools might be helpful in order to make the decision-making less hard, i.e., decision problems where the decision-maker had no ideas may prove to be solvable by structuring the situation. One problem is, however, that many decision-makers do not undertake a more formal analysis since they have already made up their minds. In addition, Keeney and Raiffa [1976], and Dreyfus [1984], argue that real decision-makers are not interested in the analytical approach of decision-making.¹ Keeney and Raiffa [1976] state that the view of many decision-makers appears to be that the formal analysis is a kind of window-dressing, only useful for the production of good-looking reports. Thus, if the decision-maker already “knows” what to do, why should he/she then bother to perform a formal analysis? The answer is, according to [Keeney and Raiffa, 1976], that there are several legitimate purposes for doing so:

- Firstly, the decision-maker might want the security of having a formal analysis that corroborates his/her unaided intuition.
- Secondly, the formal analysis might help him/her in the communication process.

¹ For an interesting reply on this statement, see Brown [1984].



- Thirdly, he/she might have to justify his/her decision to others or he/she might try to convince others of the carefulness of his/her proposed action.

4 Gap Components

Unfortunately, the use of computer-based decision analytic tools is not as easy as we would like it to be. As has been highlighted, many decisions within all types of organisations are still made by pure intuition or by following well-known paths and established rules [March, 1994]. Only a few of the decision-makers in [Riabacke, 2007] employed any type of decision analysis or computer-based decision analytic tools and similar results have been reported by other researchers in OR/MS journals, confirming the gap, see e.g. [Corner et al., 2001; Nutt, 2002]. In addition, the survey [Stenfors et al., 2006] found that the proportion of OR/MS type tools used by managers for supporting strategic decisions was very small in comparison to other types of tools such as SWOT and spreadsheet applications. Surveying the literature and using [Riabacke, 2007] as a complement, seven main gap component types were found. In the following, these are discussed.

4.1 Tendency to Simplify and Repeat

Keeney [1982] provides four basic steps for a possible decomposition of a methodology for decision analysis:

- 1) Structuring the decision problem,
- 2) Assessing possible impacts of each alternative,
- 3) Determining preferences (values) of decision-makers, and
- 4) Evaluating and comparing the alternatives.

However, decision-makers in most organisations do not follow these steps but rather well-known paths and established rules (norms), and by using different types of simplification strategies, see, e.g., [Simon, 1956; March and Simon, 1958; Simon, 1976; March, 1994; Slovic, 2000]. Moreover, as decision-making often involves attempts to

find appropriate rules to follow, this leads to attempts to fit a possibly unique decision situation into a predefined frame. In organisations, such rules typically originate from traditions, cultural norms, the structure of the organisation, and/or the advice or action of peers and superiors [Simon 1976; Turner 1985; March 1994; Riabacke, 2007].

4.2 Lack of Skills or Training

Decision-making based on experience and intuition is sufficient for some situations but far from always. People in most organisations do not possess the necessary skills in order to use decision analytic tools and to perform a more structured analysis of different situations [Keeney, 2004]. This was confirmed in [Riabacke, 2007] where none of the interviewed decision-makers in the study had any special training or education regarding decision analysis, even though they were top-level managers. Simon [1956, 1976] states that management is all about decision-making, and to be able to manage organisations you must have the proper skills for doing so, such as to make good decisions. These skills and elements of decision-making should be learned systematically. Instead, managers within most organisations are expected to be good decision-makers and to make high-quality, well-deliberated decisions in their work without any specific training, and the fact is that very few people have any training, with or without tools, in decision-making [Keeney, 2004].

4.3 Lack of Domain Knowledge

Keeney [2004] argue that decision analysis does not in itself provide the answers to a decision problem; instead, instead it provides answers to the model of the decision situation. The model is a simplification of the real problem, yet sufficiently complex for it not to be possible to solve the problem using purely unaided intuition. Furthermore, Keeney [2004] states: "Typically, the way most decision tools violate decision analysis is by not addressing the real complexities of some decisions and by oversimplifying the problem." A common view regarding what defines complexity in a decision problem is that the problem consists of a large set of parameters requiring consideration during an evaluation. The basic



standpoint is inherited from the widespread opinion that humans are incapable of aggregating a large set of parameters. However, this aggregation is not the type of complexity that a computer-based decision tool is unable to model. In fact, the tools are able to deal with this form of complexity rather well by means of, e.g., decision graph models or other ways of representing large sets of decision parameters and uncertainties. The difficulty for the decision-maker lies in how to capture an adequate representation of the environment in an abstract decision model. During the process of constructing this model, the decision-maker must be aware of and accept the necessary trade-off between readability and adequacy of the representation. However, we do recognize that the number of decision parameters in a model does not constitute the adequacy of the model, although, in some cases, omitting certain parameters will lead to the model being oversimplified². With respect to this model-building activity, general decision tools differ substantially from other types of decision support systems in that the domain-specific knowledge is completely left out of the model. There is no support for relating a particular domain to a model representing a decision in that domain. Although this is not perceived to be a weakness of the underlying theory, it could possibly be a major problem for the decision-makers regarding their view of general utility theory based decision tools as a decision aid as any domain-specific assistance is not immediately visible.

4.4 Lack of Model Fit

It is reasonable for decision-makers to ask the question as to when to employ a decision analytic approach to decision problems in their domains. In decision literature, the techniques offered by decision analysis are claimed to be, in general, applicable to *all* decision situations.

² Examples include, but are not limited to, omitting correlations, simply assuming a standard type of probability distribution, and omitting outcomes which are seen upon as extreme outcomes making their utilities hard to relate to other outcomes.

In particular, the literature focuses on those problems which are sufficiently complex such that dealing with them without the benefit of any aids is difficult, cf., e.g., [Lindley, 1985; French, 1988; Clemen, 1996]. Nevertheless, research has shown (e.g., [Carlsson and Fullér, 2002]) the existence of complex managerial decisions, not suitable for current decision analysis approaches, in which tools are to be used. When the decision-maker faces a decision situation, the knowledge that a decision analysis approach (employed by the tool) is in fact suitable for analysing the problem is important. The reason for this is that an ill-suited problem could lead to severe difficulties during the modelling stage and to a possible failure if the method were to be applied, which would not encourage further use of decision analysis.

4.5 Problem Formulation

Many books and papers exist about decision-making and almost all of the literature focuses on what to do after the crucial activities of identifying the decision problem, creating alternatives, and specifying objectives [Keeney, 1992]. However, what happens when people are confronted by real decision problems, which do not arrive readily packaged into decision trees, decision tables, or influence diagrams? The first concern of the decision-maker should be to identify the problem, or the problems, and structure these in a systematic way. Hammond et al. [1999, p.15] argue that *“You can make a well-considered, well-thought-out decision, but if you’ve started from the wrong place – with a wrong decision problem – you won’t have made the smart choice. The way you state your problem frames your decision”*.

A common denominator with reference to decision tools based on decision theory is to obtain some basic components for the model. Initially, the decision-maker may be forced to provide the tool with a set of (mutually exclusive) alternatives under consideration or to assess a set of decision objectives (criteria). However, prior to this step the decision-maker must be clear about the decision problem being modelled by the tool. The necessary step of obtaining the inputs in a decision analysis model thus appears to require an expert within the field of decision analysis, and this



intermediary expert should be able to extract the inputs from the actual problem owners.

Furthermore, a fundamental part of any decision analysis procedure is knowledge regarding the alternatives subject to analysis and comparison. Knowing what options are available in order to achieve the objectives and how these options differ from each other are also left to the decision-maker to find out in most decision tools. Merely finding a set of alternatives to analyse may not appear to be difficult. However, finding a reasonable set of “good” alternatives worthy of further analysis is often not easy. Clemen [1996, p.5] states that “*Although we usually do not have trouble finding decisions to make or problems to solve, we do sometimes have trouble identifying the exact problem, and thus we sometimes treat the wrong problem. Such a mistake has been called an ‘error of third kind’*”. Keeney [2004] adds that if you cannot identify the right problem, the uncertainties, the alternatives, and measures to indicate the degree to which the objectives are fulfilled, then almost any type of analysis will be meaningless.

Keeney [2004] also stresses the fact that *qualitative* aspects are the most important aspects of any decision analysis and that “*insights about a decision, not definitive choices about what to do, are the key products of focused thinking and analysis*”. Thus, how to place the decision within its correct context, and, further, within this context to specify mutually exclusive alternatives that in different ways may increase the level of objective satisfaction, is not straightforward. In simple terms, the question, requiring an answer by the decision-maker, is as follows. “Do we find ourselves in a situation where we should employ a decision analytic approach to a decision situation and if so: why do we have this problem, what exactly is to be analysed, and what information do we need in order to be able to analyse this in a prescriptive manner?” This is a fundamental threshold, which must be overcome before decision analysis will be viewed as a natural ingredient in managerial decision-making.

4.6 Lack of Precise Information

One main identified problem in managerial decision-making involves the lack of information and precise objective data, cf. e.g.,

[Shapira, 1995; Shapira, 1997; March, 1994; Simon, 1976; Riabacke, 2007]. Precise objective values are very seldom available in real-life decision-making situations [Merkhofer, 1987], and thus in order to be able to conform to the expected utility principle, values and probabilities must be subjectively estimated, assessed, and elicited. Bell et al. [1988, p.27] state that “*Many, if not most, real decision problems cannot be analyzed adequately using purely objective probabilities. Subjective assessments must be introduced and this once leads us into a confrontation between abstract theory and realistic behavior.*”

This was confirmed by the findings of Riabacke’s study [2007], in which the decision-makers stated explicitly that lack of information constituted a major problem. The risk and probability estimates made by decision-makers are therefore often based on incomplete or inadequate information and intuition. In addition, Keeney [2004] points out that descriptive research provides many examples “*where our intuition can go awry*”.

Additional problems include the tendency of individuals to avoid the use of precise probability and utility estimates when given the choice to reveal “softer” subjective statements. Thus, the question arises as to whether or not people are able to provide the inputs required by utility theory, cf., e.g., [Fischhoff et al., 1983].

4.7 Lack of Elicitation Procedures

An additional problem involves the fact that the decision analytic tools available today are not fine-tuned to facilitate the elicitation process to retrieve vital input data from the users. Other problem areas that have been identified, closely related to the explicit use of computer-based decision analytic tools, are difficulties concerning the use of probability and utility values. Since probabilities must, in the majority of cases, be subjectively estimated, it should be possible to elicit the numbers from the decision-maker in a trustworthy way in order to provide the decision analytic tools with the necessary input data. The elicitation and the interpretation of utilities are not readily performed, even in simplified situations, see, e.g., [Påhlman and



Riabacke 2005; Riabacke et al., 2006a; Riabacke et al., 2006b]. The task is even harder to deal with when facing complex real-life decision situations.

To be able to use computer-based decision analytic tools, the decision-makers must be able to provide the tools with input data structured in the format required for the particular computer software. Decision analytic tools, almost exclusively based on normative rules, require input data obtained by an exogenous process. The value of the tools' results is completely dependent on the quality of the input data. The cognitively difficult elicitation process, however, is in most cases left to the discretion of the users, and thus error prone for a number of reasons. As objective data is seldom available in real-life decision-making, it is generally the case that the decision-makers must subjectively assign numerical probability and utility estimates [Bell et al., 1988]. However, in decision analysis literature, there is not always a clear distinction made between these two concepts. The elicitation of probabilities has been studied to a greater extent than the elicitation of utilities, and recommendations as to how to elicit probabilities and problems with such assessments are discussed further in, for example, [Hogart, 1975; Fischhoff and Manski, 1999; Druzdzel and van der Gaag, 2000; Wang et al., 2002; Blavatsky, 2006]. The elicitation of utilities is inherently more complex due to several factors. Utility functions should accurately represent a decision-maker's individual risk attitude, and therefore utility elicitation is required for each user. In addition, subjects often do not initially reveal consistent preference behaviour in many decision situations [Keeney, 1982; Wehrung et al., 1980]. Revisions of earlier statements are common once subjects are informed of the implications of their inconsistent preferences. This places demands on the ability of the decision-maker to express his or her knowledge and attitude in the format required for decision analyses. These demands, not generally addressed in the use of decision tools, derive from the difficulties experienced by decision-makers in:

- 1) expressing their risk attitudes consistent with normative decision theory;
- 2) capturing (and accepting) subjective beliefs in different future scenarios;

- 3) relating to catastrophic outcomes to more moderate outcomes on a pre-defined value scale; and

- 4) deciding on acceptable levels of risk.

All these difficulties are related, in one way or another, to the elicitation process, i.e. how to elicit and represent the decision-makers' actual beliefs and attitudes regarding probabilities and utilities in the format required for computer-based decision analytic tools.

5 Categorisation of Gap Components

From an object point of view, the gap components fall into three categories: the Managerial Decision-Maker ("MDM" in Table 1), the Decision Model ("Model" in Table 1), and the Decision Analytic Tool ("Tool" in Table 1). Of the seven major gap component types above, the first three (tendency to simplify and repeat, lack of skills or training, and lack of domain knowledge) fall into the category Managerial Decision-Maker. The next two types (lack of fit and problem formulation) belong to the categories Managerial Decision-Maker and Decision Model since problems of these types contain elements of human mistakes as well as a fundamental problem with models in not being able to model the decision problem in a satisfactory manner. The last two (lack of precise information and lack of elicitation procedures) fall mainly into the Decision Analytic Tool category since real-life decision problems inevitably contain incomplete, imprecise, and hard-to-express information that should be handled by the tool.

However, this categorisation alone does not explain the entire width of the gap as experienced by decision-makers in organisations. If the focus is only on the objects of the gap, this does not provide the complete picture. Part of the conceptual gap comes from poor interfacing between the objects. In order to discuss the interaction between manager, model, and tool at a conceptual level, the interfaces between them have been defined. Figure 3 shows the conceptual interfaces between the concept sets (objects) of a decision-maker, a decision model, and a decision tool.

- Interface 1 is between the decision-maker and the model. This includes the decision-maker's understanding of the basic concepts of the model such as alternative, consequence, decision tree, etc.
- Interface 2 is between the decision-maker and the tool. This includes the decision-maker's understanding of the functionality of the tool such as the input dialogue, elicitation tools, modes of evaluation, etc.
- Interface 3 is between the decision model and the tool. This includes the representation of model concepts in the tool, the expressibility of statements, etc.

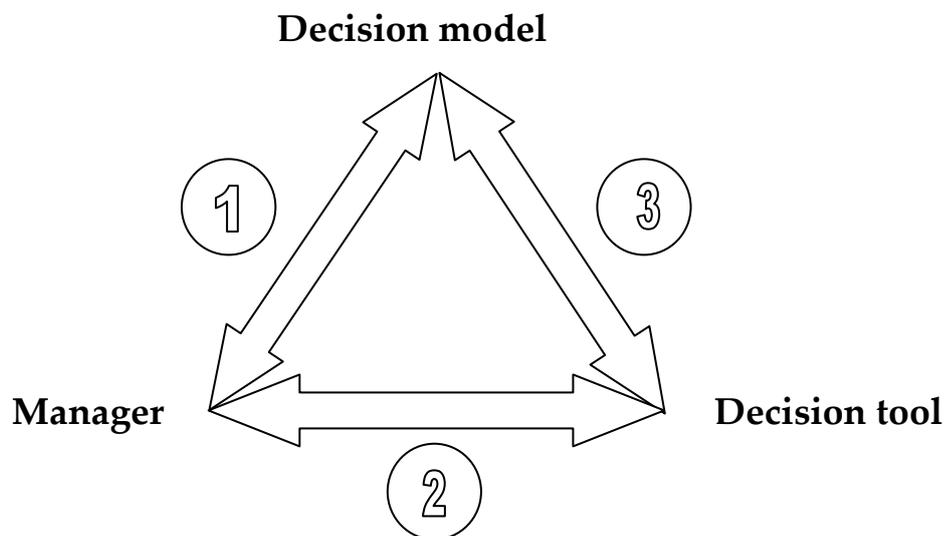


Figure 3. Conceptual interfaces

Mismatches in the conceptual interfaces lead to a widening of the gap. Of the seven gap types discussed, one (lack of training) is between the decision-maker and the model (Interface 1), one (lack of precise information) deals with both Interface 1 and Interface 2, while four (lack of domain knowledge, lack of model fit, problem identification, and lack of elicitation aid) mainly occur at Interface 2 between decision-maker and tool. One of the types (tendency to simplify and repeat) is not to any large degree attributable to interface problems. Problems relating to the interfaces lead, in turn, to objects not being able to work together in a proper manner. Effective decision aids require cooperation between all three of the object types decision-maker, model, and tool.

As two complementary categorisations are now available to assist in the understanding of the nature of the gap, it is time to provide some

proposals regarding possible remedial directions. The proposals deal with both objects and interfaces. From the managerial decision-maker object (MDM) and from Interface 1, the general research direction of *Applicability Issues* emerges. It deals with how and when decision models are applicable to managerial decision problems and a discussion follows in Section 6.1. From the model object, partly from the managerial decision-maker object, and from Interface 2, the general research direction of *Representational Issues* emerges. It deals with how to represent information in models applicable to managerial decision problems and a discussion follows in Section 6.2. From the tool object and from Interface 2, the general research direction of *Elicitation Issues* emerges. It deals with how to collect information in managerial decision problems and a discussion follows in Section 6.3. Interface 3 does not explicitly



occur in any of the issue categories and note should be taken of this fact. Some commonly held concerns, not discussed in the gap analysis and thus not encountered in the above three issue categories, deal with the tool's implementation of the decision model applied. This does not imply that such problems are uninteresting or unimportant, but merely that they do not represent any major part of the gap as seen in the literature or in the complementary investigation [Riabacke, 2007].

The three issues, namely *applicability, representation, and elicitation*, facing decision-makers within organisations when they employ decision analytic tools in their professional lives, have now been identified and a brief discussion involving the question regarding the available options for reducing the gap between managerial decision-making and the efficient use of decisions analytic tools now follows.

Gap Components	Objects			Interfaces			Issues		
	MDM	Model	Tool	□	□	□	App I	Repr	Eli c
Tendency to simplify and repeat	x						(x)	x	
Lack of skills or training	x			x			x		
Lack of domain knowledge	x				x		(x)	x	
Lack of model fit	x		(x)		x		x		
Problem formulation	x		(x)		x		x		
Lack of precise information		x	x	x	x			(x)	x
Lack of elicitation procedures			x		x				x

Table 1. Three categorisations of the conceptual gap. An 'x' indicates which objects and interfaces the gap component can be derived from, and which issue categories the gap component relates to. An '(x)' indicates a weaker relationship.

6 Discussion

One main result of this paper is the compilation of problems into issue categories. They form a characterisation of the conceptual gap that exists between managers and tools. The natural continuation is then to propose ways forward in order to reduce the gap and this section suggests one key direction of research for each issue and, in addition, developments that are aimed at gap reduction.

6.1 Applicability

We are all decision-makers and the majority of us learn decision-making by doing it. In most cases, regardless of the skills to be learned, they are broken down into small parts, which Keeney [2004, p.194] refers to as

“elements that are necessary to do well and become skilful”. One major step, felt to be important in our attempt to approach the issues, is to emphasise the importance of education. As decision problems do not arrive readily packaged in a suitable format for computer-based tools, the decision-maker is required to be able to identify the “right” problem, to place the decision in its context, and to structure all the different elements of the decision problem in such a way to make it possible to perform a more systematic analysis. Keeney [2004, p.202] states that “*there are some rather sophisticated concepts, techniques, and procedures needed to apply decision analysis when the problems are particularly complex. A person without substantial training is unlikely to be able to carry out the analysis well.*” It should also be mentioned that not all decision problems could or should be solved by computer-based decision analytic tools but the above skills would still be useful when making and thinking of most types of decisions.

Thus, since one response to our question “How to reduce the impact of applicability



issues” is education, we should then ask; 1) how we can make this happen, and 2) are decision-makers really interested? We suggest the following steps to focus on an effort to educate decision-makers in the practical use of decision analytic tools:

- Making progress in the field could be attained by focusing more on real decision-making and by asking real decision-makers what they really *want to learn* and *what type of decision problems they struggle with*, not only provide them with solutions to problems that we have created or identified.
- We must gain insight into what decisions decision-makers really care about in order to be able to teach them what they can and will learn and use. One way to achieve this understanding is to use more real-life decision-making in our research and less laboratory or pre-conceived experiments.
- Develop better ways to deal with the softer aspects of decision-making, such as vagueness and subjective ingredients.

6.2 Representation

Representational difficulties arise from the necessity to model and represent the decision-maker’s current decision environment in an abstract model. It is the opinion of some that, if the decision-maker is allowed to take part in (or perform completely by himself/herself) the construction of the model, then it is more likely to be accepted by him/her. This, however, only holds sway if the decision-maker is aware of and well-educated in the properties of the employed model. To alleviate the threshold of representational difficulties, the tools and models could be adapted and designed with an actual domain of use in mind. A feeling of recognition of the current real-world domain, at the beginning of the model-building activity, could reduce the initial threshold of attempting to formulate a representation of the decision problem. In addition, in [Stenfors et al., 2006] decision-makers states that the tools for decision-making actually being used in corporations

have, in comparison to other tools, a specific profile. Adaptations of tools may come in many forms and include support for, e.g., allowing for direct input of employed business ratios, financial objectives, and both organisation-wide and local business-unit risk thresholds. Such measures could be related to a utility function, and suggesting such utility functions may therefore be a valuable feature for the decision-maker.

It is possible that for some applications, the explicit use of general modelling tools such as decision trees or influence diagrams is not necessary. Instead, such a model may serve as an underlying model when it is necessary to deal with several dependent parameters. However, adaptations like this will limit the use to very well structured decision problems³, which are quite straightforward to formalise. Ill-structured⁴ decision problems, difficult to formalise require, by their very nature, a general type of both decision formulation support and decision analytic support in order to work as a decision aid. For such problems, the decision tools in focus in this paper deliver insufficient assistance because the most basic necessary components of the formal model are missing, that is, the set of mutual exclusive alternatives and consequences. Support of this kind is a topic of interest in the research field of “*soft operations research*”, cf. [Pidd, 1996]. Soft OR aims to study prescriptive procedures when the nature of the decision problem is of a kind that, e.g., important factors cannot be quantified, which leads to classic decision theory not being directly employable.

Hence, in order for a more widespread use of decision analytic tools in managerial decision-making, the following development opportunities with respect to the representation difficulties are suggested:

³ The objective is known, and the set of alternatives is at least partly known to the decision-maker. See [Carlsson and Fuller, 2002]

⁴ The objectives are (partly) unknown, the alternatives are (partly) unknown, and the decision context may be (partly) unknown.



- Have a specific decision context in mind and adapt general decision theoretical models and methods to a given context.
- For a given context, suggest and visualize utility functions as a function of, for example, already employed business ratios.
- Develop procedures linking problem formulation assistance with the construction of a formal model.
- Make it clear in the initial stages of employment of a software tool that the aim of the problem formulation is to construct an abstract model describing the current environment, and that the development of the decision evaluation is with respect to this model.

6.3 Elicitation

Regardless of which model a tool is based on, more focus should be placed on the human aspects of the processes that are supposed to take place between the user and the decision tool. One key step in such a process is to develop elicitation methods rendering it possible for decision-makers to express their risk attitudes, probability estimates, and utilities for reliable input data to be obtained in a format required by the tool.

Most of the tools available today do not provide the users with useful and transparent elicitation methods. This is, of course, unproductive, since both the specification and execution of the elicitation process are then left entirely to the judgment of the user. We also know that different elicitation methods yield different results [Farquahr, 1984; Jonson and Huber, 1977; Hull et al., 1973; Wang et al., 2002], and that biases in the results can be caused by several factors such as framing effects [Kahneman et al., 1982]. We have realised that people do not behave in accordance with normative rules, and, as is often forgotten, decision-makers are not, in fact, a homogeneous group, but are rather diverse with different educational, social, and cultural backgrounds.

Furthermore, in the development of elicitation methods, the tendency is to forget to

study what real decision-makers require when making real decisions – far away from experiments within research laboratories in business administration, computer science, artificial intelligence, psychology, etc. Since most tools are developed from the perspective of the developer, they implicitly assume that people interact with them in a universal manner [Riabacke et al., 2006a], which, from the developer's perspective, unfortunately is not the case.

Consequently, we should take a number of factors into consideration when developing useful, transparent elicitation methods for real decision-making, such as:

- Having more focus on how real decisions are made by different groups of decision-makers, in different contexts, etc. In order to do so we must include different groups of users, people with different educational, cultural, and social background in the development of the elicitation tools and methods, i.e. an interdisciplinary approach is badly needed for this reason [Riabacke et al., 2006a].
- The development of elicitation methods, which enable the decision-maker to express his/her subjective utilities and probabilities in imprecise terms, such as intervals, instead of fixed numbers. Precise information is seldom available, and in [Riabacke et al., 2006a; Riabacke et al., 2006b] it is shown in an explorative study that the choice of behaviour by individuals coincides, to a great extent, when comparing alternatives where the uncertainty is expressed as intervals to those where it is represented by point estimates.
- The elicitation methods must become more flexible. Decision-makers might prefer to have problems and prospects presented to them in forms other than that of the traditional methods of using probabilities to represent



uncertainty [Riabacke et al., 2006a; Riabacke et al., 2006b], and also in order to avoid framing effects which can yield different results in the elicitation process [Påhlman and Riabacke, 2005].

To match such elicitation procedures, a more flexible format for storing and operating on probabilities and utilities is required. The format should allow for the storage of vague, imprecise, and incomplete information and allow for the performance of evaluation operations. Several suggestions have been made regarding specialised formalisms for this purpose but formats using standard concepts of probabilities and utilities are also feasible [Danielson, 2004].

The discussion above merely forms one set of suggestions for each issue type. They are not exhaustive but serve as examples regarding what is conceivable within each category. Working from this perspective, each proposed gap reduction should be investigated, a solution proposed and then subsequently tested. Ways forward are discussed in Further Work below.

7 Concluding Remarks and Further Work

Acknowledgment is given to the fact that, at present, managerial decision-makers make only limited use of decision analytic tools, despite the fact that they face decision problems on a regular basis. However, these tools have been designed to offer assistance in precisely these situations. In the paper, this discrepancy is called the *gap*. There is no point in blaming a single factor for the failure. If a silver bullet remedy did indeed exist, the likelihood is that its discovery would already have occurred. Rather, our hypothesis is that the problem consists of a combination of factors creating the gap between managers and tools. In order to provide a description of the problem, we searched for components constituting the gap.

We have identified seven gap component types and related the gap components to the collaborating objects (decision-maker, decision model, and decision tool) and interfaces between them when analysing decisions using decision software. These gap

components are then bundled into a set of three explicit issues, which constitute the main research issues for additional development and further work in order to reduce the gap components to facilitate a more widespread use of decision analytic tools and techniques in managerial decision-making under risk. The final discussion contains examples of key areas to address in order to reduce the gap. The authors' further work will be focused on these areas and on other areas within the three identified gap issues.

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