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Development of Elicitation Methods for Managerial Decision Support

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Abstract

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Decision-makers in organisations and businesses make numerous decisions every day, and these decisions are expected to be based on facts and carried out in a rational manner. However, most decisions are not based on precise information or careful analysis due to several reasons. People are, e.g., unable to behave rationally as a result of their experiences, socialisation, and additionally, because humans possess fairly limited capacities for processing information in an objective manner. In order to circumvent this human incapacity to handle decision situations in a rational manner, especially those involving risk and uncertainty, a widespread suggestion, at least in managerial decision-making, is to take advantage of support in the form of decision support systems. One possibility involves decision analytical tools, but they are, almost without exception, not efficiently employed in organisations and businesses. It appears that one reason for this is the high demands the tools place on the decision-makers in a variety of ways, e.g., by presupposing that reliable input data is obtainable by an exogenous process. Even though the reliability of current decision analytic tools is highly dependent on the quality of the input data, they rarely contain methods for eliciting data from the users. The problem focused on in this thesis is the unavailability and inefficiency of methods for eliciting decision information from the users. The aim is to identify problem areas regarding the elicitation of decision data in real decision-making processes, and to propose elicitation methods that take people's natural choice strategies and natural behaviour into account. In this effort, we have identified a conceptual gap between the decision-makers, the decision models, and the decision analytical tools, consisting of seven gap components. The gap components are of three main categories (of which elicitation is one). In order to study elicitation problems, a number of empirical studies, involving more than 400 subjects in total, have been carried out in Sweden and Brazil. An iterative research approach has been adopted and a combination of quantitative and qualitative methods has been used. Findings made in this thesis include the fact that decision-makers have serious problems in many decision situations due to not having access to accurate and relevant data in the first place, and secondly, not having the means for retrieving such data in a proper manner, i.e. lacking elicitation methods for this purpose. Employing traditional elicitation methods in this realm yield results that reveal an inertia gap, i.e. an intrinsic inertia in people's natural behaviour to shift between differently framed prospects, and different groups of decision-makers displaying different choice patterns. Since existing elicitation methods are unable to deal with the inertia, we propose a class of methods to take advantage of this natural behaviour, and also suggest a representation for the elicited information. An important element in the proposed class of methods is also that we must be able to fine-tune methods and measuring instruments in order to fit into different types of decision situations, user groups, and choice behaviours.

Keywords: *elicitation methods, probability and utility assessment, interval estimations, prescriptive methods, risk elicitation*

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Riabacke, A., Managerial Decision Making under Risk and Uncertainty, *IEANG International Journal of Computer Science, 32:4, 2006.*
Article III
Påhlman, M. and Riabacke, A., A Study on Framing Effects in Risk Elicitation, *Proceedings of the International Conference on Computational Intelligence for Modelling, Control and Automation and International Conference on Intelligent Agents, Web Technologies and Internet Commerce, (CIMCA-IAWTIC'05), 2005.*
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Riabacke, A., Danielson, M. and Ekenberg, L., *A Prescriptive Approach to Probability Elicitation,* submitted for publication.

Development of Elicitation Methods for Managerial Decision Support

1 INTRODUCTION

Individuals make hundreds of decisions every day in their domestic and working lives, and they would like to believe that the majority of these decisions are made in a rational and objective manner – but unfortunately this is not the case. People are unable to be entirely rational due to, e.g., their experiences, socialisation, and additionally, because humans possess fairly limited capacities for processing information in a completely objective manner. The majority of the decisions we make are rather small, natural parts of our everyday lives, but some are of significant importance and demand a more structured approach in order to carry out a careful analysis prior to the course of action to be taken. This poses a problem, since people in organisations and societies, in general, have limited or no education regarding how to make well-deliberated decisions based on formal methods and analysis. The majority are, however, expected to be talented when it comes to making good quality decisions in their working life, i.e. they are expected to be autodidacts in complicated decision making.

Although the subject is as old as civilization, it has only been studied in a scientific manner during the last few decades. Many of the issues discussed in constructing a theory of decision making over the years have focused on the *normative* and the *descriptive* aspects of decision making, and a traditional classification in the literature regarding risky choices and decision making is the distinction between these two theories. The normative theory describes how decision-makers *should* make choices when considering risk. Whereas the descriptive theory is focused on how people actually *do* make decisions. Most people, however, do not follow the suggested normative rules [Simon 1976; Tversky and Kahneman 1982; March 1994] and rather make their decisions based on traditions, rules of thumbs, intuition or on "a hunch" that appears to be correct [Simon 1956; Simon 1976; March 1994]. Consequently, there are a number of limitations with reference to human capabilities. In order to circumvent this human incapacity to interpret decision situations, a widespread suggestion in

decision analysis (the applied form of decision theory [Raiffa 1968; Keeney and Raiffa 1976; Fischburn 1989]) is to take advantage of support in the form of decision analytical tools based on utility theory. With the formal utility and normative decision theory acting as the core, systematic procedures and guidelines in order to employ the normative rules have been constructed. Although we are convinced that the potential of decision analysis and related software tools is high, several writers, e.g., [March 1994; Shapira 1995; Corner et al. 2001; Nutt 2002; Riabacke 2006] have shown that such tools are, almost without exception, not employed in different types of organisations and businesses. Apparently, one reason for this is that the tools place demands on the decision-makers that are too high in a variety of ways. For example, the applicability of current computational decision methods is highly dependent on the quality of the input data [Påhlman 2006] and traditional decision analysis tools (c.f. PRIME Decisions, DecideIT, DPL, TreeAge Pro, AHP Expert Choice and Palisade) presuppose that reliable input data is obtained by an exogenous process. Additionally, they rarely possess structured methods for eliciting values from the users.

Many books have been written about decision making. However, almost all of the literature focuses on what to do after the crucial activities of identifying the decision problem, creating alternatives, and specifying objectives have been completed [Keeney 1992]. But what happens when people are confronted with real decision problems that do not arrive in neatly packaged decision trees, decision tables or influence diagram representations, and when useful input data must be provided by the users or, as in many cases, when the input data must be elicited from the decision-makers?

In order to reduce the gap between real decision making and the use of decision analytical tools based on normative rules many decision analysts talk of *prescriptive decision support* and *prescriptive decision analysis* as being the application of normative ideas, mindful of the findings of descriptive decision studies (see figure 1), to guide real decision making [Bell et al. 1988][1]. The prescriptive theory concerns solving problems, such as, e.g., eliciting values and beliefs about uncertainties and to deal with incoherencies. Furthermore, to construct guidance for ordinary people (not fully rational people) about how they might wish to act in different types of decision-making situations [Raiffa 1994]. The effort of the prescriptive decision theory is thus to help decision-makers solve real decision problems and to focus on one problem at a time, not on a whole class of problems, as, e.g., the normative theory does [Keeney 1992].

[1] Note that French, among others, earlier in his writings has used “normative” and “prescriptive” interchangeably, see e.g., [French 1986a, 1989].

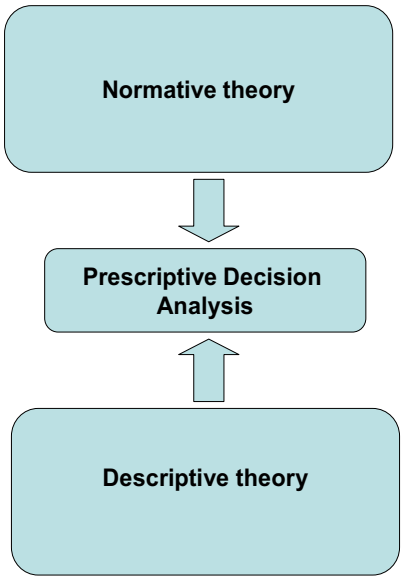

Figure 1 An illustration of the *Prescriptive Decision Analysis* as being the application of normative ideas, mindful of the findings of descriptive decision studies.

1.1 Problem focus

Three main issues that have been identified in this thesis, as major hindrances for managers to use decision analytical tools in their professional lives, are *applicability*, *representation* and *elicitation*. These three identified issues originate from seven main gap components (identified in Article I) of which *the lack of precise information* and *the lack of elicitation procedures* belong to the *elicitation* issue, which is the focus of this thesis. The identified problem areas of elicitation issues contain a number of problems that derive from the fact that precise information is seldom available in real life decision-making situations, and that decision-makers´ believes about probabilities and utilities therefore must be elicited somehow.

So, the problem focused on in this thesis is the lack of methods for eliciting information useful to prescriptive decision analysis and the overall aim is thus to;

1. Identify problem areas regarding the elicitation of probabilities and utilities in real decision-making processes. This will be performed by means of a number of empirical studies in order to study: a) why decision analytical tools almost without exception are not employed in different types of organisations and businesses, b) what type of problems people face in different types of

decision situations, where probabilities and utilities must be subjectively estimated, and c) how contextual differences affect people's choice behaviour in elicitation processes and how we can deal with such problems.

2. Develop useful elicitation methods and applications by taking people's choice strategies and natural choice behaviour into account. In addition, to put forward a class of methods for eliciting probabilities and utilities in a prescriptive manner, with regard to different types of identified problems and user needs, suitable for computer-based decision analysis.

In the categorisation of the above mentioned gap components, that represent the *conceptual gap* between the decision-makers and the decision analytical tools, we have also seen that they fall into three categories with respect to interfacing the objects of managerial decision-making, viz. decision-maker, model, and tool. Interface 1 is between the decision-maker and the model, and 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, and includes the decision-maker's understanding of the functionality of the tool, such as the input dialogue, elicitation tools, modes of evaluation, etc. And, finally, Interface 3 is between the decision model and the tool, and includes the representation of model concepts in the tool, the ability to express statements, etc., see Figure 2. The elicitation issues mainly fall within Interface 2 (again, see Article I). The main objectives of the thesis are thus accordingly the identification of problems within the field of probability and utility elicitation in the domain of the conceptual Interface 2, and the development of elicitation methods involving individual decision-makers. For that reason, specific needs and problem areas, within the field of probability and utility elicitation, have been identified in this thesis through several empirical studies (see Article II-V), and solutions for the development of elicitation methods and applications are also presented and discussed. The methodological issues regarding methods used and the design of the studies will be further discussed in section 2.

This thesis does not consider decision-making processes involving multiple actors. However, all types of decision making takes place in different types of organisational and social contexts, and therefore is it neither possible, nor desirable, to study them completely separated from these contexts. The delimitation is therefore not absolute, since no decision making takes place in vacuo [French and Rios Insua 2000].

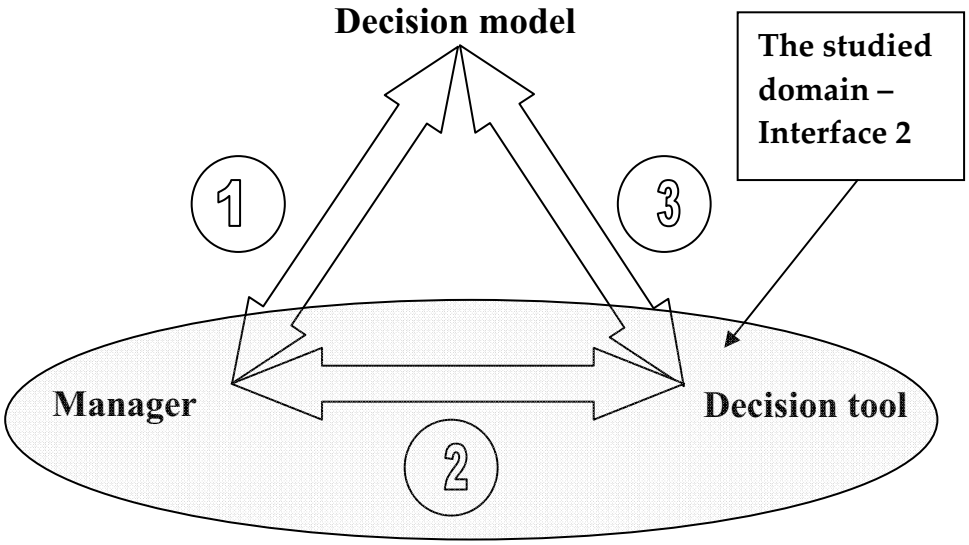

Figure 2 The conceptual interfaces between the decision-maker and the model, between the decision-maker and the tool, and between the tool and the model.

1.2 Outline

In Article I, we have identified the conceptual gap between managerial decision-making and the use of decision analytical tools, and we present an overview of problem areas within the field. From that standpoint we put forward three problem areas, *applicability difficulties, representation difficulties,* and *elicitation difficulties*, as major problem areas for decision-makers within organisations who intend to use decision analytical tools in their decision making. We propose methods regarding how to solve these problems, and thus bring managerial decision-making and decision analytical tools closer together. In Article II, we find that real decision-makers have major problems when attempting to express their beliefs numerically regarding decision situations involving risk and uncertainty. They do not know how to retrieve the information required in order to provide elicitation processes with input data for decision making. They completely lack the skills and methods necessary for this purpose. In Article III-V, we carry out three empirical studies (including 396 respondents in total, from three different universities in Sweden and Brazil), and illuminate the elicitation processes from several different perspectives. We study different aspects of these processes, using both qualitative and quantitative approaches, such as how different framing

effects can influence elicitation processes, how different choice strategies can affect risk elicitation processes, and whether contextual differences have an impact on respondents' choice behaviour in elicitation processes. Article VI points out the complications involved in relation to current elicitation methods, which, in the majority of cases, demand precise probability assessments, and instead propose an interval approach to be used in elicitation processes. The suggested interval approach appears to be more realistic, practically useful, and less demanding when eliciting data in real decision situations, as probabilities must generally be subjectively estimated.

The following sections in this introduction outline the theoretical framework for decision making under risk and uncertainty, focusing on normative as well as descriptive aspects of the problem, and point out the lack of appropriate elicitation methods as one crucial problem area within this field. Subsequently, discussions concerning methodological issues and methods used in this thesis, and also more explicit discussions regarding the methods used in each empirical study, are dealt with. The contributions and the suggested direction for further research are then presented, and finally, the included articles are presented.

1.3 The State-of-the-Art

Over the last decades decision theory and its applied form, namely decision analysis, have developed a body of theories and techniques used to study decision making and risk taking, and to assist in the analysis of complex problems in a more structured form. The body of decision theories and decision analysis techniques has become a multi-disciplinary subject, involving knowledge and influences from a wide range of areas, such as economics, sociology, statistics, philosophy, politics, mathematics, organisational theory, computer science, artificial intelligence, behavioural science, computational feasibility and operations research among others (in Figure 3 we can see a number of these influences and their respective affiliation to either the normative or descriptive theory). See e.g. early work by statisticians [Wald 1950; Savage 1954]. Current discussions regarding the principles for decision making within philosophy are provided by [Bacharach and Hurley 1991; Gärdefors and Sahlin 1988; Harper and Skyrms 1988; McClennen 1990]. The field of organisational decision theory has a long history and much of the work in the field has been done by [Simon 1955; Simon 1976; March and Simon 1958; Lindblom 1959; Cyert and March 1963, March 1994]. For a broad overview of the field of organisational theory, see Mintzberg (1979), the set of readings edited by Pugh (1971) (together with the accompanying text by Pugh et al. (1964), the report from a conference held in 1981 in Oregon, and Clough (1984)). For general surveys, see [Bacharach and Hurley 1991; Hahn and Hollis 1997]. Theories developed by psychologists, sociologists,

political scientists and others have shown that the ideals promoted by philosophers and economists are seldom exhibited in everyday decision making, see e.g., [Hogarth 1987; Kahneman et al. 1982; Payne et al. 1993; Sutherland 1992; Wright and Ayton 1994]. Thus, many argue that it is of great importance to have different approaches to the study of decision making and risk taking [Bell et al. 1988].

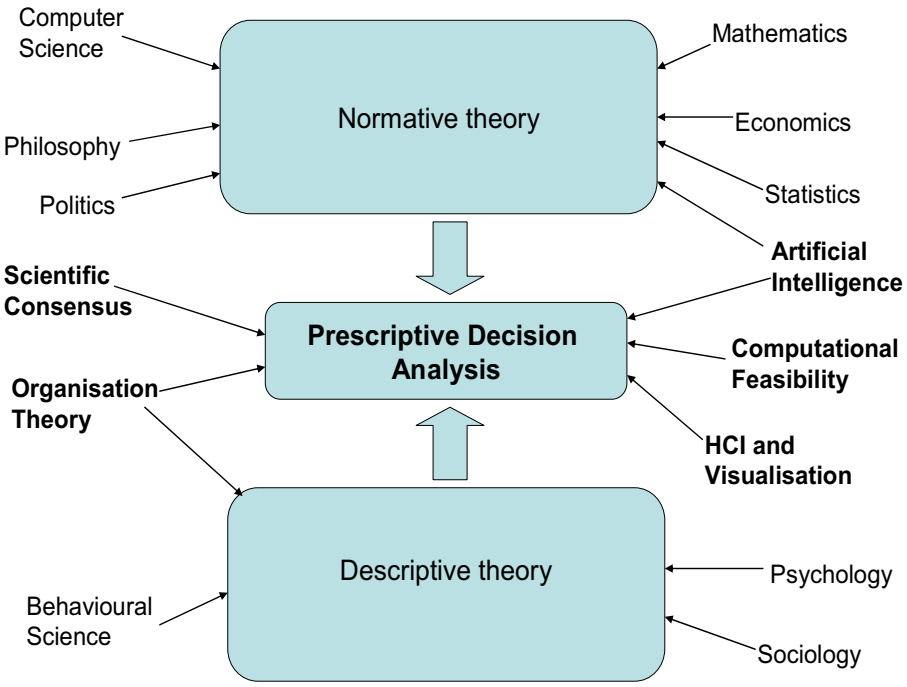

Figure 3 A representation of the different subjects from where knowledge comes into the multidisciplinary arena of decision making.

During the last 40 years or so, risk has been studied from many different perspectives, see e.g., research focusing on the capital asset theory for evaluating investments [Markowitz 1952; Markowitz 1959; Sharpe 1964], research in finance involving investors' perception of risk [Gooding 1975; Cooley 1977], research in assessing political risk in international business, [Fitzpatrick 1983]. Kunreuther and his colleagues (1978, 1979) used large scale field study methods to investigate how individuals perceived the risk of natural hazards, such as floods and earthquakes, and insured against them. The greatest amount of research with regard to recognising risk has been performed within the area of nuclear energy and other technological hazards, and leaders in this field have been [Starr 1969;

Starr and Whipple 1984; Slovic and Fischoff 1976; Slovic et al. 1978-1983; Olson 1976; Kates 1978; Keeney 1980; Keeney et al. 1984; Vlek and Stallen 1981; Kunreuther et al. 1984].

Many of the issues discussed over the years have, furthermore, focused on the *normative* and the *descriptive* aspects of decision making, and this great variety of influences has turned the arena of decision making into an arena of debate. A discussion of normative, descriptive and prescriptive decision theory finds many resonances in [Bell et al. 1988; Dowie and Elstein 1988; Eden and Radford 1990; Edwards 1992; Fischburn and LaValle 1989; Keeney 1992; Kleindorfer et al. 1993; Roy 1993; Watson and Buede 1987; White 1975]. Nowadays, however, the talk of many decision analysts is of prescriptive decision support and prescriptive decision analysis as being the application of normative ideas, while also being aware of the findings of descriptive decision research. When focusing on the development of prescriptive decision support, the number of areas of study, which must come together, increases.

For further reading regarding prescriptive analyses using normative models to guide the decision-maker, see e.g., [Brown and Vari 1992; Dempster 1985; French 1996; French and Smith 1997; French and Xie 1994; Payne et al. 1993]. Finally, since decision making and risk taking is context dependent [March and Shapira 1987], it is important to focus on the decision-making context as well. The context affects the decision-making process in many ways and we find contributions within the area in, e.g., [Allison 1971; Carter 1972; Simon 1976; French and Liang 1993; House and Singh 1987; Lee et al. 1999].

1.3.1 Normative theory and rules for choice subject to risk

Normative theory suggests a number of rules for rational decision making and the two main ones, involving choice under risk, are the *expected value rule*[2] and the *expected utility rule*[3] [Shapira 1995]. If the choice to be made *contains no risk and uncertainty* we refer to this score as a *value of* the course of action, and if the decision to be made *contains risk and uncertainty*, we then refer to this score as a *utility* of the course of action [Clemen 1996]. Statistical decision theory suggests that the *expected value* is the best rule for choice under risk [Raiffa 1968]. French (1988), however, states that expected value is simply a weighted average sum of two, or more, consequence values and that it does not consider the aspects of risk in the decision making. French (ibid) suggests the *expected utility* rule to be the criterion for decision making under risk. Precise objective probabilities are,

[2] The abbreviation EMV (expected monetary value) is used in the thesis, since this is the most commonly used interpretation of the expected value rule by economists, among others.
[3] The expected utility rule and the subjective expected utility rule (SEU) are used interchangeably in the thesis.

however, seldom available in decision-making situations [Keeney and Raiffa 1976; Merkhofer 1987], so to be able to use the expected utility principle, probabilities must be estimated [Bell et al. 1988]. Such estimates can only be subjective[4] and are a fundamental part of the risk-taking process [Shapira 1995; Kirkwood 1997]. If all the utilities and the probabilities in a decision are subjectively assigned numerical values by the decision-maker, and he/she then evaluates his/her problem according to the principles of maximising the expected utility, the decision method is called Bayesian. These subjective estimates are not necessarily logical or rational, but are rather interpreted in terms of the willingness to act in a particular way [Ramsey 1931]. It is possible to explain *utility functions* by using a diagram and thus see that; a risk-averse person has a *concave* utility function, a risk-seeking person has a *convex* utility function, and a risk-neutral person's utility function is *linear* [Arrow 1951; French 1986a]. We must, however, notice that the example above only describes one means of assessing the utility function and the attitude to risk, and that other methods also exist for this purpose, see e.g., [French 1988; Keeney and Raiffa 1976; Farquar 1984; Meyer and Pratt 1968; Harvey 1981]. Whatever method of assessment used, considerable care must also be taken to counter "behavioural biases", see [Berkeley and Humphreys 1982; Hersey et al. 1982; McCord and De Neufville 1983].

1.3.2 Criticism against normative theory

In 1738 the mathematician Daniel Bernoulli (1700-1782) published a paper in which he presented the *St. Petersburg paradox*, which completely rejected the criterion for monetary pay-off as a decision rule, see also [Bernstein 1996; Fellner 1965; Kline 1972; Arrow 1951] for more aspects concerning early development of these issues. Bernoulli pointed out that the subjective preferences are essential with regards to the decisions to be made and said that the objective methods, such as EMV, were inadequate and he was the first person to identify the difference between the objective economic outcome and the value of consequences. The expected utility model has many different purposes and economists, for instance, use it primarily as a predictive tool [Friedman 1953] and secondarily as a descriptive tool [Bettman 1979]. Schoemaker (1982) should also be consulted as he provided us with a survey of different interpretations of the utility principle and the principle of maximising the expected utility, focusing on its descriptive and predictive capabilities. There are a multitude of suggestions regarding the adoption of the expected utility rule using an axiomatic approach, see e.g., [Ramsey 1931; von Neumann and Morgenstern 1947; Savage 1972; Herstein and Milnor 1953; Suppes 1956; Luce and Krantz 1971; Jeffrey 1983]. However, even if

[4] A huge amount of theories on subjective probability and alternatives to it may be found in the literature, see e.g., [Savage 1972, chapter 3 and 4].

we accept these axioms to be of instrumental value for a decision-maker, the axiomatic approach makes strong demands on the ability of a decision-maker concerning the actual measurement of the utilities. The elicitation and the interpretation of utilities is far from easy even in simplified situations, see e.g., [Påhlman and Riabacke 2005; Riabacke et al. 2006a; Riabacke et al. 2006b; Riabacke et al. 2007b] and the problem will not become easier to deal with when facing complex real life decision problems. Another problem according to Tocher (1977) is that the elicitation of utilities, in many cases, takes the decision-maker away from the real problem, i.e. the real world, into a world of hypothetical lotteries. The principle of maximising the expected utility is insufficient for modelling all risk attitudes and Dreyfus (1984), moreover, argues that real decision-makers are not interested in the analytical approach of decision making[5]. Many people believe that the independence axioms, i.e. the sure-thing principle[6], of utility theory are fallacious, and therefore cannot be used as the core strategy of any decision theory. The most striking evidence for this hypothesis is the so-called Allais' paradox. The French economist Maurice Allais first presented his theory in 1953, and a year later Savage (1954)[7] discussed it more thoroughly. With regards to further reading, see [Allais 1953: Savage 1972; Raiffa 1968] and for a discussion about the Allais' example from both a normative and descriptive standpoint, see [MacCrimmon and Larsson 1979; Slovic and Tversky 1974]. Shapira (1995) states that situations such as those described in Allais' paradox can be found in real life situations where people use simplified decision-making rules, which can also be seen in [March and Simon 1958; Simon 1976]. This is possible, e.g., by either comparing the outcomes (without taking the probabilities into account) or by simply comparing the probability dimension preferring certain alternatives to uncertain ones (without taking into account the expected monetary outcomes). Furthermore, people in many risky-choice situations do not act in accordance with the rule of maximisation of the expected utility and empirical studies have shown that they remain inconsistent in their method of choosing even though they have been taking part in the results [Slovic and Tversky 1974], and even if they realise that their suggested decision was premature. So, why are so many people inconsistent in this respect? One theory is that irrelevant contextual effects influence people [Tversky and Kahneman 1981]. Another explanation has been presented by, among others, [McNeil et al. 1982; Slovic et al. 1983; Tversky and Kahneman 1981] who have produced startling evidence that suggests that people may choose in opposite ways and end up with contrary results when data are presented in different, but mathematically equivalent, ways. These framing effects

[5] For an interesting reply to this statement, see [Brown 1984].
[6] This is informally stated as: "If the person would not prefer f to g, either knowing that the event B obtained, or knowing that the event ~B obtained, then he does not prefer f to g [Savage 1972, p.21].
[7] Allais´ own reaction against Savage's argument can be found in [Allais 1979, p.534].

cause significant problems to the normative theory of risky choice [Fischer 1989], since it only emphasises the statistical basis for decision making [Shapira 1995]. The normative theory totally rule out such behaviour [Bell et al. 1988; Tversky and Kahneman 1981; Tversky and Kahneman 1982; Tversky and Kahneman 1986], even though the problems are well known within the area of descriptive decision research. The normative theory accordingly does not provide us with a compelling basis for choosing one logically equivalent frame over another. "Thus, the framing effects pose an interesting challenge for prescriptive decision theory, namely, to devise a principled basis for choosing among alternative ways of framing a given decision problem" [Fischer 1989 p.490]. Furthermore, several reference effects lead to violations of the "independence principle" of expected utility theory. These effects include, among others, the tendency to become risk averse for gains, but risk seeking for losses [Fischburn and Kochenberger 1979; Markowitz 1952] and the tendency to weigh losses more heavily than equivalent gains [Kahneman and Tversky 1979; Kahneman and Tversky 1984]. Another reference effect includes regret aversion, which may occur when the risky choice turns out to be "wrong" [Bell 1982]. As we can see, the normative theory faces several problems concerning the beliefs and judgements about uncertainty and we shall now more thoroughly consider additional and related inadequacies pointed out by the descriptive theory.

1.3.3 Descriptive realities

The classical model of rational choice, which is clearly dominant within decision making in economics as well as in several other disciplines, states that a rational decision-maker chooses the option, among all available options, that has the best combination of probability and utility. These probabilities and utilities must be assessed or elicited for each possible outcome and the normative theory of rational choice assumes that people are able to make these assessments properly. This is unfortunately not true according to the descriptive theory, see [Simon 1956; Tversky and Kahneman 1974; Tversky and Kahneman 1982; March 1994].

> *"Studies of decision making in the real world suggest that not all alternatives are known, that not all consequences are considered, and that not all preferences are evoked at the same time. Instead of considering all alternatives, decision makers typically appear to consider only a few and to look at them sequentially rather than simultaneously."*
>
> [March 1994, pp.8-9]

The classical decision-making approaches regard decision making as a rational process [March 1994], and the assumption is that individuals think and act with complete objectivity [Lee et al. 1995]. The descriptive approach to risky choice, however, stems from the early work by Edwards (1954), when he showed that people did not use the rules of expectation when making choices from risky prospects. Simon argues that complete rationality, assumed by the rational choice model, is unrealistic in terms of human judgement, and Edwards (1968) states that the choices made by individuals under uncertainty are inconsistent according to the rational model. Fischoff et al. (1983), among others, question the ability of people to provide the input required by utility theory, and Slovic (2000) states that "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." Simon (1955, 1976) labels this behaviour as *bounded rationality*, emphasizing the difficulties of anticipating or considering all possible alternatives and all information, c.f. e.g., [March and Simon 1958; Lindblom 1959; Lindblom 1965; Radner 1975]. Tversky and Kahneman (1974, 1982) argue that the process of human intuitive judgment is far from that required by the rational models, and they state that people rely "on a limited number of heuristic principles, which reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations." They argue that these heuristics are sometimes useful, but in many cases also lead to systematic errors due to unaided decision processes. Furthermore, they propose a set of general-purpose heuristics that underlie such judgment under uncertainty, *representativeness*, *availability,* and *adjustment and anchoring* [Tversky and Kahneman 1974]. An additional explanation to such behaviour is that irrelevant contextual effects influence people and affect the decision-making process, see [Tversky and Kahneman 1981]. Moreover, problems due to framing, i.e. how the problem is formulated, strongly affect human reasoning and the way people make their decisions [Tversky and Kahneman 1982; Tversky and Kahneman 1986]. These framing problems are, however, still not a part of the normative theory [Fischer 1989].

Other problems that decision-makers have to deal with when making decisions and handling risk, include a lack of information and objective data, see e.g., [Shapira 1995; March 1994; Simon 1976]. Since decision problems in most cases cannot be analyzed using entirely *objective* probabilities and utilities [Keeney and Raiffa, 1976; Merkhofer 1987; Bell et al. 1988], they must be *subjectively* estimated, assessed and elicited in order to provide the decision analytical tools with the necessary input data [Bell et al. 1988].

Merkhofer (1987) states that even though probabilities are the preferred means for measuring uncertainty there are two fundamentally different types of probabilities, namely the *objective* (or classical) and the *subjective* (or personal). For an extensive discussion concerning these issues, see e.g., [De Finetti 1968; Savage 1972; Holloway 1979; Parry and Winter 1981]. "The difference between objectivists and subjectivists is that the former interpret a probability as a characteristic of an identifiable physical process while the latter interpret it as a degree of belief held by a given individual" [Merkhofer 1987, p.56][8]. The subjective view argues that probabilities are a product of perception, rather than being intrinsic to physical objects. Therefore the assigned numbers, representing the probabilities, are subjective (personal) and are the result of the information available, his/her experiences, and so forth. Subjectivists are thus forced to consider all information relevant to an assessment and combine their experience with new and old information in order to reverse probabilities. This is what most decision-makers are doing several times every day when making decisions and estimating probabilities.

1.3.4 Problems in the use of computer-based decision tools

In the area of decision aid, most suggestions have focused on normative or descriptive aspects of decision making and a variety of influences have been discussed in several different contexts. Researchers have, however, convincingly demonstrated that real decision-makers do not always act in accordance with the suggested normative rules, see e.g., [Simon 1976; Tversky and Kahneman 1982; March 1994; Raiffa 1994; Shapira 1995; Bell et al.1988]. We also know that very few people make decisions on the basis of well thought-out calculations, regardless of whether the decision situation is of a private character or in a job situation, and instead often make decisions based on traditions, rules of thumb, intuition or on "a hunch" that appears to be correct [Simon 1956; Simon 1976; March 1994]. Consequently, there are a number of limitations with regards to human capabilities to the extent that individuals are unable to interpret decision situations. So, since normative theories have general problems with the issue of validation, and descriptive theories do not really purport to provide instrumental decision aid, more holistic prescriptive decision theories have recently come into focus. Basically, these aim to assist decision-makers in solving real decision problems individually by using decision analytical tools in a prescriptive manner. It should also be mentioned that with a few exceptions, very little has been done

[8] For an interesting debate between the two schools (*objectivist* and *subjectivist*), see [Abramson 1981; Kaplan and Garrick 1981] letters to the Editor published in the journal of Risk Analysis Vol. 1, No 4.

at the boundary between how real decisions, based on imprecise information, are made and the development of prescriptively useful decision analytical tools. Several writers, e.g., [March 1994; Shapira 1995; Corner et al. 2001; Nutt 2002; Riabacke 2006] have shown that decision analytical tools are, almost without exception, not employed in decision-making processes in different types of organisations and businesses. There are a number of explanations given for this and three of the main problems identified in this thesis are; 1) decision making in general and decision making where decision analytical tools are used lack precise objective data, 2) decision-makers have difficulties in formulating their beliefs and utilities in terms of estimated numbers, and 3) available decision analysis tools lack user-friendly elicitation methods and prescriptively useful elicitation applications.

To be able to use computer-based decision analytical tools, the decision-makers must provide the tools with, in the majority of cases, subjectively estimated input data that is structured in the format required for the computer software. We, however, know that people in most organisations do not possess the necessary skills in order to use decision analytical tools and to perform a more structured analysis of different decision situations [Keeney 2004]. Furthermore, we know that the presently available decision analysis tools are not fine-tuned to facilitate the elicitation process for retrieving indispensable input data from the users. It is important, for this very reason, to highlight some aspects that must be taken into consideration when risk elicitation methods are to be developed.

The elicitation of probabilities has been studied to a greater extent than the elicitation of utilities, and recommendations regarding how to elicit probabilities and problems dealing with such assessments can be reviewed further in, e.g., [Hogart 1975; Fischoff and Manski 1999; Druzdzel and van der Gaag 2000; Wang et al. 2002; Blavatskyy 2006]. The elicitation of utilities is inherently more complex due to several factors. Utility functions involve, e.g., the accurate representation of a decision-maker's individual risk attitude and therefore utility elicitation is required for each user. Furthermore, the elicitation process itself, regardless of which method is being used, is cognitively difficult for users and error prone. Also, subjects often do not initially reveal consistent preference behaviour in many decision situations [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 analysis. Decision analytical tools are almost exclusively based on normative rules and demand input data obtained by an exogenous process, and the value of the tools is completely dependent on the quality of the input data, both concerning probabilities and utilities.

One major problem in order to provide the decision analytical tools with input data is the fact that the majority of the available tools do not provide structured methods for eliciting values from the users. The specification and execution of the elicitation process is left to the discretion of the user. Needless to say, this is not optimal for several reasons. People, in general, will face a number of problems in order to accomplish such a process. For example, since people, according to Shapira (1995), have problems distinguishing between probabilities ranging from 0.3 to 0.7, there is reason to believe that people will face even greater difficulties when making their subjective estimations in an elicitation process. Furthermore, traditional methods for elicitation, see e.g., [Farquhar 1984; Jonson and Huber 1997; Hull et al. 1973], have yielded different results depending on the method used. These methods, however, do not explicitly acknowledge the possible biases caused by framing [Kahneman et al. 1982].

The elicitation and the interpretation of utilities are, furthermore, not easily performed even in simplified situations, see e.g., [Riabacke and Påhlman 2005; Riabacke et al. 2006a; Riabacke et al. 2006b] and the problem will not become easier to deal with when facing complex real-life decision problems. Additional problems are that when developing decision aid, such as elicitation methods, we must be aware that "people are different, with different psyches and emotions, capabilities, and needs, so good advice has to be tuned to the needs, capabilities, and emotional makeup of the individuals for whom the prescriptive advice is intended." [Bell et al. 1988, p.5]. Today, however, the development of decision analytical tools, in the majority of cases, takes place at a distance from the point at which the real decision making is taking place; companies and organisations, different types of businesses, different countries and cultural contexts, etc., and therefore there is a lack of ad hoc-based prescriptive solutions for different user groups and different types of decision contexts [Riabacke et al. 2006a]. Thus, the lack of prescriptively useful elicitation methods appears to be rather obvious.

1.3.5 Prescriptive decision support

We have, in the recent past, seen an increasing interest in the interaction between normative, descriptive and prescriptive theories of decision making, see e.g., [Bell et al. 1988; Fischburn and LaValle 1989; Keeney 1992], and in order to develop decision aids in any form it is of great importance to know the similarities as well as the differences between the three theories, see [Brown and Vari 1992; Dempster 1985; French 1996; French and Smith 1997; French and Xie 1994; Payne et al. 1993]. The prescriptive theory deals with the art, as well as, the science of practical decision making and can be viewed as the engineering side of the pure (normative) theory [Raiffa 1994]. Moreover, the prescriptive theory is very much concerned with the identification of the discrepancies between real (descriptive)

and idealised (normative) behaviour in decision making and to help people make better decisions. Examining the criteria by which they are evaluated can illustrate the differences between the three theories [Bell et al. 1988]:

- *Empirical validity* is the criterion used when evaluating *descriptive* models, i.e. to what degree they correspond to observed choices.
- *Theoretical adequacy* is the criterion used when evaluating *normative* models, i.e. to what degree they provide rational choice; and
- *Pragmatic value* is the criterion used when evaluating *prescriptive* models, i.e. how well they can provide suitable help to a decision-maker to make better decisions.

Keeney (1992, p.58) states that the three theories clearly address different questions and in addition *"they are distinct in terms of the breadth of their problem focus, the criterion for appraising appropriate axioms, and the judges who apply those criteria."* Keeney (1992), however, goes a step further in his classification when he, in addition, divides the theories into different classes; the normative theory focuses on all kinds of decision problems and the criterion for evaluating a set of axioms is whether or not they lead to logically consistent decisions in a rational manner. With regard to the descriptive theory the issue is whether the axioms correctly describe how people actually make decisions; and since these kinds of questions must be empirically tested the focus is on classes of decision problems such as financial decisions, group decisions, decisions involving safety issues etc. In the prescriptive theory the focus of the analysis is on one decision problem at a time and is therefore on the cell that addresses a specific decision problem. In Table 1, we can see that these two means of describing the theories [Bell et al. 1988; Keeney 1992] correspond to the criterion column.

	Problem Focus				
Theories	All decisions	Classes of Decisions	Specific Decisions	Criterion	Judges of Theories
Normative	**X**			Correctness	Theoretical Sage
Prescriptive			**X**	Usefulness	Applied Analysts
Descriptive		**X**		Empirical Validity	Experimental Researchers

Table 1 Keeney´s classification of the three theories.

Thus, the prescriptive theory focuses on one problem or problem area at a time [Keeney 1992] and the main criteria used when evaluating prescriptive models are *usefulness* [Keeney 1992] and *pragmatic value* [Bell et al. 1988], i.e. how well they can provide suitable assistance for a decision-maker so that better decisions can be made.

We have, in earlier parts of this thesis, seen that probabilities and utilities in most decision situations must be subjectively estimated [Keeney and Raiffa, 1976; Merkhofer 1987; Bell et al. 1988], and that the decision analytical tools must be provided with input data in the format required by the computer software. This is not a simple task to accomplish for several reasons. For example, people in most organisations do not have the necessary skills to handle such decision analytical tools, nor is there any tradition, in most organisations, of using computer-based decision aid [March 1994; Shapira 1995; Riabacke 2006], and, additionally, present day decision analysis tools are not fine-tuned to facilitate the elicitation process in order to retrieve the necessary input data from the users.

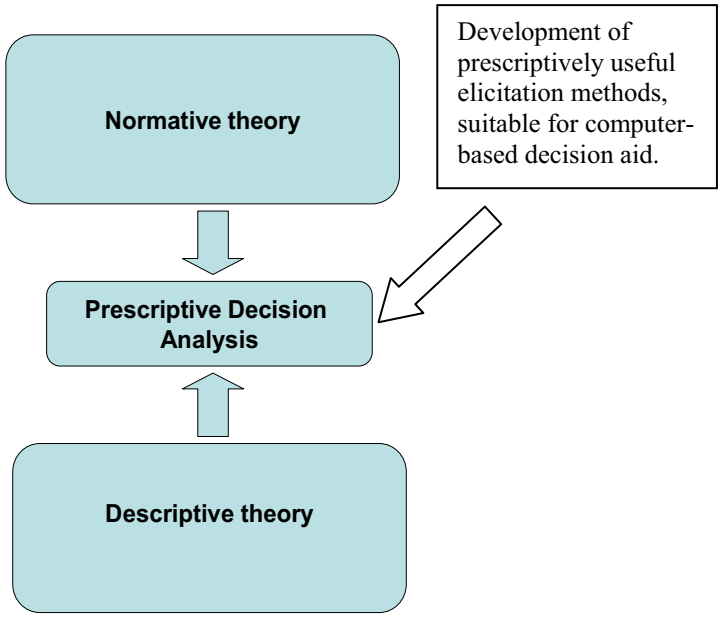

Figure 4 A visualisation of the main objective of this thesis, which is to develop elicitation methods and applications that are to be used and are useful, i.e. aids which decision-makers effectively can supply with input and use the output from.

The main focus of this thesis is thus, as illustrated in Figure 4, the development of a part of the field of prescriptive theory. The focus area is, more precisely, the development of prescriptively useful elicitation methods and applications, i.e. methods for retrieving (eliciting) data from decision-makers and aids which decision-makers can effectively supply with input and use the output obtained from them.

2 METHODOLOGY

What is, or should be, regarded as acceptable knowledge in a discipline involves information in relation to epistemological issues. According to Bryman (2004), among others, one of the most central questions in this context is whether the social world can and should be studied according to the "same principles, procedures, and ethos as the natural science." (ibid, p.11). The epistemological position that affirms the importance of using the methods of natural science to study social reality is in keeping with positivism. While the supporters of the positivistic view assume that reality can be described objectively, followers of the philosophy of the interpretative view, influenced by hermeneutics and phenomenology, argue that people and their institutions are different to those of the natural science and that subjective interpretations of the reality are therefore required. Wright (2004) claims that the epistemological clash between positivism and hermeneutics (which is a term, imported into social science from theology, concerned with the theory of interpretation of human action) reflects differences in focus with regards to the explanation of human behaviour, which is the main component of the positivistic approach on one hand, and to the social science and the understanding of human behaviour on the other. Some claim that these two approaches are incompatible, whereas others [Campbell 1988; Bryman 2004] recommend a more pragmatic approach that welcomes both perspectives.

Many writers also make a distinction between quantitative and qualitative research [Ghauri and Grönhaug 2002], and between deductive and inductive methods of reasoning [Williamson 2002]. Quantitative research is primarily influenced by the positivist view on reality and involves a deductive research process whose focus is on testing theories through quantification in the collection and analysis of objective data. Furthermore, quantitative research places less emphasis on the interpretation of results and the tendency is to place scant attention to context in, e.g., studied organisations, and thus there is less focus on the process aspects or the organisational reality [Bryman 1989]. In contrast, qualitative research mainly adopts an inductive research approach and focuses on generating theories from the findings made in the studies. In many research processes, however, the approach is neither solely inductive nor solely deductive, but rather a mixture of both and the process, when weaving back and forth between data and theory, is often called iterative – that is, there is a iterative process taking place between the collection and analysis of data [Strauss and Corbin 1988]. Quantitative research, furthermore, rejects the objective model prescribed by positivism in favour of individual interpretations of reality, which is perceived as flexible and is described in words rather than numerically.

According to Bryman (1989), the relative absence of structure in much of the quantitative research implies an additional important characteristic: flexibility, and offers the researcher the possibility to "capitalize on chance remarks or unexpected events that propel a new line of investigation" (ibid., p.138). However, as, e.g., Bryman (2004) argues, the connections between epistemological views and research approaches should be viewed as tendencies rather than definite connections, and according to [Cambell 1988; Cohen and Manion 1994; Bryman 2004; Yin 2003] the combination of quantitative and qualitative methods in the same study can be used to obtain results that can strengthen and confirm each other respectively. In addition, when using quantitative and qualitative methods in the same study, it is possible to employ the advantages of both methods simultaneously as it will, to a certain extent, be possible to control their respective disadvantages. Keeney (2004), furthermore, states that he previously thought that the most important aspects of decision analysis were the quantitative aspects but that he now believes that the greatest importance should be given to the qualitative aspects. He continues by stating that "no quantitative analysis has ever been done that did not rest on a foundation of qualitative structuring" (ibid., p.200).

When entering a new research area where little previous work exists, as in this case, it is difficult to predict how to design the entire study. Therefore, in order to proceed, it is sometimes necessary to adopt a pragmatic view with regards to the research problem. The research method in this thesis can thus be characterised as mainly explorative, and since the work aims to bridge the gap between normative and descriptive theories, the epistemological standpoint that welcomes both the positivistic and hermeneutic approaches [Campbell 1988; Bryman 2004] is adopted.

The necessity for mixed research strategies in this thesis, involving both qualitative and quantitative approaches, becomes quite apparent when considering Figure 3, which enhances the view that the areas of knowledge, brought together in prescriptive decision analysis, arise from a wide spectrum of fields. Examples of these different approaches can be found in, for instance, Article II where the area of research was relatively unexplored and the study design was therefore explorative and used an inductive approach. In Article III, we find a completely different design and a quantitative study using a deductive approach was conducted, and in Article IV both qualitative and quantitative research strategies have been used in order to strengthen and confirm the results.

2.1 Research design and methods used in the empirical studies

It is not always possible to design the entire study in advance when entering a new research area, where little previous work exists. This was particularly true in this case, since previous studies in the field of elicitation methods, with a few exceptions, have mainly focused on models requiring precise data. Very little work dealing with the boundaries between how real decisions (based on imprecise information) are made, and the formalisation of decision making processes exists. In this thesis different methods have been used in the five conducted empirical studies, which include more than 400 subjects in total. The methods used in these studies are of major interest for several reasons, one such reason being the issues concerning the relationship between design and research strategies. It is of interest to note, when discussing the reliability and measurement validity in quantitative research that the main focus is on the adequacy of measures. One should also remember that these terms, reliability and validity, are not generally applied to the practice of qualitative research even though some attempts have been made in this direction [LeCompte and Goetz 1982; Kirk and Miller 1986; Peräkyle 1997]. Others applying these concepts to quantitative research have slightly changed the sense in which the terms are used [Kirk and Miller 1986]. Hammersley (1992) places himself somewhat in the middle of the road position with regards to these matters, and according to him, validity is an important criterion in the sense that "an empirical account must be plausible and credible and should take into account the amount and kind of evidence used in relation to an account" [Bryman 2004, p.30]. Hammersley proposes *relevance* as a criterion, and argues that the relevance criterion must be assessed from the viewpoint of the contribution it makes to the literature in the field or of the importance it has to the topic.

In the following section the background and design for each article with an empirical approach (Article II-V), will be presented and discussed. This is performed in order to provide the reader with adequate information and insight into the research design and strategies used in order to be able to assess the validity, reliability and, most of all, the relevance of the work in this thesis.

In Article II, *Managerial Decision Making under Risk*, a descriptive study, an explorative and inductive approach was adopted. The problems to be examined in this article were of a qualitative type, such as, how managers make real risky decisions and what type of problems they actually experience when dealing with decision situations involving risk and uncertainty. This is a typical case where the positivistic view is not appropriate, and a hermeneutic approach with subjective interpretations of the reality is required. In this study, 12 semi-structured in-depth interviews with managers within the Swedish forest industry were conducted.

These semi-structured interviews were based on an interview protocol (see attachment 1), and the respondents were asked to read through the interview questions in advance. They received the interview protocol beforehand via mail. The protocol served as the basis for the interviews and "probing" was used whenever it was necessary in order to gain more information from the respondents. This approach gave the interview some flexibility that, according to Bryman (1989), gives the researcher the possibility to take advantage of unexpected situations which may occur. The answers received from each interview were transcribed and analysed shortly after that the interview session was ended. Each interview lasted between two and three hours. The interview study was a two-stage study, the first stage consisting of the interviews and the second stage consisting of the questionnaire in which the managers chose from different risky prospects (see Appendix in Article II). The participants in the study were not chosen at random. Instead, an effort was made to secure a broad spectrum of managers from many different spheres of activities. The number of respondents is rather limited (12), making it difficult to generalise further from the findings made in this study. Instead, the results are used in order to provide us with ideas and assistance in identifying problem areas that real decision-makers face when making risky decisions in vague domains. Furthermore, the results assist in the search for future directions to focus on when developing prescriptively useful decision analysis tools and methods.

In Article III, *A Study on Framing Effects in Risk Elicitation*, a survey study, we based our hypotheses on descriptive theory in which it is argued that framing effects cause significant problems for normative theory [Shapira 1995; Fischer 1989], whereas we used a normative measuring scale, since this forms the basis for decision analytical tools. In this article, the combination of an inductive and deductive approach was used, i.e. an iterative process [Strauss and Corbin 1988]. The motivation behind the adoption of the quantitative approach using questionnaires, was to study the behaviour of people when offered choices between differently framed prospects. Since it is difficult to find, and gain access to, a large number of real decision-makers, 240 undergraduate students were chosen to conduct our test on. The subjects were not randomly chosen, instead students were chosen from two different Universities within the areas of computer science and economics in order to obtain subjects with similar academic skills, and who would be able to understand the task within a reasonable amount of time. The questionnaires, with closed questions, were initially tested on four groups with a total of 40 subjects, and were partly redesigned after the test. Four types of questionnaires were used with two different presentation formats (or formulations) of the same problems, i.e. there were 8 different questionnaires. Each subject answered 7 questions on either chance or risk prospects and the

survey was conducted using 8 groups containing 30 students in each group. We verbally explained that there were no right answers and this was also stressed in the description of the task in the questionnaires. We, furthermore, emphasized that their anonymity would be preserved, in order to promote the idea that subjects should make their choices according to their own beliefs and not according to what they thought would be the "correct" choice to make. The results from 23 persons (out of 240) were not included in the aggregated data, since they had clearly misunderstood their task (e.g., if a pervasive characteristic in their choice behaviour was that they did not prefer a higher chance of winning an amount, or a smaller risk of losing an amount – which was tested by using control questions), or had simply failed to fill out the entire questionnaire. The response rate, or to be more precise, the rate of usable questionnaires was 90%. The usable rate had, however, no effect on the results presented in the study, since no correlation can be identified between the studied behaviour and the grounds for not successfully completing the questionnaire. Finally, the results were aggregated and a statistical analysis was performed using paired T-tests to determine whether differences between the results from the questionnaires (using different presentation formats and probability orders) were significant and not due to chance.

In Article IV, *How Different Choice Strategies Can Affect the Risk Elicitation Process*, we have combined the quantitative results from Article III with results obtained by using qualitative methods (12 semi-structured interviews were carried out). This combined approach can be used, as mentioned previously, to obtain results that can strengthen and confirm each other respectively [Campbell 1988; Bryman 2004; Yin 2003]. This study, which follows from Article III, focuses on deviations from normative behaviour. The respondents used in this article (IV) were undergraduate students from the same type of courses as the subjects in Article III. The 12 students were interviewed in order to identify and understand different strategies employed when making these choices. The semi-structured interviews included questions concerning each choice they made, i.e. the size of the amounts, the size of the probabilities, their combination, whether they used any type of strategy, or if they made their choices based on intuition. Each interview lasted 30 to 40 minutes. Probing was used as an attempt to reinforce the achieved results in Article III by studying whether decision-makers use different strategies when making their choices, i.e. to go beyond the earlier results and quantitative figures. The focus of this study is therefore on qualitative aspects, such as risk perception and choice strategies.

When analysing the results and the interview answers, at each measuring point, we could identify three different choice strategies. Since the number of respondents is so small, no generalizations can be made from the results. Instead

the results can provide a notion of the factors that are important to identify and take into account when designing decision analysis tools, and performing research within this area.

In Article V, *Risk Elicitation in Precise and Imprecise Domains – A Comparative Study, Sweden and Brazil*, a survey study, we focused on how contextual differences influence behaviours in risk elicitation. The study was conducted using 66 undergraduate students at Mid Sweden University in Sundsvall and 62 undergraduate students at PUC University in Rio de Janeiro, i.e. 128 students in total. The students were not randomly chosen, instead we used students with similar educational background to those in Article III and IV, and more specifically we attempted to obtain as similar groups as possible in both Sweden and Brazil with regard to such parameters as age, and economic and educational backgrounds. The Brazilian respondents were thus chosen in order to correspond to the Swedish respondents with regards to the above mentioned parameters[9]. The results from 8 persons (6 out of 66 in the Swedish group, and 2 out of 62 in the Brazilian group) were not included in the aggregated data, since they had clearly misunderstood their task or simply failed to complete the entire questionnaire. The questionnaires with closed questions were initially tested on 10 subjects and were partly redesigned after the test. The rate of usable questionnaires was in total 94%. The usable rate, in a manner similar to that for Article III, had no effect on the results presented in the study. Each respondent answered a questionnaire with 12 questions dealing with prospects with a chance of gain and the survey was conducted using 6 groups with approximately 20 students in each group. The questionnaires were distributed to the students after a 15 minute long presentation where they were asked to picture themselves in the situations described by the prospects. The presentation to the Swedish students was in Swedish and the presentation for the Brazilian students was in Portuguese. Furthermore, they were told that these situations take place only once, that there was no risk to themselves of losing anything, and that there were no right answers. The students had 20 minutes to fill out the questionnaires. Finally, a chi-square test (χ^2) was performed in order to establish how strongly the changes in behaviour that where identified in different choice situations can be corroborated.

[9] In Rio de Janeiro, the top 10% of the employees earn R$ 3,946.55 on average [Síntese de Indicadores Sociais 2005, Instituto Brasileiro de Geografia e Estatística – IBGE, pp. 145, 2005]. According to interviews made with University staff at PUC, the students at PUC come from families with incomes even higher than the top 10%, approximately equivalent to the Swedish average income - SEK 17,997.58 [Statistics Sweden, SCB, http://www.scb.se/templates/tableOrChart_159845.asp, 20060512], about R$4500 (approximately equivalent to 2400 USD) at the time of the study.

2.2 Article overview

The course of the work in the thesis has progressed as follows. During the author's three month stay at IIASA (International Institute for Applied System Analysis) in Laxenburg in 2001, within the Young Scientists Summer Programme, he worked within a project where flooding problems in the Upper Tisza region in Hungary were studied, see the project report [Ekenberg et al. 2003] in the Appendix (Flood Risk Management Policy in the Upper Tisza Basin – A System Analytical Approach). The project was jointly carried out by researchers from IIASA, Stockholm University and KTH, Mid Sweden University, the Hungarian Academy of Sciences, and the University of Budapest. This became one of the early triggers for observing difficulties in eliciting decision information from knowledgeable subjects. The author conducted a number of interviews with stakeholders in the Upper Tisza region during the summer of 2001 and returned for another set of interviews in the spring of 2002. Problem areas observed in these empirical studies were, among other things, that real decision-makers had problems regarding risk and probability estimations and that they had no decision support available when making risky decisions in imprecise domains. These findings proved to be the starting point for the author's research, which was carried out within FSCN (Fibre Science and Communication Network). Part of the results from the research conducted during this period were presented in the author's licentiate thesis "Computer Based Prescriptive Decision Support" in 2002, which was of a more descriptive nature, and in the above mentioned project report. During this period, thoughts on less descriptive theory led to an interest in prescriptive decision theory. Some early versions of the ideas given in Article I were generated during this period, and acted as guiding principles in the research that followed. Article II is an epitome of the author's licentiate thesis and marks the beginning of the second stage of the thesis research, from late 2002 and onwards. As the research questions became more focused, Article III–V (in that order) explored different properties of decision-makers' behaviours and were written in an iterative process where each step built on the previous ones. Indications from Article III–V led to the work on proposing the class of elicitation procedures in Article VI. A more detailed account of each article included in the thesis is given below.

In **Article I [Riabacke, A., Larsson, A. and Danielson, M., Conceptualisation of the Gap between Managerial Decision-Making and the Use of Decision Analytic Tools, submitted to *The International Journal of Public Information Systems*],** the authors initially discuss the fact that decision making in most types of modern organisations is made in a non-rational manner. One reason for this is the human lack of capacity to process information in order to provide meaning in

decision making, and for many years this has been a key issue in the research regarding behavioural decision theory. It is a well known human tendency, when coping with complex problems, to simplify the problem and only consider a subset of, e.g., the available alternatives. This type of imperfect rationality basically means that since people are not able to handle all the possible alternatives, parameters, uncertainties, etc., they simplify complex decision problems into smaller sub-problems (see section 1.3.3 Descriptive realities). A widespread suggestion, in order to circumvent this lack of capability, has been to take advantage of decision support, e.g., in the form of decision analytical tools. However, several writers have concluded that decision analytical tools are, almost without exception, not employed in managerial decision-making (see section 1.3.4 Problems in the use of computer-based decision tools). Thus, we have posed the question why this is so?

One general explanation has been that the tools place too high demands on the decision-makers in a variety of ways and too little has been done in order to find out how the problems could be solved. A number of studies have been carried out in order to discover how real decision making takes place in organisations and how real decision problems could be solved through the use of computer-based decision aid.

We put forward a number of suggestions regarding how to narrow the gap between the lack of capability of real decision-makers, their aversion to employ computer-based decision aid, and the use of decision analytical tools. Our hypothesis is that there exists a conceptual gap between the managers and the decision analytical models and tools. We have identified a number of gap components and describe them as being: a tendency to simplify and repeat, a lack of skills or training, a lack of domain knowledge, a lack of model fit, problem formulation, a lack of precise information and lack of elicitation procedures. Thereafter, from an object point of view, these components fall into three categories: managerial decision-maker, the decision model, and the decision analytical tool. However, since part of the conceptual gap is derived from poor interfacing between the objects, the above categorisation alone is unable to explain the complete gap as experienced by decision-makers within organisations. Thus, in order to discuss the interaction between the manager, model and tool at a conceptual level, the interfaces between them have been identified as follows:

- 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 ability to express statements, etc.

Thus, in order to assist in the understanding of the nature of the gap, some proposals for remedial directions have been suggested. 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. From the model object, partly from the managerial decision-maker object, and from Interface 2, the general research direction of *Representational Issues* emerges. From the tool object and from Interface 2, the general research direction of *Elicitation Issues* emerges. It is notable that Interface 3 does not occur explicitly in any of the issue categories. Having identified these three issues, the paper offers a discussion regarding the question of what is possible in order to reduce the gap between managerial decision-making and the efficient use of decision analytical tools.

The main results and contributions of this article are the identification of the conceptual gap and the categorisation of problems into issue categories. They form a characterisation of the conceptual gap that exists between managers and tools. For each issue, we propose ways forward and give suggestions on key areas and directions of research to address, in order to reduce the gap.

In **Article II [Riabacke, A., Managerial Decision Making under Risk and Uncertainty, *IEANG International Journal of Computer Science, 32:4, 2006*]**, interviews with twelve top-level mangers in three Swedish forest industries were conducted. The aim of the study was to examine what problems real decision-makers have when making real decisions involving risk and uncertainty (see section 1.3.3 Descriptive realities).

One main problem that was identified in the study is the lack of information and precise data. The risk and probability estimations made by the managers are, in fact, often based on inadequate information and intuition. Many of the managers said that they did not have the necessary skills to estimate different types of risks and that they therefore made their decisions based on mere intuition and gut feeling. Most of them also said that there were many unwritten rules built into the culture and three of them gave comments such as: "there are some patterns that implicitly guide people to act in certain ways." Furthermore, the managers did not act in accordance with suggested normative rules. They explicitly expressed their inability to handle many risky situations due to lack of

information and also expressed their fears of doing something wrong, i.e. making poor decisions. The use of computer-based decision support could provide means of circumventing traditional, well-established, ways of thinking and making decisions. However, only a few of the managers used computers when making decisions and none of them used any type of decision analytical tool.

Based on the results from this paper, the elicitation processes and the practical use of probabilities as well as utilities, pose a major obstacle in managerial decision-making at present. The main results and contributions of this article are the fact that the managers do not have the necessary information available for most decision situations involving risk and uncertainty, and that they generally have serious difficulties in attaining it. Therefore, in order to improve the decision-making processes, mainly based on subjective probability estimations and the use of computer-based decision tools in this realm, it is of great concern to develop practically useful techniques and methods for the elicitation of utility and probability measures (see section 1.3.5 Prescriptive decision support).

In **Article III [Påhlman, M., Riabacke, A., A Study on Framing Effects in Risk Elicitation,** ***Proceedings of the International Conference on Computational Intelligence for Modelling, Control and Automation and International Conference on Intelligent Agents, Web Technologies and Internet Commerce, (CIMCA-IAWTIC'05)*****],** we have studied individuals' behaviour with reference to their choices regarding different prospects concerning wins and losses. The study was conducted using 240 respondents. Since empirical studies of methods for elicitation of utilities have shown that different methods have a tendency to yield different results, it was considered essential to further investigate how people behave when faced with different types of questions presently used in utility elicitation. Thus, the aim of the study was to examine whether the presentation format and the presentation order of probabilities affected the results.

Since most decision analytical tools are based on normative rules, and the behaviour of the majority of people deviates from such rules, it is of the outmost importance to bridge the gap that occurs between the two if the benefits of using such tools in decision making are to be obtained (see section 1.3.2 Criticism against normative theory). This study provides a view regarding how different forms of framing can yield different results in the elicitation process, and how this can be used in order to narrow the discrepancy between the normative and the descriptive theory by taking different framing effects into account.

Our results confirm that framing has an influence on elicited risk data, and additionally, other aspects, such as the presentation order of probabilities can affect the results. Compensation for the effects noted in this study in order to retrieve risk data more in accordance with normative rules, and thus reduce the gap between normative and descriptive theories, can be made by being aware of

the following: 1) regardless of which presentation format is being used when dealing with chances of winning, one specific order of probabilities is to be preferred; and 2) when handling risks of losing, specific combinations of presentation format and probability order are preferred. In this study, the methods using loss prospects are even more sensitive to framing than methods utilizing gain prospects in order to elicit risk attitudes.

The results from this study are quantitative in nature and contribute to insights concerning how the respondents act when choosing from given prospects. However, actual understanding of their reasoning when making their choices, or whether any strategy had been used, was not gained.

Based on the quantitative results in Article III, it was decided to study the behaviour of individuals from a qualitative perspective in **Article IV [Riabacke, A., Påhlman, M., Larsson, A., How Different Choice Strategies Can Affect the Risk Elicitation Process, *IEANG International Journal of Computer Science, 32:4, 2006*]**. This study was conducted in order to gain insight into the strategies used by the respondents, i.e. how they perceived the different prospects regarding the size of the probability of gain or loss and the values under consideration. The focus of this study was, therefore, on aspects such as risk perception and choice strategies, i.e. whether their strategies were explicit for them or whether their behaviour was implicit or even ad hoc. The former study, conducted using 240 students in Article III, was complemented with an interview study, including an additional 12 respondents, in order to identify and understand different strategies employed when making choices. In this study, the focus was on prospects having uncertain outcomes with lower or higher probabilities of either a gain or loss, since the deviations observed in the first study were increasing at these levels. Three main strategies that the subjects used when choosing from the alternatives in the offered prospects were identified. As can be seen in the previous section, the behaviour differs in these categories depending on whether the probabilities are high or low, whether they were making choices in chance or risk domains, and on the order of the probabilities. Some of the main characteristics that were identified in the respondents' choice behaviour are:

- Many of the respondents expressed their evaluation strategy in terms of converting probabilities expressed as percentages into frequencies, e.g., one out of four instead of 0.25. Several of the respondents returned to the fact that they found some probabilities such as 0.25 and 0.75 more familiar and, therefore, gave more weight to them.
- Another observed tendency was that some of the respondents intuitively recalculated the risk of losing into a chance of not losing at all.

- A clear tendency was that many of the respondents, irrespective of the probabilities, chose the second alternative when the difference of the values between the first and second alternative was approximately 1000 SEK. Many respondents explicitly stressed the fact that 1000 SEK in many situations corresponded to a 0.1 probability, i.e. they were willing to pay that amount in order to increase the chance or reduce the risk by that probability. This tendency is an important observation of erratic behaviour as the impact of an increased/decreased chance or risk of 0.1 differs considerably depending on the sizes of the values.

It appears that some people may prefer to have prospects presented in forms other than those of traditional methods, which use single-event probabilities to represent uncertainty. Alternative representation formats are, e.g., representations as frequencies, probability wheels, and probabilities in intervals. The latter approach diminishes the requirement for precise data, which is not available in many cases of real-life decision making.

The findings in this study contribute with further knowledge regarding the lack of useful elicitation methods, and that no existing elicitation method is universally applicable with regard to user strategies. Elicitation methods that tolerate and handle different user strategies must therefore be developed and the same is true for methods that allow adjustments to different business, cultural, and social contexts.

In **Article V [Riabacke, A., Påhlman, M. and Baidya, T., Risk Elicitation in Precise and Imprecise Domains – A Comparative Study, Sweden and Brazil,** ***Proceedings of the International Conference on Computational Intelligence for Modelling, Control and Automation and International Conference on Intelligent Agents, Web Technologies and Internet Commerce, (CIMCA - IAWTIC'06)***], a comparative study in Sweden and Brazil was conducted, involving 120 students. The study investigates whether there are differences in choice behaviours when the uncertainty in the prospects is expressed as interval estimates instead of the traditional use of point estimates, as well as when prospects are displayed with and without expected monetary values. Furthermore, in order to identify whether there are differences in risk behaviour between groups from different cultural contexts when choosing from risky prospects, choice behaviours were compared between groups from Sweden and Brazil. Since the overall aim of the study was to illuminate how cultural differences influence risk behaviour and risk elicitation, the groups were made as similar as possible in Sweden and Brazil regarding such parameters as age, economic and educational background. The Brazilian respondents, students at Pontifícia Universidade Católica, PUC University, in Rio

de Janeiro, were thus chosen to correspond to the Swedish respondents with regards to the above mentioned parameters.

The most common method of representing uncertainty within decision analytical applications still involves the use of point estimates. The probabilities required by decision analytical tools have, e.g., traditionally been fixed as numerical probabilities. However, since the available information is often imprecise and even conflicting, and since preferences in many cases are inconsistent or incomplete, probability estimations have to be based on insufficient information (see sections 1.3.1 Normative theory and rules for choice subject to risk, and 1.3.4 Problems in the use of computer-based decision tools). Interval estimates reduce the demands for preciseness, but how people perceive and make choices from the available prospects where the uncertainty is expressed as intervals is still a relatively unexplored area. Furthermore, the most common approach in, e.g., managerial decision-making is to look at the expected value of each alternative during evaluation (again, see 1.3.1 Normative theory and rules for choice subject to risk). Thus, it is worth investigating how people perceive alternatives where uncertainty is expressed as point estimates and comparing this with the corresponding alternatives where the expected monetary value, EMV, is also displayed as interval estimates. Additionally, a major obstacle in the use of decision analytical tools is the fact that most of the tools are developed in the Western parts of the world and none of them take cultural differences into account. Therefore, this study also focuses on the possible differences in risk behaviour among people from different cultures since this is often completely disregarded in the design of decision analytical applications, as well as, in studies on probability elicitation (see section 1.3.4 Problems in the use of computer-based decision tools).

The results of the study show that the Swedish and Brazilian groups display similar choice behaviours when making their choices from given prospects where uncertainty is expressed as point vs. interval estimates *(p-value 0.98)*, but that the Brazilian respondents are more affected by the EMV information. The results indicate that the employment of intervals to represent uncertainty can be beneficial and could facilitate the elicitation part of decision analytical tools. Consequently, the results from this study give further substance to the previously mentioned need for more flexible tools, since people from different cultural contexts appear to differ in their choice behaviours. Thus, in order to develop more useful and flexible decision analytical tools, different groups of users should be included which ought to involve people with different educational, cultural, and social backgrounds in the design and development process. In conclusion, a more multidisciplinary approach is necessary in order to improve the usage of such tools.

Article VI [Riabacke, A., Danielson, M. and Ekenberg, L., A Prescriptive Approach to Probability Elicitation] deal with current models of decision analytical support, which assume that the users have knowledge concerning how to identify, structure, and model the decision problem. Furthermore, such applications do, in most cases, require precise input data from the users. These facts place high demands on the users, since precise data is seldom available, and since the users lack the necessary skills in order to assess subjective values in a proper manner (see section 1.3.4 Problems in the use of computer-based decision tools). In Figure 1, we visualise a general elicitation process, divided into four stages, and discuss the fact that most decision analytical tools overlook stages 1 and 2, i.e. the elicitation of data from the decision-makers. It is thus assumed that decision-makers themselves are able to provide the models with the required input data. As a result, the focus of this article is on stage 2 in Figure 1, i.e. to investigate how we can support decision-makers in an elicitation process by taking their natural choice behaviour into account.

The results of the previous studies in the thesis (Article III-V) can be interpreted differently depending on the perspective used in the analysis. From a descriptive perspective, the respondents seem to be victims of framing effects (see sections 1.3.2 Criticism against normative theory, and 1.3.3 Descriptive realities). From a normative perspective, the results seem simply wrong. The respondents appear to be unable to communicate consistent beliefs of the situations encountered, at least from the viewpoint of attempting to elicit single points. However, by taking a prescriptive approach (see section 1.3.5 Prescriptive decision support), we use the observed gap, called an *inertia gap* due to respondents' inertia in shifting views, to our advantage in proposing a class of elicitation procedures (the GIGA class) more aligned to the observed behaviours. The inertia (unwillingness to shift) effect is present in several elicitation situations. Only in some cases will it be possible to bring the width of the gap down to zero, i.e. elicit the same point from oppositely traversing prospects. Consequently, the GIGA class of methods we propose to overcome the gap difficulties described above consists of: 1) use two different presentation formats in the elicitation process in order to find the inertia interval; 2) use intervals in the elicitation process, since the elicitation output contains intervals; and 3) use a computationally efficient interval representation format for storing the elicited information.

Results and contributions from the article are the observation of the inertia gap and the proposed GIGA class of methods. The core idea of the GIGA class is to acknowledge the existence of the identified inertia gap, use it to our advantage, and, as a consequence, not merely elicit single point numbers but rather intervals containing all points indistinguishable for the decision-maker in an elicitation process. The intervals should be elicited, using an interval elicitation technique, by

a meta-procedure approaching the inertia interval from both sides, i.e. from both the upper and lower bounds.

2.3 Author's contributions

Riabacke is the main author of **Article I** [Riabacke, A., Larsson, A. and Danielson, M., Conceptualisation of the Gap between Managerial Decision-Making and the Use of Decision Analytic Tools], and he introduced the problem area dealt with. He has also written the main part of the theoretical framework, in particular those sections regarding normative, descriptive and prescriptive aspects of the problems it concerns. Riabacke has furthermore identified the conceptual gap and carried out the majority of the analysis.

Riabacke is the sole author of **Article II** [Riabacke, A., Managerial Decision Making under Risk and Uncertainty].

The work conducted in **Article III** [Påhlman, M. and Riabacke, A., A Study on Framing Effects in Risk Elicitation] was jointly carried out by the two authors (background studies, research ideas, carrying out studies, and interpretation of results).

The empirical work, as well as most of the writing, conducted in **Article IV** [Riabacke, A., Påhlman, M., and Larsson, A., How Different Choice Strategies Can Affect the Risk Elicitation Process] was jointly carried out by the two main authors Riabacke and Påhlman.

In **Article V** [Riabacke, A., Påhlman, M. and Baidya, T., Risk Elicitation in Precise and Imprecise Domains – A Comparative Study, Sweden and Brazil] the main work was jointly carried out by the two main authors Riabacke and Påhlman.

Riabacke is the main author of **Article VI** [Riabacke, A., Danielson, M. and Ekenberg, L., A Prescriptive Approach to Probability Elicitation], and he has identified the inertia gap, which is fundamental in the proposed GIGA class of elicitation methods. Riabacke has, furthermore, developed the suggested meta-technique regarding interval elicitation. The other authors identified the need for the elicited data to be stored in a computationally efficient way.

3 CONCLUDING REMARKS

3.1 Conclusions

In this thesis, we explore the question regarding why decision analytical tools, almost without exception, are not employed in different types of organisations and businesses. Three main problems are identified, namely: 1) decision making in general, and in particular decision making where decision analytical tools are used, lack precise objective data, 2) decision-makers have difficulties in formulating their beliefs and utilities numerically, and 3) available decision analytical tools lack user-friendly and prescriptively useful elicitation applications. Initially, we have identified a conceptual gap that exists between the managers and the decision analytical tools, and we have pointed out a number of gap components. From an object point of view, these gap components fall into three categories: the decision-maker, the decision model, and the decision analytical tool. One of the major hindrances identified in the use of decision analytical tools is the gap components within Interface 2 between the manager and the decision tool (see Article I). Several reasons for the elicitation difficulties within Interface 2 have been observed, such as the findings made in Article I, where we note the serious difficulties high-level decision-makers have when assessing probabilities and utilities in decision-making situations (involving risk and uncertainty). Furthermore, findings from Article III-V highlight the fact that no existing elicitation method seems universally convergent on its own. Two other problems in the area of probability and utility elicitation are that people do not act in accordance with the suggested normative rules and, as it appears, from a descriptive point of view, are victims of framing effects. Thus, the current elicitation methods do not provide us with the appropriate means to accurately capture the decision-makers´ true preferences. A problem in this area is that most current elicitation models handle precise data, i.e. the format used for probability estimates are precise numbers, which place strong demands on the ability of the user to express his or her knowledge in the required format. Furthermore, the use of existing single-point elicitation methods, such as those used in Article III, yield results that reveal an inertia gap, i.e. there is an intrinsic inertia (unwillingness) in people's natural choice behaviour to shift between differently framed equal prospects. Problems associated with the use of point-wise elicitation methods are that they may elicit a point anywhere in the inertia gap (see Article VI), and that a subsequent sensitivity analysis of the decision problem could consider points outside (above and below) the inertia gap, i.e. points not even endorsed by the decision-maker. Only in some cases will it be possible to bring the width of the gap down to zero, i.e. to elicit the same point from oppositely traversing prospects. Hence, elicitation techniques should take the inertia effect into account.

Another issue that has been identified in this thesis is the fact that the problem area involved in Interface 2 (see Article I) is context dependent in a variety of ways. As pointed out in Article V and VI, there is a need for more flexible decision analytical tools regarding the elicitation process. One difficulty is that most of present day tools are designed in developed countries by people who have a relatively homogeneous educational background, mostly within the field of computer science. To presuppose that people behave in a standardized manner when making decisions, judging probabilities and expressing their attitudes to risky choices, is a dangerous mistake. We have identified that people display different choice behaviours even though they have similar educational backgrounds [Article III and V] and that differences in the social contexts can have an effect on results, see e.g., the differences in choice behaviours between the Swedish and Brazilian respondents in Article V. Consequently, we should include different groups of users, with different educational, cultural, and social backgrounds, in the development of prescriptively useful elicitation methods, and also adopt a more multidisciplinary approach to the process.

Since no existing elicitation method appears able to deal with the general problems regarding how to express uncertain probabilities and values, and considering the problems that people's natural choice behaviour cause [Article II-V], we suggest a class of methods to approach these elicitation difficulties in a prescriptive manner. Consequently, the class of methods we propose, as a result of the studies carried out in Article II-V, to overcome the gap difficulties is to use two opposing presentation formats in the elicitation process in order to assess the inertia gap in an unbiased way. Furthermore, since we receive the elicitation output as an interval representation, we could also use intervals in the elicitation process, see Article V and VI. If we have a set of elicited ranges of the kind described above, they must be represented in a suitable format. Thus, the third component in the class of methods we suggest is a suitable representation format for storing the elicited information, and for this purpose we use an interval representation format accessible for computer algorithms [Article VI]. The proposed format allows the storage of vague, imprecise, and incomplete information and also the performance of evaluation operations. In this format, ranges are stored as pairs of inequalities. Moreover, for them to be of instrumental use, basic checks must be performed to ascertain that there are no internal inconsistencies. The proposed format is an interval representation, interpreting the increasing and decreasing data points as endpoints of an interval describing the decision-maker's best estimate. The intervals could then be checked for consistency using ordinary linear programming procedures. The proposed class of elicitation methods can be considered reasonable due to the results obtained in Article V, where people perceived intervals as at least as representative as points in the elicited information. An important element in the proposed class of

suggested methods is that it must also be possible to fine-tune methods and measuring instruments in order to fit into different types of decision situations, user groups, and choice behaviours.

3.2 Further research

The research in this thesis could be extended in a number of interesting directions depending on the level at which to continue the research. Thus, the proposed further research is divided into the following three levels:

Level 1. Further study of the other two issue categories found in Article I as being the main obstacles for achieving more efficient managerial use of decision tools: applicability and representation. Regarding *applicability*, the most promising paths (based on the analysis of gap components in Article I) are further investigations concerning the types of problems real decision-makers face in their daily work, and the types of skills required in order to become better decision-makers. In order to achieve an understanding of what real decision-makers require, and what type of aids they need, it is necessary to use more real-life decision situations in our research and less pre-conceived experiments. Regarding *representation*, the most promising paths (again based on the analysis of gap components in Article I) are to develop domain specific decision aids and to incorporate features, such as employed business ratios, in order to further adjust the tools to specific domains.

Level 2. Further study the different aspects of the currently studied *elicitation* issues, such as identifying similarities as well as inconsistencies between different user group behaviours, in order to further develop prescriptively useful methods. Moreover, study how the proposed class of interval elicitation methods works when applied to different types of decision problems in different types of businesses, cultural and social contexts. Findings in this thesis, which are important for further research in the field, include the fact that people are not a homogeneous group and their behaviours differ in a great variety of ways, not least concerning the means by which they judge probabilities and express their attitudes with regard to risky situations. However, decision tools are, in the majority of cases, designed from a developer's perspective, and therefore implicitly assume that people interact with such tools in a universal manner. This is, however, not true and it is therefore problematic to sit in, e.g., Sweden and develop tools that are to be used by decision-makers around the world, in different cultures, with different methods of reasoning, handling problems, working, etc. Thus, in order to develop more useful decision analytical tools, one direction of future work includes further studies focusing on the differences in choice behaviour and decision making styles among different groups of users, people with different educational, cultural, and social backgrounds.

Level 3. Further study of interval elicitation processes by instantiating the proposed GIGA class of methods. An evaluation should be conducted with regards to how well the suggested GIGA-extended measurement methods (wheels and bars in Article VI) work by incorporating them into decision analytical software, and studying how such tools would work as graphical interfaces for different user groups. In addition, one path is to compare interval wheels and interval bars with ordinary wheels and bars, as well as, other interval elicitation methods in a larger study, and also study what type of domains the suggested approach could be useful in.

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Included Articles

Article I
Riabacke, A., Larsson, A. and Danielson, M., Conceptualisation of the Gap between Managerial Decision-Making and the Use of Decision Analytic Tools, submitted for publication.

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Article V
Riabacke, A., Påhlman, M. and Baidya, T., Risk Elicitation in Precise and Imprecise Domains – A Comparative Study, Sweden and Brazil, *Proceedings of the International Conference on Computational Intelligence for Modelling, Control and Automation and International Conference on Intelligent Agents, Web Technologies and Internet Commerce, (CIMCA - IAWTIC'06), 2006*.

Article VI
Riabacke, A., Danielson, M. and Ekenberg, L., A Prescriptive Approach to Probability Elicitation, submitted for publication.

Article I

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.

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 being 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, 2006] 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. Figure 1 illustrates the situation where, on one side we have the decision-makers, full of activities, 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.

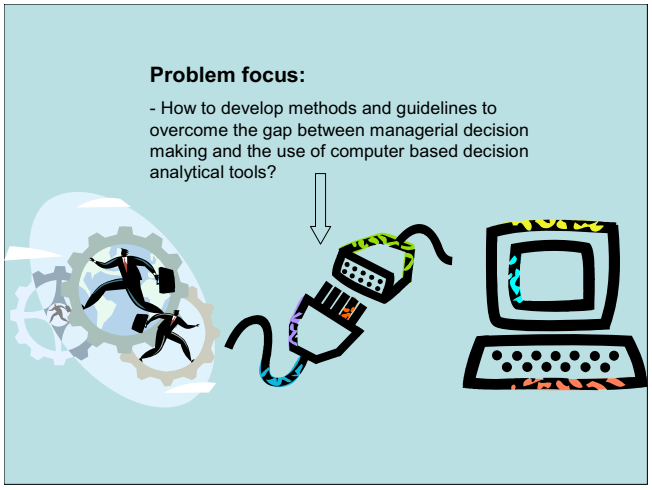

Figure 1. Problem focus

As a complement to the literature, a larger empirical study of managers was carried out [Riabacke, 2006]. 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, 2006]. 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, 2006] 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, 2006] 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 *Decide*IT (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. 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. 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.

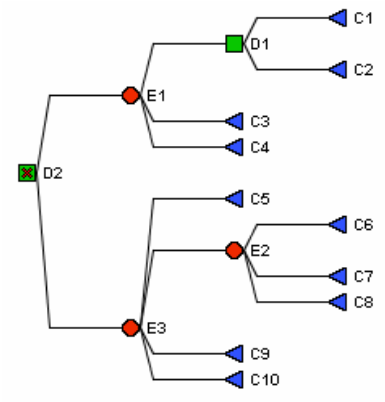

Figure 2. A small decision tree. Decision-makers are to assign to each consequence node (C_i) a utility value and to each emanating path from all event nodes (E_j) a probability. Decision nodes (D_k) represent the decisions to be made. For example, if selecting the upper alternative in D2, the outcome of E1 may lead to either a new decision D1 to be made, the consequence C3, or the consequence C4.

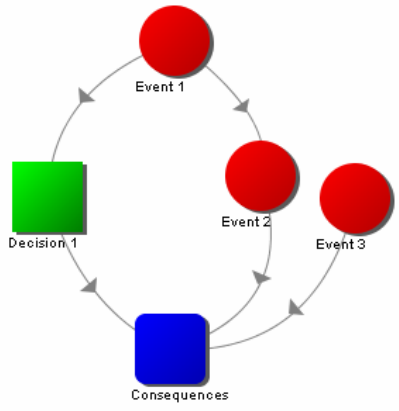

Figure 3. A small influence diagram. Decision-makers are to assign to each outcome of an event (chance) node a probability (and possibly also a value) conditional on outcomes or alternatives in the direct predecessor nodes.

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.

3.1 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, 2006].

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.
- 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, 2006] 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, 2006] 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

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

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; March 1994; Riabacke, 2006].

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, 2006] 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, step by step. 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 oversimplified[2]. 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 left completely 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. 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

[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.

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, 2006]. 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 [2006], 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; Blavatskyy, 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), the Decision Model, and the Decision Analytic Tool, see 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 4 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.

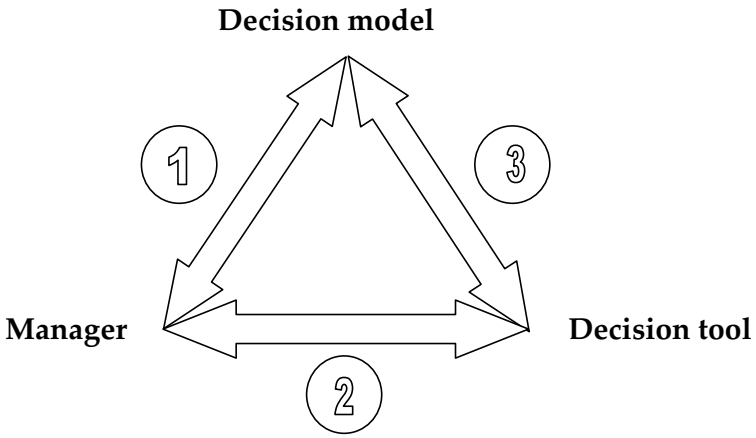

Figure 4. Conceptual interfaces

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, 2006].

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.

	Objects			Interfaces			Issues		
Gap Components	**MDM**	**Model**	**Tool**	**①**	**②**	**③**	**Appl**	**Repr**	**Elic**
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 problems[3], which are quite straightforward to formalise. Ill-

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

structured[4] 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:

- 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, see Figure 5.

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

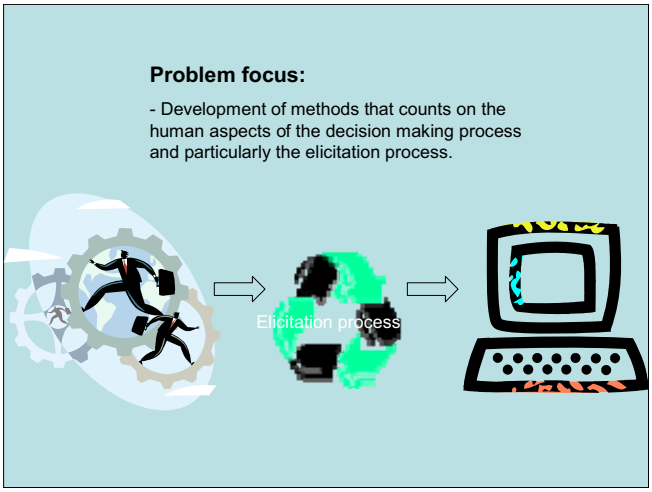

Figure 5. Problem focus.

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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Article II

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Managerial Decision Making Under Risk and Uncertainty

Ari Riabacke

Abstract—**This paper focuses on managerial decision making under risk and uncertainty. Since no one, so far, has studied managers´ risk attitudes in parallel with their actual behavior when handling risky prospects the area still remains relatively murky. Interviews have been done with 12 managers in the Swedish forest industry concerning how they define risk, how they handle risk, how they make risky decisions, and how the organizational context affects the decision-making process. Problems that have been identified in this study are the lack of information and precise objective data, that risk and probability estimations made by the managers are often based on inadequate information and intuition, that no formal analysis is carried out, that no computer based decision tools are used in the decision making processes, and therefore most decisions are based on intuition and gut feeling.**

Index Terms—**Risk taking, decision making, computer based decision tools.**

I. Introduction

Today we know by experience that very few people make decisions on the basis of well-deliberated calculations, no matter if the decision situation is of private character or in a job situation. We also know that people often neglect the normative rules when making risky decisions, and that they often make decisions by intuition or on "a hunch" that seems correct. The descriptive theory gives us some explanations why people make decisions the way they actually do and why the suggested normative rules for decision-making under risk and uncertainty are not followed [1, 2]. For instance people make decisions by following well-known paths and by following well established and built in norms, see e.g. [3] and the discussion concerning *Basic Underlying Assumptions*.

We have, in the recent past, seen an increasing interest in the interaction between *normative, descriptive* and *prescriptive theories* of decision-making (see for example [4] and [5]). In order to develop decision aids it is of great importance to know the similarities as well as the differences between the three theories see [6] and [7]. Furthermore, decision-making and risk taking is context dependent [8], which makes it important to study the decision-making context. The context affects the form of decision analysis in many ways and the way decisions are made [9]. *"No decision takes place in vacuo: there is always a context"* [10]. In other words, the structure as well as the culture of organizations must also be examined, since they both influence the decision-making processes to a great extent. With the exception of a study by [11] and [12], empirical research has not generally focused on the conceptions of risk and risk taking held by managers. Since no one, so far, has studied managers´ risk attitudes in parallel with their actual behavior when handling risky prospects, the area still remains relatively murky.

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II. Attitudes toward risk

Among others [13] and [14] state that risk means different things to different people, and that they perceive risk in different ways depending on what area they are working within. Many studies have attempted to deal with this problem and studied the role of risk in their respective fields; see for example [15] and [11]. According to [16]: "risk is a much overused word; indeed, it has been used in so many senses as to become virtually meaningless." In addition [17] provide us with a useful definition of risk in the field of decision-making. Their definition distinguishes three types of decision-making situations. We can say that most decision-makers are in the realms of decision-making under either: (a) Certainty, where each action is known to lead invariably to a specific outcome. (b) Risk, where each action leads to one of a set of possible specific outcomes, each outcome occurring with a known probability. (c) Uncertainty, where actions may lead to a set of consequences, but where the probabilities of these outcomes are completely unknown. A risky situation is thus a situation where the outcome is unknown to the decision-maker, i.e. he/she is not sure which outcome will occur and the uncertainty may lead to erroneous choices.

Rather than accepting risk, managers avoid it [18] and in the classical literature (see for example [19]) it is widely accepted that most people are risk-averse, and that risk and return are positively related. Some studies, however, point out that managers may not necessarily believe that risk and return are

positively related [20] and in a study, made by [12], 73% of the managers believed that risk was manageable. According to [21] one of the major tenets of portfolio analysis is that risk and return are positively correlated, i.e. if a person wants a higher return, he should, on average, also take a higher risk. However, others (e.g. [22] and [23]), show that there may be a negative correlation between accounting measures of risk and return. In the study by [12], 43% of the managers felt that risk and return were related in one way or another and 48% felt that the two were not necessarily related. Several studies show that managers do not accept that the risks they face are inherent in the situation, and avoid accepting risk by considering it as subject to control [24]. Rather, they believe that using skills to control the dangers can reduce risk. In the study by [12] 73% of the managers believed that risk was manageable and saw risk as controllable. They also made a definite distinction between gambling (where the odds are exogenously determined and uncontrollable) and risk taking (where skill or information can reduce the uncertainty) (ibid., p.73).

To be able to improve the managerial decision-making by providing decision makers with prescriptive decision aids we need to interview decision makers concerning their way of making decisions. In addition, we must study the organization and the decision-making context where the decision-making takes place; an aspect that none the less is often neglected.

This study aims to examine how managers in the Swedish forest industry define risk, how they handle risk, how they make risky decisions and how the organizational context affects the decision-making process. So, the main problems to be examined are; how do managers make real decisions and what type of problems do they actually experience when dealing with decision situations involving risk and uncertainty?

III. The Study Outline

This study was carried out in two major Swedish forest companies and includes interviews with twelve managers. The research method can be characterized as descriptive and explorative. The semi-structured interviews were based on an interview protocol, and the respondents received the interview protocol in advance. The protocol served as the basis for the interviews and "probing" was used whenever it was necessary in order to gain more information from the respondents. Each interview lasted between two and three hours. The interview study is a two-stage study, the first stage consists of the interviews and the second stage consists of the questionnaire in which the managers choose from different risky prospects. In the first half of the interview study, ideas of [12] serves as a basis. The amount of money in the offered prospect varied, since the aim was to examine if the behavior of the managers changed when the sums increased. The participants in the study were not chosen at random. Instead, an effort was made to secure a broad spectrum of managers from many different spheres of activities. Since there are relatively few respondents participating in the study, the results are not generally applicable.

IV. The Study

A. *WHAT IS RISK?*

When asking the managers how they defined risk, most of them distinguished between different types of risks, such as fire risk, financial risk, technical risk, commercial risk, and investment risk. They said that a risky situation is a situation where the outcome is unknown to the decision-maker, i.e. he/she is not sure which outcome will occur and the uncertainty leads to erroneous choices. When the managers were asked to describe a risky decision they had recently made, or a risky situation they had been involved in, more than half of them associated this with different kinds of investment activities and divided them into such categories as (a) investing in new machines and techniques, (b) acquisition of new companies, (c) development of new products and entering new markets.

(a) They were uncertain about whether they would reach the expected production speed within the scheduled time, if they would be able to produce top quality paper, and the reliability of the new machines. One manager said, "New techniques are always riskier than old techniques. So, we must decide if we, for example, want to be first in a new market or the first with a new product, or if we should hold back for a while and enter the market as number two. Another risky area pointed out by a manager was that they were very vulnerable concerning issues related to information technology.

(b) One problem that a manager did bring up is related to the acquisition of other companies. He said, "I do not think that we really are aware of how to estimate different types of risk that we need to deal with." He also said that even though the "mathematical part" of many problems was easily solved since they have figures concerning the cash flow, the potential development and so on, they are still greatly governed by the "soft aspects" of the decision-making process. He also said that they often invest in projects that they believe will be good investments, and that they do not only focus on figures or the investment index. Three others expressed the same sentiments concerning the acquisition of new companies by saying that they sometimes even ignore the figures they have and base their decisions on their "gut reaction".

(c) One example of risk, which is difficult to estimate and predict, is when to leave an existing market. The risky element in such a case is that once you have left a market you can not return. One manager, who refers to such a case concerning entering a new market with newspaper-paper, said, "These kinds of decisions are very unreliable." Therefore, many decisions of that type are based on subjective appraisals of the decision-makers – not on any calculations. Regarding the future interest rates risk one of them said, "We used to consult a bank and some other institutions regarding these kinds of matters, but we make the final decision by "gut feelings", i.e., we choose the alternative that feels good."

1) Risk and return – are they related?

The managers in this study were asked their opinion with regard to the following argument, "When taking larger risks there are expectations of larger returns." Ten of them explicitly said that risk is related to profit in one way or another. Statements such as the following were made: "Higher risk must result in higher profit", "Yes, everything is about maximizing the return, and in order to do so we must take risks all the time", "Higher risk corresponds to higher potential profit." and "I believe that if you are not willing to take any risk at all you will not receive a good profit either." However, although most of them agreed with the statement that there is a relationship between risk and return, four of them said that it is important to minimize the risks and not take too great risk. Two of them also said that they were no gamblers and therefore were very careful when taking risks, which was the recurring statement during the interviews. All of them agreed to the statement that "if you don't take risks there will be no returns." Four of them were convinced that it was necessary to take risks almost always – "otherwise nothing will get done" as one of them pointed out.

Four of the managers regarded risk and uncertainty as almost the same thing and thought that they are strongly correlated. Some statements made were: "For me there is a strong relation between risk and uncertainty, I cannot see any difference between them", and "If you know all the necessary facts then you do not take any risk, but if you do not know all about the future, which you do not!, then you take a risk. Risk and uncertainty are thus correlated." In the last quotation we also find a recurring statement, namely that uncertainty refers to a future state. The opinion of four of the managers was that uncertainty was the reason for the existence of risk. According to them, the level of uncertainty could in many cases be reduced if the actual case was analyzed in an orderly fashion

2) Dealing with risk

The managers were asked what they did when faced with a problem that involves risk, and they had to rank the alternatives below;

(a) Avoid taking risks (5,28)
(b) Collect more information (1,68)
(c) Check different aspects of the problem (1,86)
(d) Actively work on the problem to reduce the risk (2,54)
(e) Delay the decision (4,71)
(f) Delegate the decision (5,50)
(g) Other (specify)

The responses are displayed in the right-hand column. The sum is the average of the answers (1 was the most preferred alternative and 6 was the least preferred alternative).

The pattern of how they try to tackle decision problems involving risk was fairly clear. In order these were (b) collect more information, (c) check different aspects of the problem, (d) actively work on the problem and in due time (e) delay the decision. The majority of them agreed that taking risks was necessary for the organization. However, four of them stressed that they would avoid taking risks if the consequences could be "catastrophic", i.e. if the organization could not manage the situation if it turned out wrong. An interesting statement made by several of the managers was that if the financial status of the company was poor then they would avoid all kinds of risk taking.

3) Can risk be managed?

When asking the managers if they thought that risk could be managed all of them said yes. They said that risk could be managed if you have correct information, sufficient knowledge about the problem, and if you are experienced in the field it concerns. Most of them, once more, emphasized the importance of alternatives (b) Collect more information, (c) Check different aspects of the problem, and (d) Actively work on the problem to reduce the risk. Five of the managers also mentioned that they use their intuition or feeling to decide what is right or wrong, in other words they make subjective estimations about future states of the world. Other ways that the managers attempted to manage the risk included:

- buying insurance, thus reducing the consequences of a risk,
- carrying out a pilot-study before making decisions,
- using check-lists of points to take into consideration when making decisions,
- "sign-away" at least a part of the risk when for example buying a new machine (i.e. let the supplier take part of the risk and make this clear in the purchase contract).

The risk estimates made by the managers were often based on what they identified as experience and intuition. Only one of the managers explicitly expressed that he tried to calculate and quantify the risk.

4) Is it possible to identify risk-prone and risk-averse persons?

According to five of the respondents risk-prone people are those who want to make progress and go forward and three of them also said that risk-prone people work more independently than others do. Several of the managers considered risk-prone persons as those who are willing to make a decision without having "everything" perfectly clear. Other characteristics that were identified among risk-prone individuals:

- their risk behavior has more to do with their personality, and less with their background and education,
- people "who are risk-prone are not afraid of making mistakes"
- people higher up in the organization were more risk-prone.

An interesting angle is that, even though both risk-prone and risk-averse behavior are desirable qualities in different situations, the managers thought that risk-prone behavior was

something positive and that risk-averse behavior was something negative. For instance, one manager said that "a risk-prone person is someone who really wants to make progress and that is the kind of people companies are looking for." Risk-averse people, on the other hand, were identified as those who would "rather be safe than sorry", and three of the managers said that many people in the forest industry belong to this category. What do the managers think of themselves - are they risk prone or risk averse? Two of them said that they do not like risk taking, four of them said they consider themselves neither one way nor the other, and finally the remaining six stated that they like risk taking.

5) Do the managers use any computer-based decision aids when working with risk estimations and/or decision problems?

None of them used, or had ever used, any kind of computer-based decision-tool or program. However, after some probing it appeared that one of them sometimes did use Excel when he made some risk estimations regarding financial risks. A couple of the others said that they sometimes use Excel for modeling when doing investment calculations and also when following up as to whether investments had succeeded. Why do they not make more use of computers when making decisions and handling risk? One of the very top managers said "I have never ever, in any company, in any council or in any other situation, used any kind of computer based decision aid. I think that many people try to ´take the easy way´ and that they therefore do not spend time learning how to use such decision tools – which is a pity since I think it could be advantageous in many situations."

B. THE DECISION MAKING CONTEXT

The managers in this study were asked, "How do you perceive the *structure* of the organization?"

(a) Mechanistic (*Bureaucracy*) with highly centralized decision-making
(b) Organic (*Adhocracy*) with decentralized decision-making
(c) Other

The answers they gave were only in one single case just (a), (b) or (c). Several of them thought that the structure is a mixture of the alternatives offered and three of them said that it is something between (a) and (b). Three others said that it is (b) or at least on its way towards (b) and one of these three said "the decision-making becomes more and more decentralized, and there has been a lot of progress made during the past ten-years." Half of the respondents, irrespective of whether they chose (a) or (b), had one opinion in common, namely that they agreed that decentralized decision-making was only true up to a certain level, i.e. that most of the important decisions where made higher up in the hierarchy. One manager said "the organization is organic and decentralized at the ´factory level´, but very bureaucratic above that level – which is unpleasant." Moreover, one of the middle level managers said that "many of us are afraid of making decisions that ´daddy´ perhaps may disapprove of." Similar "feelings" were expressed by others who said that the forest industry, by tradition, has been very hierarchical and that you must always be aware of what people above your level like or dislike. Another observation made in this study was that people at the middle management level did not, to the same extent, think that the decision-making in the organization is decentralized as those higher up in the hierarchy. Thus, we can see from this study that the managers' answers were not unanimous and that it was not possible to say whether the studied organizations were mechanistic or organic. The organizations were rather, according to the managers, a mixture of both. It could perhaps be explained by the fact that several of the managers perceived the organizations as organic at the factory level, but on the other hand, as mechanistic at the top level.

The managers were also asked to choose between two alternatives regarding the *culture* in the organization, concerning the level of trust in subordinates.

The alternatives were:

(a) Autocratic with a low level of trust in subordinates
(b) Democratic with a high level of trust in subordinates
(c) Other.

A majority of them chose alternative (b), but once again, even those who had chosen alternative (b) said things that reinforced the feeling that trust and commission were somehow limited. A few examples of what they said are: "Relatively democratic decision-making, but the final decisions are always made higher up in the hierarchy", "Democratic, yes, but not when it comes to the big decisions", "The top man is the one and only one in charge." The managers were also asked about whether they thought there were, or not, unconscious, taken-for-granted beliefs that guide the decision-makers in some way. Eight of them said that there definitely were more of unconscious and taken-for-granted beliefs that guided them when they made different kinds of decisions. Three of them made statements such as the following: "There are some patterns that implicitly guide people to act in some ways ´as it always has been done´", "Yes, there is definitely a built-in culture that tells people what is right and what is wrong" and "I think we have quite a lot ´built into the walls´, a lot of unwritten rules that guide people in their decision-making." Three of the other managers talked about discipline and the importance of adapting to the organizational norms. One of them said that many of the workers had become very disciplined and the reason was, according to him, that either the workers chose to "adapt the style" or leave/lose their job. He also added that "We are free, to a large extent, to perform our job as we want – as long as it fits in to the built in norms." Several of the mangers also talked about the importance of "adapting the style", to learn what is right and what is wrong – even though most of the rules are in unwritten form. Two of the top-level managers also

discussed these matters, and they agreed that it is important to employ people who possess fundamental values that will suit the business concept. Furthermore, they wanted to see employees who are willing to adapt to the style of the firm and who suit the prevailing culture. One of them also said that "People have a tendency to follow a well-worn path in the organization. Most of those who have worked in the company for a long time have adapted to the style of work and how to make decisions – stated by others who have been working there even longer."

C. HOW DO THE MANAGERS CHOSE RISKY PROSPECTS?

When studying how the managers chose from the risky prospects in situations 1 – 3 (see appendix) we observed the *certainty effect*. We can see that the majority of them preferred alternatives that are certain in preference to alternatives that are merely probable, even though the expected value is higher in the alternative that was not certain. We can thus see that they preferred prospects that had a small variance or no variance at all. However, if the variance becomes larger in the prospects, such as from 100% to 25% in situations 2.1B and 2.2B, and from 80% to 20% in situations 2.1A and 2.1B, then they instead chose the alternative that offered the largest possible outcome. This was, however, not always true. In situations 4.1 and 5.1 we can see that if the difference in the variance was large then most of them had a tendency to choose the alternative where winning was more probable. We can, on the other hand, see in situations 4.2 and 5.2 that if the probability of winning dramatically decreases and the chance of winning is possible but no longer probable, then they chose the alternative that offered the largest gain. We can, at this stage, establish that the managers did not act in accordance with the expected utility rules.

When replacing wins by losses we can observe a phenomenon called the *reflection effect*, i.e. that the risk aversion in the positive domain is replaced by risk seeking in the negative domain, see situations 7–9. In situation 8.1 we can for instance see that eight of the managers preferred the certain alternative (3.000.000 SEK, 100%) to the uncertain one (4.000.000 SEK, 80%). But, when looking at the loss domain, in situation 8.2, we can see that most of them were willing to accept an 80% risk of losing -4.000.000 SEK in preference to a certain loss of -3.000.000 – although situation 8.2A has a lower expected value. In situation 10 we can observe the reflection effect in a different form. In the positive domains the majority of them disregarded the fact that the probabilities are low if the possible outcome is large. In the loss domain, on the other hand, we can see that most of them chose the certain loss of -500 SEK in preference to -500.000 SEK with probability 0,001%. Finally, in situations 11 and 12 we can observe the *isolation effect*. The isolation effect appeared when the majority of the managers made their choices, obviously not taking into account the components that the alternatives shared, which in situation 11 is 100.000 SEK and in situation 12 is 200.000 SEK. So, even though the offered prospects are identical in final states, i.e. the expected value in all four situations is 150.000 SEK, they proved to have risk-averse tendencies for positive prospects and risk-seeking tendencies for negative prospects. The results in situations 11 and 12 also exhibited framing problems, i.e. that people may choose in opposite ways and end up with contrary results when data are presented in different, but mathematically equivalent, ways.

So, what about the managers in this study – are they risk-prone or risk-averse? Half of them labeled themselves as risk takers. Only two of them said that they are risk-averse and the other four stated that they are somewhere in between. When analyzing the choices they have made among the offered prospects in the questionnaire we can, nevertheless, see that a majority prove to be risk-averse in positive domains, see e.g. the results in situations 1.1, 2.1, 3.1, 4.1, 5.1, 6.1, and 8.1. In the negative domains, on the other hand, most of the managers tend to exhibit risk-prone behavior; see e.g. situations 7-9 where the reflection effect appears. Results from the study indicate that the managers do not act in a completely rational manner, nor in accordance with the suggested normative rules.

V. DISCUSSION

One main problem that has been identified in this study is the lack of information and precise objective data. The risk and probability estimations made by the managers are therefore often based on inadequate information and intuition. Furthermore, many of the managers said that they did not have the necessary skills to estimate different types of risks and that they therefore make their decisions based on intuition and gut feeling. Most of the managers also pointed out the lack of information as a source of risk and uncertainty. Moreover, all of them thought that risk could be managed if one has the correct information and good knowledge about the problem. Ten of them explicitly said that risk is related to profit in one way or another, and all twelve of them agreed with the statement that "if you don't take risks there will be no returns." The managers were also asked to choose between two alternatives about the culture in the organization, as to whether the level of trust in subordinates was low or high. Most of them did choose the alternative that expressed that the organization is organic and that the decision-making in the organization was decentralized. But, once again many of them said that the decentralized decision-making was only partly true. Most of them said that there were a lot of unwritten rules built into the culture and three of them said things such as: "there are some patterns that implicitly guide people to act in some ways - as it always has been done." When asking the managers how they perceived the structure of the organization most of them agreed that it is a mixture of a bureaucratic and an organic organization with a mixture of centralized and decentralized decision-making. This question is crucial for many reasons since the structure sets or creates the boundaries within which people are expected to act, i.e. make their decisions.

According to the managers it is relatively easy to identify whether a person is *risk-prone* or *risk-averse*. Five of them said that risk-prone persons are those who want to make progress

and go forward, and three of them also said that risk-prone persons work more independently than others – "they do not have to ask about everything." Other characteristics of risk-prone persons that the managers pointed out were; the capacity to make rapid decisions, the ability to make decisions without having "everything" perfectly clear, and that risk-prone persons are not afraid of making mistakes. In contrast to the opinions about the risk-prone persons the risk-averse persons were labeled as those who "complain about innovations", and as those "who do not like any kind of change." And while risk-prone persons were perceived as those who could make decisions without having control of everything, risk-averse persons were, according to two of the managers, those who wanted to have control of everything before making a decision. Interestingly, however, it was observed that risk-prone persons were regarded as the "desired ones", and that the risk-averse were regarded as the "undesired ones". For instance, one of the managers said, "It is always better to work with persons who take risks in comparison to those who try to avoid risk in every situation." One of them said, "A risk-prone person is someone who really wants to make progress and that is the kind of person companies are looking for."

VI. CONCLUSIONS

Conclusively, the managers did not act in accordance with suggested normative rules, explicitly expressed their inability to handle many risky situations due to lack of information and expressed their fear of doing something wrong, e.g. making poor decisions. A majority of the managers also stressed the fact that there are a lot of unwritten rules built into the culture that guide them when making decisions. Using computer-based decision support could be one way to circumvent such traditional, well-established, ways of thinking and making decisions.

The analysis of the managers' behavior tells us, furthermore, that it would be beneficial to do a formal analysis of several of the decision problems they deal with. When doing such a formal analysis of decision situations, computer-based decision tools would be useful, e.g. in order to do sensitive analysis, risk estimations and to visualize the outcomes of different prospects. Today, however, only a few of the managers use computers when making decisions and none of them actually use any type of decision analysis tool.

Furthermore, a major obstacle when analyzing managerial decision problems is the elicitation processes and the practical use of probabilities as well as utilities. Therefore, in order to improve the use of computer-based decision tools, it is of great concern to develop better techniques and methods for the elicitation of utility and probability measures. This is a quite new and vivid area of research covering a quite extensive field of formal and informal methodologies (cf., e.g. [25], [26] and [27]), but so far, little has been concluded. This is particularly true when handling scenarios involving imprecise data.

In conclusion, a prescriptive computer-based approach that attempts to help the managers make better decisions by identifying the discrepancies between real (descriptive) and idealized (normative) decision-making, would undoubtedly be of great value for the managers in their decision making processes.

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APPENDIX

Situation 1:
1.1 Which of following would you prefer?
A. 250.000 SEK with p. 33% or B. 240.000 SEK with cert.
240.000 SEK with probability 66%
0 SEK with probabilty 1%
(2 pers.) (9 pers.)
1.2 Which of following would you prefer?
A. 250.000 SEK with p. 33% or B. 240.000 SEK with p. 34%
0 SEK with p. 67% 0 SEK with p. 66%
(9 pers) (2 pers.)
Situation 2:
2.1 Which of following would you prefer?
A. 4.000.000 SEK with p.80% or B. 3.000.000 SEK with cert.
(3 pers.) (8 pers.)
2.2 Which of following would you prefer?
A. 4.000.000 SEK with p. 20% or B. 3.000.000 SEK with p. 25%
(10 pers.) (1 pers.)
Situation 3:
3.1 Which of following would you prefer?
A. 400.000 SEK with p.80% or B. 300.000 SEK with cert.
(4 pers.) (7 pers.)
3.2 Which of following would you prefer?
A. 400.000 SEK with p. 20% or B. 300.000 SEK with p. 25%
(10 pers.) (1 pers.)
Situation 4:
4.1 Which of following would you prefer?
A. 600.000 SEK with p. 45% or B. 300.000 SEK with p. 90%
(2 pers.) (9 pers)
4.2 Which of following would you prefer?
A. 600.000 SEK w. p. 0.001% or B.300.000 SEK w. p.0.002%
(9 pers) (2 pers.)
Situation 5:
5.1 Which of following would you prefer?
A. 6.000.000 SEK with p. 45% or B. 3.000.000 SEK with p. 90%
(0 pers.) (11 pers.)
5.2 Which of following would you prefer?
A. 6.000.000 SEK w. p. 0.001%or B. 3.000.000 SEK w.p.0.002%
(9 pers) (2 pers.)
Situation 6:
6.1 Which of following would you prefer?
A. 400.000 SEK with p. 80% or B. 300.000 SEK with cert.
(4 pers.) (7 pers.)
6.2 Which of following would you prefer?
A. -400.000 SEK with p. 80% or B. -300.000 SEK with cert.
(5 pers.) (6 pers.)
Situation 7:
7.1 Which of following would you prefer?
A. 400.000 SEK with p. 20% or B. 300.000 SEK with p. 25%
(10 pers.) (1 pers.)
7.2 Which of following would you prefer?
A. -400.000 SEK with p. 20% or B. -300.000 SEK with p. 25%
(3 pers.) (8 pers.)
Situation 8:
8.1 Which of following would you prefer?
A. 4.000.000 SEK with p. 80% or B. 3.000.000 SEK with cert.
(3 pers.) (8 pers.)
8.2 Which of following would you prefer?
A. -4.000.000 SEK with p. 80%or B. -3.000.000 SEK with cert.
(9 pers) (2 pers.)
Situation 9:
9.1 Which of following would you prefer?
A. 4.000.000 SEK with p. 20% or B. 3.000.000 SEK with p. 25%
(10 pers.) (1 pers.)
9.2 Which of following would you prefer?
A. -4.000.000 SEK w. p. 20% or B. -3.000.000 SEK w. p. 25%
(3 pers.) (8 pers.)
Situation 10:
10.1 Which of following would you prefer?
A. 500.000 SEK w. p. 0,001% or B. 500 SEK with cert.
(7 pers.) (4 pers.)
10.2 Which of following would you prefer?
A. -500.000 SEK w. p. 0,001% or B. -500 SEK with cert.
(2 pers.) (9 pers)
Situation 11:
In addition to whatever is going to happen in a business situation, you have already received 100.000 SEK. You are now asked to choose between
A. 100.000 SEK with p. 50% and B. 50.000 SEK with cert.
(4 pers.) (7 pers.)
Situation 12:
In addition to whatever is going to happen in a business situation, you have already received 200.000 SEK. You are now asked to choose between
A. -100.000 SEK with p. 50% and B. -50.000 SEK with cert.
(8 pers.) (3 pers.)

Article III

A Study on Framing Effects in Risk Elicitation

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Abstract

Decision analysis tools are an effective way of structuring complex decision situations. However, their failure to incorporate reliable methods for elicitation is a shortcoming that needs to be dealt with. Since different elicitation methods have shown to yield different results, it is important to more thoroughly emphasize on aspects that can reduce biased results. The development of methods that explicitly recognize framing problems and aim to reduce these effects are needed. This study deals with framing problems within elicitation and how to reduce discrepancies between normative and descriptive behaviour in elicited risk data. The results indicate that the extra transitional state in one of the presentation formats, here referred to as Trade for, generated data that deviated more from normative rules when participants experienced gain prospects. On the other hand, for loss prospects the format more in line with normative rules depended on the presentation order of probabilities.

1. Introduction

Decision analysis is often applied when a more structured form of decision making is needed, for example, in organizations when intuitions and rules of thumb alone are insufficient. Most current applications for decision analysis are highly dependent on accurate input data, both probabilities and utilities. Decision problems can in most cases not be analyzed using entirely *objective* probabilities [1], and utilities are always *subjective*. Since probabilities and utilities are normally estimated subjectively in real decision making (see for example [2, 3]), it puts demands on the ability of the decision maker to express his or her knowledge and attitude in the format required for decision analysis. By studying people's behaviour when offered mathematically equivalent prospects framed differently, we attempt to illuminate some factors that cause biased results when using elicitation methods, and thus improve the process of eliciting data in order to make it more suitable for incorporation with decision analysis tools. With awareness of how problems relating to the framing process influence the behaviour of decision makers, it should be possible to reduce some of these effects, and thereby also reduce the gap between normative theories (see, for example, [4, 5]) that suggests rules for the decision-makers and states how they *should* make decisions, and descriptive theories (see, for example, [6, 7]) which, on the other hand, try to explain how real decisions are made, that is, how we actually *do* decide.

1.1 Framing Problems

Whatever method of assessment is used, considerable care must be taken to counter "behavioural biases" (see [8, 9, 10]). It is important to note that the formulation of the decision problem has great impact on preferences, as has been noted by, for example, [11]. The question format and problem presentation can influence individual preferences, and [12, 13, 14] have produced startling evidence suggesting that people may choose in opposite ways and end up with contrary results when data are presented in different, but mathematically equivalent ways. These framing effects cause significant problems to the normative theory of risky choice, since it only emphasizes the statistical basis for decision-making [15]. However, such framing problems are still not a part of the normative theory. Nevertheless, they are the descriptive realities and are well-known to researchers in the field. These findings point out that we definitely need to be aware that the framing of problems is

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prescriptively important if we aim to help people make better choices. Perhaps it is even more important for those who try to use normative principles under such conditions [1]. This is particularly true concerning the development of more precise methods for elicitation of preferences.

2. The Study

In this section the problem and the hypotheses are described, as well as the design of the study.

2.1. Problem Formulation

In this article, we study individuals' behavior when they choose between different prospects about wins or losses. Since empirical studies of methods for elicitation of utilities have shown that different methods have a tendency to yield different results (see, for example, [16]), we find it essential to further investigate how people behave when faced with questions of the character presently used in utility elicitation (for a summary, see [17]). Since framing has been shown to have significant effects on results, we aim to study if, (1) the presentation format of the task, and (2) the presentation order of probabilities affect results. We studied these aspects from both chance and risk perspectives. Our initial hypotheses were:

State transition hypothesis: The presentation format of the question, expressed as either a trade or an initial choice, would yield different results even though the formats are mathematically equivalent. In one format (Trade for), they were asked to picture themselves *already in a situation*. Thereafter, they were asked whether they would be willing to *trade it* for other alternatives. This could result in an extra transitional step, as opposed to the second presentation format (Choose between), where they choose between pair wise alternatives. The *Trade for* format can be seen as more similar to real situations that decision makers often find themselves in. Although the questions were hypothetical, we made the assumption (based on results by, for example, [18]) that even small differences in presentation format would affect choices.

Presentation order hypothesis: The presentation *order of probabilities* should not affect results, since the choice is made between two prospects and whether the size of the probability in the alternative placed to the left is smaller or larger than the alternative to the right (see Figure 1) has not previously been reported to affect choices.

2.2. Study Outline

The study was conducted with 240 undergraduate students, divided into 8 groups. They were asked to make choices about hypothetical gains or losses. Furthermore, in order to reduce monotony, we alternated the sums 2000 SEK[1] and 4000 SEK[2] in the questionnaires, and made the assumption that subjects had an approximately linear utility function between these two sums. Also, to minimize possible effects of question order, the ordering of questions varied in all questionnaires. To avoid the certainty effect [13], that is, that people overweight outcomes they consider certain relative to probable outcomes, we did not use certain outcomes, or outcomes below 0.15 and above 0.85. Four types of questionnaires were used with two different presentation formats (or formulations) of the same problems, that is, there were eight different questionnaires. Each subject answered 7 questions on either chance or risk prospects. At each of these 7 measuring points (see Table 1 for the probability levels) people were given a choice between one alternative with a specific probability of winning or losing a sum of money, and another alternative with a fixed probability (either 10% larger or smaller than the first alternative) and an interval within which they could pick an amount for which the second alternative would be more attractive to them, see Figure 1 and Table 2. In the interval of the second alternative, an amount that resulted in the corresponding EMV value of the first alternative was always available for choice. The probabilities of the alternatives were either ordered as increasing or decreasing in size, that is, the chance of winning was increasing or decreasing, or the risk of losing was increasing or decreasing.

For each subject, we mapped the EMV values of his or her second alternative (at each probability level) onto the reference line EMV = 1. For example, if a subject chooses an alternative where the EMV (of the certainty equivalent) is 1000 SEK over an alternative with the EMV of 800 SEK, the mapped EMV value equals 1.25 (1000 divided by 800). See figures 2-5 for the aggregated results of all subjects at each of the measuring points.

[1] Abbreviation for the Swedish currency – Krona. USD equivalent is approximately $275.
[2] USD equivalent is approximately $550.

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Original alternative:		*Second alternatives:*	*Choose between the following alternatives:*		
65 % chance to win 2000 kr	**TRADE FOR?**	**75% chance to win one of the following amounts:**	**65 % chance to win:**	**OR**	**75 % chance to win:**
		☐ 500 kr	☐ 2 000 kr		☐ 500 kr
		☐ 1 000 kr	☐ 2 000 kr		☐ 1 000 kr
		☐ 1 200 kr	☐ 2 000 kr		☐ 1 200 kr
		☐ 1 400 kr	☐ 2 000 kr		☐ 1 400 kr
		☐ 1 600 kr	☐ 2 000 kr		☐ 1 600 kr
		☐ 1 800 kr	☐ 2 000 kr		☐ 1 800 kr
		☐ 2 000 kr	☐ 2 000 kr		☐ 2 000 kr

Figure 1. Example of the two presentation formats *Trade for* and *Choose between* when the chance of winning is increasing.

1	2	3	4	5	6	7
(0.15, 0.25)	(0.25, 0.35)	(0.35, 0.45)	(0.45, 0.55)	(0.55, 0.65)	(0.65, 0.75)	(0.75, 0.85)

Table 1. The probability levels of the 7 measuring points.

Let $l_{org} = \langle p_{org} \cdot x_{org},\ (1-p_{org}) \cdot 0 \rangle$ be the original prospect (presented on the left side), and let $L = \{l_1, l_2, ..., l_n\}$ be a set of prospects (presented on the right side).
Chance of winning is increasing In the *Trade for* format, the subject is asked if it is desirable to switch the original prospect l_{org} with $x_{org} > 0$ for some or none of the prospects in the set L, where each l_i is a prospect such that $l_i = \langle p \cdot x_i,\ (1-p) \cdot 0 \rangle$, $x_1 < x_2 < \ldots < x_n$, $p = p_{org} + 0.1$ and $n = 7$. In the *Choose between* format, the subject chooses between l_{org} and the prospects in the set L.
Chance of winning is decreasing In the *Trade for* format, the subject is asked if it is desirable to switch the original prospect l_{org} with $x_{org} > 0$ for some or none of the prospects in the set L, where each l_i is a prospect such that $l_i = \langle p \cdot x_i,\ (1-p) \cdot 0 \rangle$, $x_1 < x_2 < \ldots < x_n$, $p = p_{org} - 0.1$ and $n = 8$. In the *Choose between* format, the subject chooses between l_{org} and the prospects in the set L.
Risk of losing is increasing In the *Trade for* format, the subject is asked if it is desirable to switch the original prospect l_{org} with $x_{org} < 0$ for some or none of the prospects in the set L, where each l_i is a prospect such that $l_i = \langle p \cdot x_i,\ (1-p) \cdot 0 \rangle$, $x_1 > x_2 > \ldots > x_n$, $p = p_{org} + 0.1$ and $n = 7$. In the *Choose between* format, the subject chooses between l_{org} and the prospects in the set L.
Risk of losing is decreasing In the *Trade for* format, the subject is asked if it is desirable to switch the original prospect l_{org} with $x_{org} < 0$ for some or none of the prospects in the set L, where each l_i is a prospect such that $l_i = \langle p \cdot x_i,\ (1-p) \cdot 0 \rangle$, $x_1 > x_2 > \ldots > x_n$, $p = p_{org} - 0.1$ and $n = 8$. In the *Choose between* format, the subject chooses between l_{org} and the prospects in the set L.

Table 2. A mathematical representation of a question. Note that in the questionnaires, 7 questions (with the probabilities depicted in Table 1) were randomly ordered.

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3. Results

By aggregating results from all individuals within each group, we can observe where there are discrepancies between the subjects' perceptions of the two presentation formats and how the order of the probabilities affects results, from both chance and risk perspectives. The results from 23 persons (out of 240) were not included in the aggregated data, since they had clearly misunderstood their task (for example, if they did not prefer a higher chance of winning an amount, or a smaller risk of losing an amount), or simply failed to fill out the whole questionnaire.

3.1. Chance of winning

If we study the *order of the probabilities* (increasing or decreasing), the interval that occurs in Figure 2 indicates that there is a discrepancy between the perception of the mathematically equivalent alternatives depending on which presentation format is used when the order of the probabilities is decreasing. In a paired T-test of the aggregated mean of the measuring points, the mean difference is 0.13 and the corresponding P-value is 0.008.

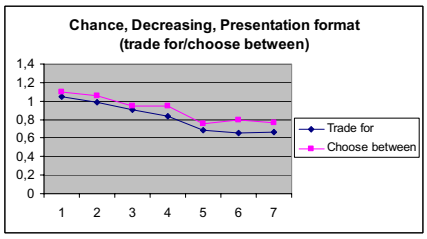

Figure 2. Comparison of the two presentation formats when the order of the probabilities is decreasing (from the chance perspective). The y-axis shows the mapped EMV value of the 7 measuring points.

However, when the order of the probabilities is increasing instead, there is hardly any difference. Thus, it seems as if the framing of the question has stronger influence on the perception of the alternatives offered to the subjects when the order of the probabilities is decreasing. If, instead, we study how each *presentation format* (Trade for or Choose between) is affected by the order of the probabilities, we can see a difference between the order of the probabilities within the Trade for presentation format, see Figure 3. In a paired T-test of the measuring points, the mean difference is 0.15 and the corresponding P-value is 0.000. There is no such effect between the increasing and decreasing probability order if the alternatives that are offered are in the Choose between presentation format.

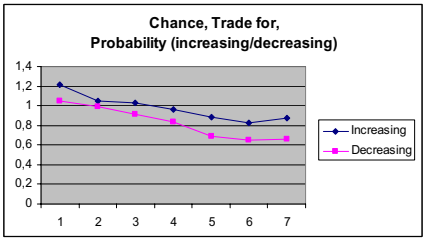

Figure 3. Comparison of the order of the probabilities when the presentation format *Trade for* is used (from the chance perspective).

3.2. Risk of losing

When we look at the risk of losing instead, we observe larger differences between results when varying the presentation format as well as the order of the probabilities.

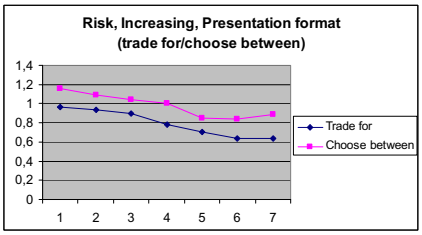

Figure 4. Comparison of the two presentation formats when the order of the probabilities is increasing (from the risk perspective).

There are discrepancies between subjects' perceptions of the offered alternatives in the presentation formats (Trade for or Choose between) from both the increasing and decreasing order of the probabilities, but the difference is larger in the case where they are increasing, see Figure 4 (as opposed to the chance of winning case when there was no difference between the presentation formats for increasing, only for decreasing, see Figure 2). In paired T-tests, the mean difference between the two presentation formats in the case where the probability order is increasing is -0.19 and the corresponding P-value is 0.000, whereas in the case where the probability order is decreasing, the mean difference is -0.15 and the corresponding P-value is 0.001.

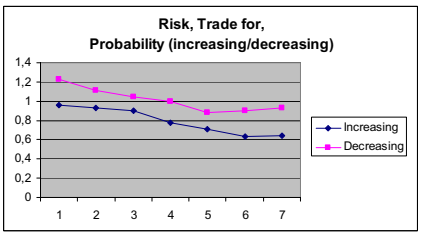

Figure 5. Comparison of the order of the Probabilities when the presentation format *Trade for* is used (from the risk perspective).

If, instead, we study how each presentation format (Trade for or Choose between) is affected by the order of the probabilities, we can observe differences between the order of the probabilities in both presentation formats, but there is a stronger effect in the Trade for case, see Figure 4. Paired T-tests show that the mean difference between the two ways to arrange the probabilities in the Choose between case is 0.09 and in the Trade for case it is -0.22 and the corresponding P-values are both 0.000.

4. Conclusions

This study gives us a view of how different forms of framing can yield different results in the elicitation process. If people are to use and trust decision analysis tools, they need to have confidence in the accuracy of generated results. Most of these tools are based on normative rules (see, for example, [19, 20, 21]), whereas people's true behavior often deviates from such rules [6, 7, 22]. In this respect, to bridge the gap between normative and descriptive theory is of outmost importance if we are to benefit from such tools in decision making.

Our results confirm that the framing has influence on elicited risk data, but also that such differences as the order of probabilities can affect results. Our first hypothesis concerning the framing of the questions used to elicit risk attitudes was confirmed. To begin with, the extra transitional step of the *Trade for* presentation format (where subjects had to picture themselves already in a situation and then asked whether they were willing to trade for another alternative) resulted in different results in comparison to the mathematically equivalent questions of the *Choose between* presentation format. The framing of the *Trade for* questions with chances of winning resulted in risk data that deviated more from the normative rules, especially when the order of the probabilities were decreasing. This was however not the case when probabilities were increasing. Results from the *Choose between* presentation format deviated less from normative rules on average, although for probabilities above 0.5 there were apparent discrepancies in both presentation formats. The presentation format has even greater effect on results when it comes to the risk of losing, although differences are larger and noticeable when using both probability orders, that is, increasing and decreasing. Consequently, our second hypothesis, which proposed that the order of probabilities should not have effect on results, had to be rejected. As mentioned, this was especially true from the risk perspective, but also gave inconsistent results in one of the methods from the chance perspective.

Compensating for the effects noted in this study in order to retrieve risk data more in accordance with normative rules, and thus reduce the gap between normative and descriptive theories, can be achieved by being aware of the following:

- Regardless of which of the two presentation formats that is used when dealing with **chances of winning**, an increasing order of probabilities is to be preferred. If for some reason the decreasing probability order must be used, the *Choose between* format is favorable.

- When handling **risks of losing**, the *Trade for* presentation format using a decreasing probability order, and the *Choose between* presentation format using an increasing probability order are to be preferred, although the first is slightly better.

In this study, the methods using loss prospects are even more sensitive to framing than methods utilizing gain prospects to elicit risk attitudes. Furthermore, in 3 out of 4 questionnaires, elicited data deviates more from normative rules when using the *Trade for* presentation format.

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Article IV

IAENG International Journal of Computer Science, 32:4, IJCS_32_4_13

How Different Choice Strategies Can Affect the Risk Elicitation Process

Ari Riabacke, Mona Påhlman, and Aron Larsson

Abstract—**This paper presents a study focusing on deviations from normative behavior in risk elicitation. Such deviations have implications on the process of eliciting reliable input data in applications of decision analysis. No existing elicitation method seems to be universally useful based on the findings made in this study. Since people obviously do not act in accordance with the normative rules, and different choice strategies have been identified, a prescriptive approach with individual assistance of the decision makers in the elicitation process thus seems to be necessary.**

Index Terms—**Decision analysis, elicitation, risk behavior**

I. Introduction

Traditional decision analytic tools often presuppose that reliable input data is obtained by an exogenous process and the tools are almost exclusively based on normative rules, cf. [1, 2]. The specification and execution of the process is, though, left to the discretion of the user, which poses a problem as the applicability of computational decision methods often rests on the quality of input data. Needless to say, this causes problems when using decision analysis tools in real decision making situations. For example, since people have difficulties distinguishing between probabilities ranging from approximately 0.3 to 0.7 [3], there is reason to believe that human decision makers will face similar problems when making subjective probability estimations in an elicitation process. However, despite this, numerical probabilities and utilities are subjectively assigned by the decision maker in most decision problems [4, 5]. Subjective, in this sense, means that the values reflect the decision maker's actual beliefs and preferences. These are not necessarily logical or rational, but rather interpreted in terms of the willingness to act in a certain way [6]. Thus, individual risk attitudes affect the outcomes of such processes. 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 can be reviewed further in, e.g., [7]. The question arises as to whether or not people are able to provide the inputs which utility theory requires [8], and more specifically - how can we reduce deviations from the normative rules in elicitation processes? For example, [9] suggests modifications of normative theories to include cognitive concerns as a way of reducing discrepancies between real and idealized behaviour. Therefore, it is essential to consider human aspects on reasoning and understanding more explicitly when designing decision analysis tools. There is a need to incorporate deliberate elicitation methods that lead to higher input quality (in line with decision tool assumptions), and thus improve the usage of computer based decision making applications.

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II. The Study

In this article, we study individuals' behavior when they choose alternatives in risky prospects with respect to gains or losses. In [10], we observed that the behavior of the subjects tended to deviate more from normative rules when the probability of a gain or loss in the prospects were lower than 0.25 or higher than 0.75. Furthermore, we could observe the choices subjects made, but had no information about their strategies, that is, how they perceived the different prospects regarding the size of the probability of gain or loss and the values in consideration. Thus, in order to identify if decision makers use different strategies, it was necessary to interview some of the subjects. The focus of this study is therefore on qualitative aspects, such as risk perception and choice strategies.

III. Study Outline

This study, which follows from [10], focuses on deviations from normative behavior. The study was conducted with 252 undergraduate students, divided into 8 groups. They were asked to make choices about hypothetical gains or losses, and 12 students were also interviewed in order to identify and understand different strategies employed when making these choices. Each subject answered questions on prospects with either a chance of gain or a risk of loss. We will use the following notation for an alternative A_i in a risky prospect,

$$A_i(p, x_i)$$

where p denotes the probability of ending up with a (not necessarily positive) monetary value of x_i.

(Advance online publication: 12 November 2006)

TABLE I

1	2	3	4
$A_1(0.05, x_1)$ and $A_2(0.15, x_2)$	$A_1(0.15, x_1)$ and $A_2(0.25, x_2)$	$A_1(0.75, x_1)$ and $A_2(0.85, x_2)$	$A_1(0.85, x_1)$ and $A_2(0.95, x_2)$

Table 1. The probability levels of the 4 measuring points used, here presented in an *increasing probability order*. In measuring point 1, the subject is asked (given a value of x_1) at different values of x_2 about his/her preference order of A_1 and A_2.

In the current study, four so called *measuring points* were used (see Table 1). A measuring point may be considered as a risky prospect represented by a pair of alternatives $\langle A_1(p_1, x_1), A_2(p_2, x_2)\rangle$ with differing probabilities of ending up with a gain or loss such that the probability in the second alternative (A_2) is 0.1 higher or lower than in the first (A_1).

At each of the four measuring points, the subjects were offered a choice between two alternatives; one with a specific probability of gain or loss, another with a fixed probability and an interval within which they could pick a monetary value so that the second alternative would be preferred over the first. The probability of the second alternative was higher or lower than the first depending on whether the order of the probabilities was increasing or decreasing. In the interval of the second alternative, a value that resulted in the corresponding EMV[1] of the first alternative was always available for choice. In order to reduce monotony, the monetary values 2000 SEK[2] and 4000 SEK were alternated in the fixed alternative on the left hand side of the risky prospects. We could not observe irregularities in the subjects' choice patterns between alternatives with different amounts of gains or losses, and therefore assume that their utility perceptions within the applied monetary range were linear.

IV. RESULTS

Traditionally when describing risk behavior, people are categorized into three groups; risk-prone, risk-neutral and risk-averse [11]. Based on this division, the results from the study and interviews are here categorized into three main groups. We called the groups **A**, **B** and **C**, and the behavior of respondents in each group is described as follows:

- **A.** In this category, subjects demand a higher EMV (at least 10% higher or more) of the second alternative in order to prefer it.
- **B.** In this category, subjects prefer the second alternative with a corresponding EMV (±10%) of the first alternative.
- **C.** In this category, subjects prefer the second alternative although it has a lower EMV than the first alternative (at least 10% lower or less).

Below, the results have been divided into the three group categories for each offered choice situation, the results are depicted in Figures 1-4. In addition, significant interview results are presented for each choice situation. Note that when we refer to *subjects* below, we describe the behavior of all study participants (252 persons), whereas those referred to as *respondents* are the 12 complementary interview subjects.

A. Chance of gain

Chance of gain means that for each prospect $\langle A_1(p_1, x_1), A_2(p_2, x_2)\rangle$, the value of x_i is positive.

1) Increasing probability order

a) Choose between $A_1(0.05, x_1)$ and $A_2(0.15, x_2)$

In category **A** (7/12), the respondents perceived the chance of gain in both alternatives as very low.

In category **C** (5/12), all of the respondents perceived the chance of gain in the alternative A_2 as very small and therefore chose the second alternative to a lower EMV.

b) Choose between $A_1(0.15, x_1)$ and $A_2(0.25, x_2)$

In category **A** (6/12), a few respondents perceived the chance of gain in both alternatives as very low, although more prominent was their tendency to choose A_2 when the values of x_1 and x_2 differed with 1000 SEK.

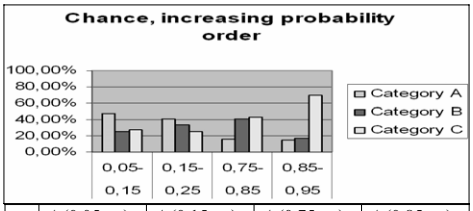
In category **C** (4/12), the respondents consider 0.25 as a much higher probability than 0.15 and therefore chose A_2 more or less immediately. One of the respondents reflects on the fact that 0.25 is one chance out of four.

c) Choose between $A_1(0.75, x_1)$ and $A_2(0.85, x_2)$

In category **A** (3/12), the respondents perceived both probabilities as high chances of gain and therefore mainly considered the values of x_1 and x_2 when evaluating the prospects.

In category **B** (3/12), the respondents perceived the probabilities as almost equal, and based their choices on a combination of probabilities and values.

In category **C** (6/12), some of the respondents explicitly stated that they perceived 0.85 as almost certain, and therefore they were prepared to choose that alternative at a much lower value of x_2 than of x_1.



	$A_1(0.05, x_1)$ and $A_2(0.15, x_2)$	$A_1(0.15, x_1)$ and $A_2(0.25, x_2)$	$A_1(0.75, x_1)$ and $A_2(0.85, x_2)$	$A_1(0.85, x_1)$ and $A_2(0.95, x_2)$
A	47%	41%	16%	15%
B	26%	34%	41%	16%
C	27%	25%	43%	69%

Fig. 1. The aggregated data of all subjects, divided into the three categories **A**, **B** and **C**.

[1] Expected Monetary Value

[2] Abbreviation for the Swedish currency – Krona. 1 USD is approximately equivalent to 8 SEK.

d) Choose between $A_1(0.85, x_1)$ and $A_2(0.95, x_2)$

In category **A** (3/12), the respondents perceived 0.85 as a huge chance of winning and therefore only considered the values of x_1 and x_2.

In category **C** (6/12), the choices of the respondents varied, some felt that 0.95 was close to one, and therefore chose an alternative with a much lower EMV.

2) Decreasing probability order

a) Choose between $A_1(0.15, x_1)$ and $A_2(0.05, x_2)$

In category **A** (4/12), all of the respondents perceived 0.05 as a very small probability of gain and therefore did not choose A_2 until its EMV was much higher than the EMV of A_1.

In category **C** (8/12), the respondents perceived the chance of gain in both alternatives as very low. They pointed out that they did not care much about the probabilities (as both were low), but rather based their choices on the values of x_1 and x_2.

b) Choose between $A_1(0.25, x_1)$ and $A_2(0.15, x_2)$

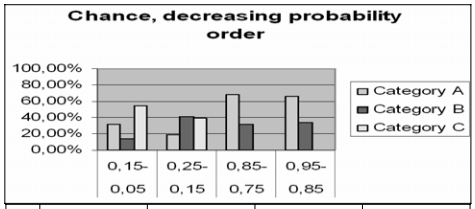
In category **A** (4/12), the respondents considered 0.25 as a much higher probability than 0.15 and therefore chose A_1 until the value of x_2 was more than twice the value of x_1.

In category **B** (5/12), the respondents did not calculate explicitly, although they considered both the values of x_1 and x_2 as well as the probabilities. When considering the alternatives, two of the respondents converted the probabilities into odds, for example, 3 out of 20 or less than 1/5 instead of 0.15.

In category **C** (3/12), the respondents perceived the chance of gain in both alternatives as quite low.

c) Choose between $A_1(0.85, x_1)$ and $A_2(0.75, x_2)$

In category **A** (6/11), the respondents perceived 0.85 as almost certain and therefore demanded a higher EMV of A_2 in order to choose it. However, one respondent pointed out that he found A_2 attractive since it is easier to recognize and deal with in terms of the odds 3 out of 4.



	$A_1(0.15, x_1)$ and $A_2(0.05, x_2)$	$A_1(0.25, x_1)$ and $A_2(0.15, x_2)$	$A_1(0.85, x_1)$ and $A_2(0.75, x_2)$	$A_1(0.95, x_1)$ and $A_2(0.85, x_2)$
A	32%	19%	68%	66%
B	14%	41%	32%	34%
C	54%	40%	0%	0%

Fig. 2. The aggregated data of all subjects, divided into the three categories **A**, **B** and **C**.

mentioned the fact that 0.25 equals ¼, and said that since they recognized ¼ they tended to overweight it intuitively.

In category **B** (5/11), the respondents perceived both probabilities as high and felt that they did not differ to a great extent. They based their choices on a combination of the probabilities and the values of x_1 and x_2.

d) Choose between $A_1(0.95, x_1)$ and $A_2(0.85, x_2)$

In category **A** (7/11), the respondents felt that 0.95 was next to certain and therefore they were unwilling to choose an alternative with a lower probability of gain.

In category **B** (4/11), the respondents felt that the probability of gain was large in both cases.

B. Risk of Loss

Risk of loss means that for each prospect $\langle A_1(p_1, x_1), A_2(p_2, x_2)\rangle$, the value of x_i is negative.

1) Increasing probability order

a) Choose between $A_1(0.05, x_1)$ and $A_2(0.15, x_2)$

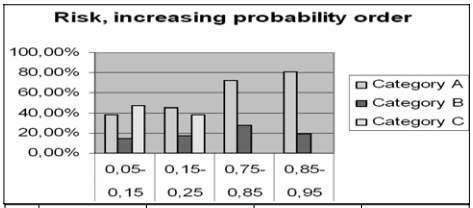
In category **A** (6/12), the respondents perceived the risk of loss in A_1 as very low, "almost safe" as several of them stated, and therefore did not choose A_2 until the EMV of that alternative was much higher.

In category **B** (4/12), the respondents perceived the risk of losing as small in A_1, but still considered the amounts they risked to lose.

In category **C** (2/12), the respondents focused more on the amounts they risked to lose than the probabilities, and considered what amounts they could afford to lose.

b) Choose between $A_1(0.15, x_1)$ and $A_2(0.25, x_2)$

In category **A** (5/12), the respondents felt that 0.25 was a much larger risk than 0.15 and were reluctant to choose A_2 until the EMV of A_2 was much higher.



	$A_1(0.05, x_1)$ and $A_2(0.15, x_2)$	$A_1(0.15, x_1)$ and $A_2(0.25, x_2)$	$A_1(0.75, x_1)$ and $A_2(0.85, x_2)$	$A_1(0.85, x_1)$ and $A_2(0.95, x_2)$
A	38%	45%	73%	81%
B	15%	17%	27%	19%
C	47%	38%	0%	0%

Fig. 3. The aggregated data of all subjects, divided into the three categories **A**, **B** and **C**.

In category **C** (4/12), the respondents chose A_2 when the values of x_1 and x_2 differed with 1000 SEK.

c) Choose between $A_1(0.75, x_1)$ and $A_2(0.85, x_2)$

In category **A** (11/12), the respondents perceived 0.85 as much higher than 0.75 and were reluctant to choose A_2 until the EMV was much higher. Three of them said that 0.85 felt like a sure loss. Six of the respondents chose the alternative with a higher probability when the values of x_1 and x_2 differed with 1000 SEK, which some explicitly pointed at. One person said that he looked solely on the magnitudes of the probabilities and disregarded the values.

In category **B** (1/12), the respondent perceived the probabilities as relatively equal and did not want to increase the EMV of a possible loss.

d) Choose between $A_1(0.85, x_1)$ and $A_2(0.95, x_2)$

In category **A** (12/12), the respondents perceived 0.95 as a sure loss and were reluctant to choose A_2 although the EMV was higher than for A_1. A couple of them did not calculate on the risk of loss, but instead looked at the chance of not losing anything, that is, they compared a 0.15 chance with a 0.05 chance to end up with no loss.

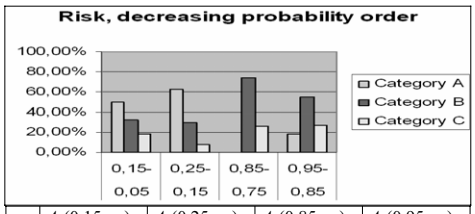
2) Decreasing probability order

a) Choose between $A_1(0.15, x_1)$ and $A_2(0.05, x_2)$

In category **A** (10/12), the respondents perceived both probabilities as relatively low and mainly considered what amounts they could afford to lose.

In category **B** (1/12), the respondent felt that 0.05 was a very small risk and chose that alternative when the value of x_2 was an acceptable potential loss to him.

In category **C** (1/12), the respondent felt that 0.05 was next to nothing and chose that alternative no matter the value of x_2, i.e., what he risked losing.



	$A_1(0.15, x_1)$ and $A_2(0.05, x_2)$	$A_1(0.25, x_1)$ and $A_2(0.15, x_2)$	$A_1(0.85, x_1)$ and $A_2(0.75, x_2)$	$A_1(0.95, x_1)$ and $A_2(0.85, x_2)$
A	49%	62%	0%	18%
B	32%	30%	74%	55%
C	19%	8%	26%	27%

Fig. 4. The aggregated data of all subjects, divided into the three categories, A, B and C.

b) Choose between $A_1(0.25, x_1)$ and $A_2(0.15, x_2)$

In category **A** (10/12), half of the respondents only considered the values as they perceived the probabilities as relatively equal, whereas the others perceived 0.25 as much higher than 0.15. Three respondents from the latter group

In category **B** (1/12), the respondent said that for a lower probability he could accept to risk a higher value and combined the sizes of the probabilities and the values when he made his choice.

In category **C** (1/12), the respondent perceived 0.15 as a much smaller risk and chose that alternative immediately. He did not consider the size of potential loss.

c) Choose between $A_1(0.85, x_1)$ and $A_2(0.75, x_2)$

In category **B** (9/12), the respondents perceived the probabilities as relatively equal. One person mentioned the fact that he did not want to increase the possible loss with more than 1000 SEK and based his choice on this criterion. Five others made the same choice and one of them said that it was worth the risk of losing 1000 SEK more for a probability reduced with 0.1.

In category **C** (3/12), one respondent said that 0.85 was much higher than 0.75 and therefore chose A_2 no matter the value of x_2 in order to increase his chance of no loss.

d) Choose between $A_1(0.95, x_1)$ and $A_2(0.85, x_2)$

In category **A** (5/12), the respondents perceived both probabilities as very high, almost sure losses, and therefore did not want to increase the amount they risked to lose.

In category **B** (6/12), the respondents made a trade-off between probabilities and amounts. Initially, they considered the sizes of the probabilities, but as the values increased negatively in size, they weighted what amount they could afford to lose.

In category **C** (1/12), the respondent perceived 0.85 as a much smaller risk and therefore chose that alternative although the EMV was much lower.

V. Analysis

In this study, we have observed that people's behavior deviates from normative rules in different ways when choosing between alternatives in risky prospects where the probabilities of gains or losses are in the ranges 0.05-0.25 and 0.75-0.95. Two factors that we have identified as having significant effects on people's behavior are the size of the probability mass on a gain or loss, and more notably, the order in which the two alternatives having differing probabilities of gain or loss are presented.

A. Chance of gain, increasing probability order

When offered prospects with low probabilities, and comparing a probability of 0.05 of a gain to a probability of 0.15 of gain[3], the majority of the subjects is in category **A** and, thus, demands a higher EMV of the alternative with a higher

[3] Henceforth, we will simply write, e.g., "0.05 to 0.15" when referring to such a situation (measuring point).

probability in order to choose it. In both prospects, the respondents perceived the probabilities in the two alternatives as more or less equal and therefore mainly considered the sizes of the values involved. In the prospects with probabilities 0.15 to 0.25, we can see an increased tendency to choose according to the EMV, and the number of subjects in category **B** increase.

When offered prospects with high probabilities, we can observe a willingness to choose alternatives with higher probabilities and lower EMV, which is more evident in the probability range 0.85 to 0.95. Several of the respondents stated that they perceived a probability of 0.95 as next to certain, which we will call the "close to 100% effect".

B. Chance of gain, decreasing probability order

Subjects have two main strategies when we look at their choices of prospects with low probabilities, 0.15 to 0.05. The dominant group is category **C**, in which respondents did not pay that much attention to the probabilities (as they perceived them as low and moderately equal), but based their choice on the sizes of the values. Respondents with the other strategy perceived the probability of 0.05 as very low, and therefore demanded a much higher EMV in order to choose that alternative. In the other low probability range, 0.25 to 0.15, the number of members in both category **A** and **C** decrease considerably, and we can observe that more subjects make choices more in line with normative rules.

When offered prospects with high probabilities, the dominant strategy was in both cases category **A,** (0.85 to 0.75 and 0.95 to 0.85). None of the subjects was placed in category **C**, that is, no one was willing to choose an alternative with a lower EMV.

C. Risk of loss, increasing probability order

For low probabilities, most subjects make choices that fall under strategies **A** or **C**. Regarding prospects with probabilities 0.05 to 0.15, respondents in the first group perceived 0.05 as a very low risk, almost safe as they stated, whereas the respondents in the other group mainly focused on the values and calculated on how much they could afford to lose. For probabilities 0.15 to 0.25, more subjects demand a higher EMV in order to choose the 0.25-alternative and the respondents explained their behavior by stating that they perceived 0.25 as a much higher probability than 0.15 in a risk of loss situation. Several of the respondents reflected about the fact that 0.25 equals ¼ and that they may overweight it due to this ease of conversion to something more recognizable.

For high probabilities, the majority of subjects fall within category **A**. When choosing between alternatives in prospects with the probabilities 0.75-0.85, the respondents perceived 0.85 as a much larger risk. This tendency was even more noteworthy for prospects with probabilities 0.85-0.95. Most respondents perceived a probability of 0.95 as an almost certain loss, although a few said that they preferred to know exactly what they would lose. Furthermore, some said that they calculated their chances of losing nothing instead, that is, they compared a probability of 0.15 to a 0.05 probability of no loss instead of comparing a probability of 0.85 to a 0.95 probability of loss.

D. Risk of loss, decreasing probability order

Almost half of the subjects fall within category **A** when choosing between alternatives with probabilities 0.15 to 0.05. The respondents explained their behavior by saying that they perceived the probabilities as almost equal and did not want to face the risk of losing a much higher amount even though the probability of losing in the second alternative was only ⅓ of the first (0.15 to 0.05). The respondent in category **C** felt that a probability of 0.05 was close to no risk at all and therefore chose that alternative regardless of the values involved. Concerning alternatives with probabilities 0.25 to 0.15 of a loss, we note an increase of subjects that fall within category **A**. Half of the respondents state that they perceive the probabilities as relatively equal and therefore only consider the amounts, whereas some perceive 0.25 as much larger than 0.15 (although their choices did not correspond with this statement). Very few choose according to strategy **C**.

None of the subjects choose according to strategy **A** for alternatives with probabilities 0.85 to 0.75, and the majority belongs to category **B**. In category **B**, the respondents perceive the probabilities as relatively equal, and therefore make a trade-off between the differences in the amounts of the two alternatives when making their choice. As opposed to the case with probabilities 0.85 to 0.75, we find a group belonging to category **A** in the 0.95 to 0.85 case. These respondents perceived both probabilities as large, almost certain losses, and did not want to risk losing a larger amount with a lower probability. The majority in this case still belong to category **B**.

VI. CONCLUSIONS

From the results in a previous study, [10], it was not possible to explain how the subjects made their choices, that is, what strategies the subjects used and how they perceived the prospects. In this study, we focused on prospects having uncertain outcomes with lower or higher probabilities of either a gain or loss, since deviations observed in the first study were increasing at these levels. We have identified three main strategies that the subjects (in groups **A**, **B** and **C**) used when choosing among the alternatives in the offered prospects. As can be seen in the previous section, the behavior differs in these categories depending on whether probabilities are high or low, chance or risk domains, and the order of the probabilities. The main characteristics that were identified in the respondents' choice behavior are:

- They more often perceive the low probabilities as more or less equal, which is not the case to the same extent concerning the higher probabilities. This is particularly true regarding the chance prospects.
- For prospects with higher probabilities the respondents were keener to choose an alternative with a probability closer to 1 for a lower amount and did, in such cases, mainly focus on the probabilities.
- In the risk prospects, on the other hand, the respondents based their strategy for both lower and higher probabilities on how much they could afford to lose.
- In both chance and risk prospects we noticed the "close to 100% effect". The subjects' willingness to choose a

chance alternative with a lower EMV increased when the probability of gain approached 1. We also noted an aversion to choose alternatives in risk prospects that were almost certain losses.

- Many of the respondents expressed their evaluation strategy in terms of converting probabilities expressed as percentages into odds, e.g., 1 out of 4 instead of 0.25. Several of the respondents return to the fact that they find some probabilities such as 0.25 and 0.75 more familiar and, perhaps, therefore overweight them.
- Another tendency we observed was that some of the respondents intuitively recalculated the chance of losing into a chance of not losing at all.
- A clear tendency was that many of the respondents, irrespective of the probabilities, chose the second alternative when the difference of the values between the first and second alternative was approximately 1000 SEK. Many respondents explicitly stressed the fact that 1000 SEK in many situations corresponded to a 0.1 probability, that is, they were willing to pay that amount in order to increase the chance or to reduce the risk. This tendency is an important observation of erratic behavior as the impact of an increased/decreased chance or risk of 0.1 differs considerably depending on the sizes of the values.

VII. DISCUSSION

The findings of this study have implications on the process of eliciting reliable input data to decision analysis tools. If the elicitation process is incorporated in tools, it needs to be more flexible, since some people may prefer to have prospects presented in other forms than the traditional methods of using single-event probabilities to represent uncertainty. Cognitive research has shown that the human mind does not process such probabilities effectively and that even experienced statisticians make errors when reasoning about them [12]. Furthermore, using a single number to represent an uncertain quantity can confuse a person's judgment about uncertainties with the desirability of various outcomes [13]. Examples on alternative representations of uncertainties are presentation formats such as odds, probability wheels, and probabilities in intervals. The latter approach relaxes the need for precise data, which is not available in many cases of real life decision making. Furthermore, the elicitation part should be designed so that it can more easily be adjusted to different types of behaviors, depending on what strategies people display.

No existing elicitation method seems to be universally useful based on the findings made in this study. Since people obviously do not act in accordance with the normative rules, and different choice strategies have been identified, a prescriptive approach with individual assistance of the decision makers in the elicitation process thus seems to be necessary. This is a different approach in comparison to approaches of, e.g., normative theories which suggests rules for whole classes of problems. However, a functional prescriptive aid is a difficult task to accomplish. It demands a lot from the decision analyst and the toolbox of methods he intends use.

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Article V

Risk Elicitation in Precise and Imprecise Domains – A Comparative Study, Sweden and Brazil

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Abstract

This paper presents a comparative study between two groups from different cultural contexts, Sweden and Brazil, when choosing among risky prospects. The study explores whether there are differences in choice behaviours when the uncertainty in the prospects is expressed as interval estimates instead of the traditional use of point estimates, as well as when prospects are displayed with and without expected monetary values. Both groups display similar choice behaviours when they choose among prospects where uncertainty is expressed as point vs. interval estimates, whereas the Brazilian respondents are more affected by EMV information. The results indicate that the employment of intervals to represent uncertainty can be beneficial and could facilitate the elicitation part in the use and development of decision analytical tools. Furthermore, there is a need for more flexible tools, more adapted to a prescriptive approach, since people from different cultural contexts seem to differ in their choice behaviours.

1. Introduction

Decision analysis tools offer promising solutions to complex decision making, yet they are rarely utilized within organizations for this purpose (see for example, [1]). Such tools are heavily influenced by the normative theories and the rational model on risk behaviour within decision making. This approach assumes that people judge information and make decisions according to statistical principles, which is quite contrary to the descriptive approach. The latter approach assumes that people's ability to process given information highly influences their behaviour [2]. Thus, the perceived context affects the outcome, which is not accounted for in traditional decision analysis tools. For example, [3] and [4] have shown that people act differently depending on the sizes of the probabilities, and also that the framing of alternatives highly influences their choice behaviour.

Traditionally, the probabilities required by decision analytical tools have been sharp numerical probabilities. However, available information is often vague or conflicting, or preferences are inconsistent or incomplete. In such cases probability estimations have to be based on insufficient information, which has its drawbacks. For instance, using a single number to represent an uncertain quantity can confuse a person's judgment about uncertainties with the desirability of various outcomes [5]. In an elicitation process, most people would probably find it easier to estimate the probability for the occurrence of an event to be, e.g. in the range of 20-30% instead of stating that the uncertainty is exactly 24%. Closely related to, or entwined with, these problems are problems with judgment of exact probabilities, e.g. [6] claims that people have problems distinguishing between probabilities in the range 0.3 and 0.7. Consequently, it can be cognitively difficult for a person to distinguish between 0.3 and 0.4, which would in many cases affect the results notably regarding, for instance, calculations of Expected Monetary Values.

An alternative approach to the traditional use of point estimates within decision analysis applications, aims to solve this problem by using intervals to represent uncertainty instead (see e.g. [7]). The use of interval estimations relaxes the need for precise data,

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which is a more realistic approach since it is easier to approximately assess the uncertainty (the true value is more likely to be part of the interval than equivalent to a subjectively assessed point estimate). Also, since the lack of time is one of the major constraints in decision making processes [8], the interval approach can be beneficial as it is probably more time and cost efficient (it is most likely easier to state an interval for an uncertainty than an exact value. In addition, the interval approach can be useful when several experts are asked to make subjective judgments and their assessments differ and have to be combined somehow (see e.g. [9] for further information on aggregating probability distributions).

The most common way of representing uncertainty within decision analysis applications is still by using point estimates, which has its respective share of problems. Interval estimates reduce the demands for preciseness, but how people perceive and make choices among prospects where the uncertainty is expressed as intervals is still a relatively unexplored area. Furthermore, the most common approach in, for example, managerial decision making is to look at the expected value of each alternative during evaluation [10]. Thus, exploring how people perceive alternatives where uncertainty is expressed as point estimates and comparing this with the corresponding alternatives where the Expected Monetary Value, EMV, is displayed as well, and with alternatives where the uncertainty is expressed as interval estimates seems highly motivated.

Today, most of the decision analytical tools are developed in the Western parts of the world and none of them take cultural differences, such as those identified by e.g. [11], into account. In individualistic cultures, e.g. the US [12], individuals are expected to bear the consequences of risky decisions on their own, whereas people in more collectivistic cultures (like China) are more reliant on the help of family members in case the result of a risky decision is unbearable. The possible difference in risk behaviour among people from different cultures is often completely disregarded in the development of decision analytical applications and in studies on probability elicitation.

2. The Study

In this explorative study, we investigate interval estimates as an alternative way of representing uncertainty in risky alternatives (as opposed to point estimates), as well as presenting the alternatives without or with the expected monetary value, EMV. Furthermore, in order to identify whether there are differences in risk behaviour between groups from different cultural contexts when choosing among risky prospects, we compare choice behaviours between groups from Sweden and Brazil.

Since the overall aim with the study is to illuminate how cultural differences influence risk behaviour and risk elicitation, we strive to get as similar groups as possible in Sweden and Brazil regarding such parameters as age, and economical and educational background. The Brazilian respondents, students at Pontifícia Universidade Católica do Rio de Janeiro, PUC University in Rio de Janeiro, were thus chosen in order to correspond to the Swedish respondents regarding the above mentioned parameters.[1]

The prospects presented to the Swedish respondents were expressed in SEK, and the corresponding amounts in the prospects presented to the Brazilian respondents were expressed in R$. The ratio between the Swedish and Brazilian amounts used in the prospects was 4:1 at the time of the studies.

2.1. Problem Formulation

1. Whether there are differences between people's behaviours when they choose between different alternatives in risky prospects when using intervals to express uncertainty (instead of point values).
2. Whether people choose differently when the respective EMV value of each alternative in risky prospects is presented.
3. Whether there are any differences in the choice behaviours between the Swedish and Brazilian samples.

2.2. Study Outline

The study was conducted with 60 undergraduate students at Mid Sweden University in Sundsvall and 60 undergraduate students at PUC University in Rio de Janeiro, i.e. 120 students in total. Each respondent answered a questionnaire with 12 questions on prospects with a chance of gain. The questionnaires were distributed to the students after a 15-min long presentation where they were asked to picture themselves in the situations described by the prospects. Furthermore, they were told that these situations take place only once, that they would under no circumstances risk to lose anything, and that there were

[1] In Rio de Janeiro, the top 10% of the employees earn R$ 3,946.55 on average [13]. According to interviews made with University staff at PUC, the students at PUC come from families with incomes even higher than the top 10%, approximately equivalent to the Swedish average income - SEK 17,997.58 [14], about R$4500 (approximately equivalent to 2400 USD) at the time of the study.

no right answers. The students had 20-min to fill out the questionnaires.

We will use the following notation for an alternative A_i in a prospect,

$A_i(p_i, x_i)$

where p_i denotes the probability of ending up with a monetary value of x_i.

In the current study, four choice settings were used, I)-IV). In each choice setting, four alternatives (A, B, C and D) were presented to the respondents and they were asked to choose the alternative they preferred the most. Furthermore, each choice setting was presented in two different ways (situations), the uncertainty of each alternative was either presented as a point estimate, p, or as an interval, $[p_1, p_2]$ (where the midpoint is assumed to be equivalent to the point estimate of the corresponding alternative, since the centroid of the interval is unknown). Half of the respondents in each group answered questions where the alternatives were presented as $A_i(p_i, x_i)$ (see Ex. 1 in Table 1) and as $A_i([p_j, p_k], x_i)$ (see Ex. 3 in Table 1). The other half answered the same questions with the additional information of the expected monetary value (EMV) for the alternatives with point estimates (see Ex. 2 in Table 1).

In choice settings I) and II), the EMVs of the different alternatives in I) are equal to the corresponding alternatives in II). In these choice settings, alternatives C and D are identical, but the amounts and probabilities of alternatives A and B differ between the two choice settings. In choice setting III), the probabilities of the alternatives are no larger than 0.5, and in choice setting IV) all alternatives have the same EMV. The details of the alternatives in the risky prospects can be viewed in section *3 - Analysis of Results*.

After making their choices regarding the prospects, the respondents were asked the following question:

Q1. *When the uncertainty was expressed as an interval instead of a point value, did you find it: 1) Easier 2) Harder or 3) No difference when making your choices?*

Also, the respondents in the groups where the EMV information was explicitly given for each alternative were asked an additional question:

Q2. *Did you consider the expected monetary value (EMV) for the alternatives when making your choices? 1) Yes 2) No or 3) Sometimes – If yes, what made you consider it sometimes?*

From hereon, when we refer to situations 1, 2, and 3, we refer to the three different ways of presenting the prospects to respondents (see Table 1).

3. Analysis of Results

We have divided the analysis of results into four different sections, each presenting the results from the different choice settings I)-IV). Detailed information of the prospects used and the choice frequencies of the respondents are displayed in tables 2-9.

1. Point Estimates

Ex.1)

	A	B	C	D
Amount	10000	6000	4000	3000
Probability	0,2	0,4	0,7	0,9

vs.

2. Point Estimates with EMV

Ex.2)

	A	B	C	D
Amount	10000	6000	4000	3000
Probability	0,2	0,4	0,7	0,9
EMV	2000	2400	2800	2700

and

3. Interval Estimates

Ex.3)

	A	B	C	D
Amount	10000	6000	4000	3000
Probability	0,15-0,25	0,35-0,45	0,65-0,75	0,85-0,95

Table 1. Examples of the different ways of presenting the prospects to respondents. The comparisons made in the analysis of the results are between the first way of presenting the prospects to respondents (1. Point Estimates) and the second way (2. Point Estimates with EMV), and between the first and the third (3. Interval Estimates) way of presenting the prospects.

Comparisons within each group, Sweden and Brazil, are made according to the following division:

- 1 vs. 2 – A comparison of results from prospects *without* EMV information and those presented *with* the additional information of the EMV for each alternative. Point estimates were used in both cases to represent uncertainty.
- 1 vs. 3 – A comparison of results from prospects where *point* estimates were used and those where *interval* estimates were used to represent uncertainty**.**

Also, following the results from each choice setting in I)-IV), a comparative analysis of the results from each type of prospect is made between the groups, Sweden and Brazil. In addition, comparisons between choice settings I) and II) are made after choice setting II), and after choice settings III) and choice setting IV) there are discussions on the behaviours of the respondents in general. In the analysis two principals forming testable contrast have been used: 1) It must be

possible to perform a Chi²-test (forming a 2x2 contingency table), and 2) In each comparison, essential effects are contrasted.

3.1. Choice setting I)

Sweden:

	A	B	C	D
Amount	10000	6000	4000	3000
Probability	0,2	0,4	0,7	0,9
EMV	2000	2400	2800	2700
1) Choice Frequency	11%	4%	32%	54%
2) Choice Frequency	16%	0%	32%	52%
Amount	10000	6000	4000	3000
Probability	0,15-0,25	0,35-0,45	0,65-0,75	0,85-0,95
3) Choice Frequency	14%	4%	29%	54%

Table 2. Results from the Swedish respondents in choice setting I.

In general, the preferences in the Swedish group remain quite equally distributed over the alternatives in both comparisons (1 vs. 2, and 1 vs. 3).

Brazil:

	A	B	C	D
Amount	2500	1500	1000	750
Probability	0,2	0,4	0,7	0,9
EMV	500	600	700	675
1. Choice Frequency	4%	7%	52%	37%
2. Choice Frequency	6%	3%	39%	52%
Amount	2500	1500	1000	750
Probability	0,15-0,25	0,35-0,45	0,65-0,75	0,85-0,95
3. Choice Frequency	4%	11%	37%	48%

Table 3 Results from the Brazilian respondents in choice setting I.

1 vs. 2: In situation 2 where the EMV was presented for each alternative, the respondents seemed to find alternative C less attractive (a decrease of 13 percentage points), whereas the majority now preferred alternative D (an increase of 15 percentage points) although this alternative had a slightly lower EMV (p-value=0.27).

1 vs. 3: In situation 1, the majority of the respondents (52 percentage points) choose alternative C, whereas 15 percentage points less choose this alternative in situation 3. Instead, we can see an increased tendency to choose alternative D in situation 3 (p-value=0.31).
Note that the p-values in both comparisons are relatively high, which makes the results inconclusive.

3.1.1. A comparative analysis of choice setting I)

Sweden 1) – Brazil 1):
The major differences when considering situation 1 is that majority of the Swedish respondents choose alternative D, whereas the majority of the Brazilian respondents choose alternative C (p-value=0.15).

Sweden 2) – Brazil 2):
In general, the respondents choose similarly.

Sweden 3) – Brazil 3):
In general, the respondents choose quite similarly between the two groups.

3.2. Choice setting II)

Sweden:

	A	B	C	D
Amount	6700	4800	4000	3000
Probability	0,3	0,5	0,7	0,9
EMV	2010	2400	2800	2700
1. Choice Frequency	4%	7%	25%	64%
2. Choice Frequency	0%	6%	28%	66%
Amount	6700	4800	4000	3000
Probability	0,25-0,35	0,45-0,55	0,65-0,75	0,85-0,95
3. Choice Frequency	0%	7%	21%	71%

Table 4 Results from the Swedish respondents in choice setting II.

In general, the preferences in the Swedish group remain quite equally distributed over the alternatives in both comparisons (1 vs. 2, and 1 vs. 3).

Brazil:

	A	B	C	D
Amount	1675	1200	1000	750
Probability	0,3	0,5	0,7	0,9
EMV	500	600	700	675
1. Choice Frequency	4%	7%	56%	33%
2. Choice Frequency	9%	6%	36%	48%
Amount	1675	1200	1000	750
Probability	0,25-0,35	0,45-0,55	0,65-0,75	0,85-0,95
3. Choice Frequency	4%	7%	48%	41%

Table 5 Results from the Brazilian respondents in choice setting II.

1) vs. 2): When the EMV was presented, the choice frequency of alternative C decrease 20 percentage points, and instead we can see an increase of 15 percentage points in the amount of respondents who chose alternative D (p-value=0.16).

3.2.1. A comparative analysis of choice setting II)

Sweden 1) – Brazil 1):
The majority of the Swedish respondents choose alternative D, whereas the majority of the Brazilian respondents choose alternative C (p-value=0.015).

Sweden 2) – Brazil 2):
When the EMV information of each alternative is explicit, the majority of the respondents in both groups more frequently choose alternative D.

Sweden 3) – Brazil 3):
The majority among the Swedish respondents go for alternative D, whereas the choice frequency among the Brazilian respondents is more equally distributed between C and D (P=0.02).

3.2.2. A general interpretation of choice behaviour in settings I) and II)

In choice settings I) and II), alternatives C and D are the same, and the EMVs of all alternatives in setting I) are equal to the corresponding alternatives in situation II). In the Swedish group, we can see that alternative D becomes more attractive in setting II) (p-value=0.05). Perhaps the increased tendency to choose the alternative with the highest probability can be explained by the fact that the highest possible gain in an alternative has decreased from 10000 to 6700 (although the EMV is the same for these alternatives). In the Brazilian group, an interesting change in behaviour occurs when the EMVs are presented for the alternatives as many switch from alternative C (with the highest EMV) to alternative D (with a slightly lower EMV). The p-value is 0.08. This tendency can perhaps be explained by comments made by some of the respondents, e.g. one respondent says "When the difference between the EMVs was small, I chose the alternative with the highest probability and a little smaller EMV". This tendency could not be noticed in the choice behaviour of the Swedish respondents.

3.3. Choice setting III)

Sweden:

	A	B	C	D
Amount	10000	6000	4000	3000
Probability	0,1	0,2	0,4	0,5
EMV	1000	1200	1600	1500
1. Choice Frequency	0%	4%	50%	46%
2. Choice Frequency	16%	9%	31%	44%
Amount	10000	6000	4000	3000
Probability	0,05-0,15	0,15-0,25	0,35-0,45	0,45-0,55
3. Choice Frequency	4%	14%	46%	36%

Table 6 Results from the Swedish respondents in choice setting III.

1) vs. 2): When comparing situations 1 and 2, we can see that when the EMV is presented we have a 16 percentage point increase in the number of respondents that choose alternative A.[2] Furthermore, we can see that 19 percentage points less choose alternative C, whereas the appeal of alternative D remains stable (p-value=0.14).

Brazil:

	A	B	C	D
Amount	2500	1500	1000	750
Probability	0,1	0,2	0,4	0,5
EMV	250	300	400	375
1. Choice Frequency	8%	8%	56%	28%
2. Choice Frequency	9%	0%	67%	24%
Amount	2500	1500	1000	750
Probability	0,05-0,15	0,15-0,25	0,35-0,45	0,45-0,55
3. Choice Frequency	8%	8%	58%	27%

Table 7 Results from the Brazilian respondents in choice setting III.

1) vs. 2)
When the EMV of the alternatives are presented, we can observe an appeal of alternative C (11%), the alternative with the highest EMV (p-value=0.41).

3.3.1. A comparative analysis of choice setting III)

Sweden 1) – Brazil 1):
When the probability span is lower than in I) and II) (between 0.1 and 0.5), the choice frequency of the Swedish respondents are equally distributed between alternatives C and D, whereas among the Brazilian respondents the majority prefer alternative C, as also noted in I) and II) (p-value=0.30).

[2] Note that there are too few respondents (from 0 to 5) to perform a Chi²-test regarding the appeal of alternative A.

Sweden 2) – Brazil 2):
Among the Brazilian respondents, a majority prefers alternative C (67 percentage points), whereas among the Swedish respondents we can see a small preference for alternative D (p-value=0.02).

Sweden 3) – Brazil 3):
The choice distribution among the alternatives is moderately similar between the two groups.

3.3.2. A general interpretation of choice behaviours when prospects have lower probabilities

In choice setting III), the probabilities of the alternatives range between 0.1 and 0.5. When prospects have lower probabilities, alternative D is no longer as dominant in the Swedish group (as opposed to settings I) and II)), and when the EMVs are presented there is suddenly an increase (from 0 to 16 percentage points) of alternative A.[3] The EMV of this alternative is 1000 SEK, an amount that could have triggered their behaviour (see [15]). In the Brazilian group, there is an increase in choice frequency for alternative C when the EMVs are revealed, which differs from the behaviours in settings I) and II). This alternative has the highest EMV value, which could be the reason for the Brazilian behaviour, see e.g. the following comment from one respondent: "When the probability of gain is high (e.g. > 80%), I choose this alternative independently of the EMV. When the highest probability of gain is still low, I look for the highest EMV when I make my choice."

3.4. Choice setting IV)

Sweden:

	A	B	C	D
Amount	16000	8000	5400	4000
Probability	0,2	0,4	0,6	0,8
EMV	3200	3200	3240	3200
1. Choice Frequency	11%	11%	32%	46%
2. Choice Frequency	19%	6%	19%	56%
Amount	16000	8000	5400	4000
Probability	0,15-0,25	0,35-0,45	0,55-0,65	0,75-0,85
3. Choice Frequency	14%	4%	36%	46%

Table 8 Results from the Swedish respondents in choice setting IV.

1 vs. 2
When the EMV information of the alternatives are revealed, there is a decrease in the appeal of alternatives B and C and an increase in the appeal of alternatives A and D (p-value=0.27).

Brazil:

	A	B	C	D
Amount	4000	2000	1350	1000
Probability	0,2	0,4	0,6	0,8
EMV	800	800	810	800
1. Choice Frequency	4%	12%	38%	46%
2. Choice Frequency	12%	6%	39%	42%
Amount	4000	2000	1350	1000
Probability	0,15-0,25	0,35-0,45	0,55-0,65	0,75-0,85
3. Choice Frequency	11%	15%	37%	37%

Table 9 Results from the Brazilian respondents in choice setting IV.

In general, the preferences in the Brazilian group remain quite equally distributed over the alternatives in both comparisons (1 vs. 2, and 1 vs. 3).

3.4.1. A comparative analysis of choice setting IV)

Sweden 1) – Brazil 1):
The respondents' choices are quite similar between the two groups.

Sweden 2) – Brazil 2):
When the EMV information is given for each alternative (which is the same for all alternatives), the two groups mainly differ regarding their choices of alternative C (p-value=0.07).

Sweden 3) – Brazil 3):
The respondents' choices are quite similar between the two groups.

3.4.2. A general interpretation of choice behaviours when the alternatives of the prospects have equal EMVs

In choice setting IV) the alternatives all have the same EMV. When the EMV of the alternatives is revealed, we can see an increase in the appeal of alternative A in all cases, and an increase or unchanged preferences for alternative D. Respondents seem to move towards the extreme alternatives (either the lowest probability of gaining the largest outcome or the highest probability of gaining the lowest outcome).

[3] Note that there are too few respondents to perform a Chi²-test regarding the appeal of alternative A.

3.5. Respondents' statements on interval estimates and choice strategies

After making their choices regarding the prospects, the respondents were asked:
Q1. *When the uncertainty was expressed as an interval instead of a point value, did you find it: 1) Easier 2) Harder or 3) No difference when making your choices?*

In the groups where no EMV information was explicitly given to respondents, 50% of the Swedish group stated that they found it harder to make their choices, whereas only 11% of the Brazilian group perceived it harder. 89% of the latter group found it Easier or Indifferent to make their choices, whereas the corresponding figure for the Swedish group was 50%.

In the groups where the EMV information was explicitly given for each alternative, the Swedish and Brazilian groups answered similarly – about half of them stated that they found it harder, and the rest found it easier or were indifferent.

The respondents in the groups where the EMV information was explicitly given for each alternative were asked an additional question:
Q2. *Did you consider the expected value (EMV) for the alternatives when making your choices? 1) Yes 2) No or 3) Sometimes – If yes, what made you consider it sometimes?*

In the Swedish group as much as 62% stated that they did not consider the EMV information at all when making their choices, whereas only 12% of the Brazilian respondents stated the same. In the Brazilian group as much as 88% stated that they in some or all cases considered the EMV information, which is 50 percentage points more than in the Swedish group.

4. Conclusions

In general, when comparing alternatives where the uncertainty is expressed as intervals (where the midpoint is assumed to be correspondent to the point estimate, since the centroid of the interval is unknown) with those where it is represented by point estimates, the Swedish and Brazilian respondents' choice behaviours are equal (p-value=0.98). The respondents appear to perceive the interval representations equivalent to the point estimates.

When the EMV information of alternatives is displayed, the Brazilian respondents are affected. Their choices change in at least two noteworthy ways. Firstly, when the probabilities of the alternatives are high (choice settings I and II) and the difference in EMV between alternatives is considered low in comparison to the difference between probabilities, an alternative with a lower EMV is found more attractive (p-value=0.06). Secondly, when probabilities are lower (as in choice setting III) there is an increase in the appeal of the alternative with the highest EMV as opposed to choice settings I) (p-value=0.03) and II) (p-value=0.01) when the EMV information is revealed.

The fact that the Brazilian respondents are more prone to be affected when the EMV information is displayed is also supported by their answers to Q2 (see section 3.5), where as much as 88% of the Brazilian respondents stated that they always or sometimes took the EMV information into consideration when making their choices (2.3 times more common).

5. Discussion

The results from this explorative study indicate that the employment of intervals to represent uncertainty could prove beneficial within applied decision making. However, there is a need for larger and more thorough studies. The use of intervals could be fruitful for several reasons (e.g. precise data is seldom available and people have problems making exact probability assessments) and may facilitate the elicitation part in the use of decision analytical tools. However, from the results of this study, it seems like the respondents' choice behaviours can be affected by numeric triggers in several ways (the same applies to point estimates) and differ in behaviour in different probability ranges [15, 16]. People tend to focus more on the monetary values in prospects when probabilities are lower, see e.g. the Swedish group's behaviour in choice setting I) and II) regarding alternative *A*. A similar phenomenon has earlier been identified in positive domains when probabilities get very low, approaching 0 [3]. This makes it necessary to address such problems more thoroughly.

An important aspect derived from the results of this study is the need for more flexible decision analytic tools regarding the elicitation process. Most available tools, see e.g. Prime Decisions, TreeAge Pro, DPL and DecideIT, have been developed in developed countries, by a relatively homogeneous group of people with a similar educational background, quite often in the field of computer science. Since the tools, in most cases, are developed from a developer perspective, they implicitly assume that people interact with such tools in a universal manner. However, people in general are not a homogeneous group and their behaviours differ in a great variety of ways, not least concerning their way of making decisions, judging probabilities and expressing their attitudes to risky situations.

In this study, for instance, we have identified different choice behaviours regarding how respondents perceive prospects where the EMV of the alternatives

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is displayed. The Brazilian respondents take the EMV into account to a higher extent than the Swedish respondents, and are more risk-prone in comparison. Furthermore, contrary to rational behaviour, some of the respondents disregard the EMV information whereas some take it into account sometimes.

We should bear in mind that this study was performed with two groups that were chosen on purpose in order to obtain groups that were similar to each other from an economical and educational point of view and where the social context was the main difference between them. It is obvious that the differences in the social contexts, between these two (quite similar) groups, yield different results. So, it is not hard to imagine that the differences in choice behaviour that have been identified in this study is only a fraction of what would have been discovered if the study had also included other groups with different educational and social backgrounds from both countries.

Based on the results from this study, there is a need for development of decision analytical tools which can handle problems such as those pointed out, and allow us to adapt the elicitation process to the behaviours of real users in a prescriptive manner. It is hard, if not impossible, to sit in, e.g. Sweden and develop tools that are to be used by decision makers around the world in different cultures with different ways of reasoning, handling problems, working etc.

In order to develop more useful decision analytical tools, we must include different groups of users, people with different educational, cultural, and social background in the development process. A more multidisciplinary approach is needed in order to improve the usage of such tools. Much of the existing tools are not in tune with decision makers' reality and the existing problems, and there is a gap between the developers' knowledge of such problem areas and the real decision makers' needs.

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Article VI

A Prescriptive Approach to Probability Elicitation

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Abstract

Most current decision analytical tools and elicitation methods are built on the assumption that the decision makers are able to make their probability and utility assessments in a proper manner. This is, however, not the case. The specification and the execution of the elicitation process are in the majority of cases left to the discretion of the users. A number of studies have shown, among other things, that people's natural choice behaviour deviates from normative assumptions, and that the results display an inertia gap due to differently framed prospects. One reason for the occurrence of the inertia gap is people's inability to express their preferences as single numbers. Instead of considering this as being a human error, the paper uses the inertia gap in order to develop a class of methods more aligned to the observed behaviour. The core of the proposed GIGA (General Inertia Gap Assessment) class of methods is to acknowledge the existence of the inertia gap and, as a consequence, not elicit single point numbers. Instead, an interval approach is suggested, concerning the framing process as well as the process of storing the elicited information.

1. Introduction

Many current models of decision analytic support are based on the same or similar conceptualizations. First of all, they assume that the users have knowledge regarding how to identify, structure, and model the reasoning problem, e.g., how to model the problem into a suitable structure. In addition, the applications, in many cases, require precise input data. Precise probabilities are, however, seldom available in real-life situations, see [Keeney and Raiffa 1976; Merkhofer 1987, Riabacke 2006].

The classical model of rational reasoning states that a rational decision-maker chooses the option with the optimal combination of probability and utility. Thus, to be able to use such methods, probabilities have to be subjectively estimated [Bell, Raiffa, and Tversky 1988], and somehow elicited from the users. Normative theories assume that people are able to make these assessments accurately. However, several authors, cf. [Fischoff, Goitein, and Shapira 1983; Shapira 1995], have raised the question as to whether people are capable of providing the input information that utility theory requires. Moreover, according to Kirkwood (1997), the use of a single number to represent an uncertain quantity can confuse a person's judgment about uncertainties where there are various desirable outcomes. Cognitive researchers such as Anderson (1998) have shown that the human mind does not process single number probabilities efficiently and that even experienced statisticians make errors in this area.

Traditionally in elicitation models, the input data is supposed to be obtained by an exogenous process, see [Riabacke, Påhlman, and Larsson 2006], and the specification and execution of the process is left to the discretion of the user. One main problem is that most current elicitation models handle precise data, i.e. the probability estimates are required to be expressed as single numbers. These facts place demands on the ability of the user to express his or her knowledge in the format required. This is, of course, not an easy task, since users in the majority of cases lack the necessary skills with regards to assessing subjective probability values.

Other elicitation methods that have been suggested are the use of verbal descriptions of probabilities and utilities. Merkhofer (1987), however, provides us with some examples that show the difficulties associated with such an approach, and state that "*the fact that different individuals assign very different probabilities to the same expression demonstrates vividly the danger of using word to communicate uncertainty*". Thus, using such verbal communication in order to express judgments about uncertainty can, according to [Kirkwood 1997], cause a serious risk for miscommunication.

At stage 1 of the elicitation process, in Figure 1, we find the decision-makers possessing information that somehow should be elicited and structured. To be able to do so, we will in this paper propose a class of methods that use two opposite presentation formats when assessing prospects. We will, moreover, propose the use of a suitable representation format for the elicited data and introduce an interval format. Thus, the focus of the proposed method class is on Stage 2, the tool-box that should be available to the decision analyst in order to elicit data from decision makers (in order to provide the decision analysis models with accurate input data). One should also mention, stated by Keeney 2004, that many decision problems are never required to be completely analysed. They could probably be correctly solved if it was possible that the initial process in the elicitation process at Stage 2 was more appropriate. Therefore, Stage 2 is an important step in making better decisions, no matter whether the elicited data will serve as the basis for the final decision or will be further analysed and fine-tuned to fit into different types of decision analytical tools.

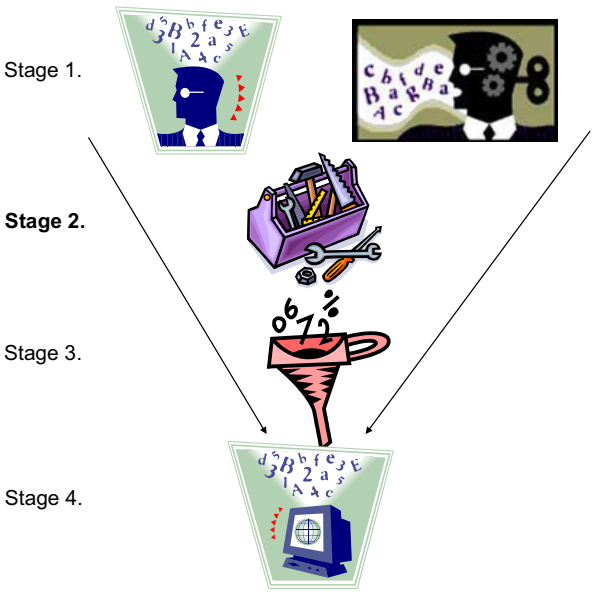

Figure 1. The elicitation process.

Today, most decision analytical processes overlook Stage 1 and Stage 2, and assume that decision-makers are themselves able to provide the models with the required input data, but this is unfortunately not always the case. Consequently, we will investigate how we can support an elicitation process in the following manner:

How can we support decision-makers in an elicitation process by taking their natural choice behaviour into account?

Section 2 will present some studies made into elicitation processes, and Section 3 will discuss the implications of the results for elicitation methods. Finally, Section 4 contains further research.

2. Studies

The results presented in this paper are based on findings made in a series of studies [Påhlman and Riabacke 2005; Riabacke, Påhlman, and Baidya 2006; Riabacke 2006; Riabacke, Påhlman and Larsson 2006]. The authors have in these studies used people from different contexts with respect to professional, educational, social, economic, and cultural backgrounds. The studies are of both qualitative and quantitative nature and different methodologies have been used in order to confirm the results. Different types of questionnaires have been used in the studies of qualitative character [Påhlman and Riabacke 2005; Riabacke, Påhlman, and Baidya 2006], and the studies include a total of 396 subjects. The studies of quantitative character [Riabacke 2006; Riabacke, Påhlman, and Larsson 2006] includes interviews with 24 subjects. The semi-structured interviews lasted between two and three hours in the first study, and approximately 30 minutes each in the second study.

A study carried out in [Påhlman and Riabacke 2005] illuminates some additional aspects of the problems within the area of probability and utility elicitation. Since empirical studies of methods for elicitation have shown that different methods have a tendency to yield different results, Påhlman and Riabacke (2005) further investigated how people behave when faced with different types of questions that are presently used in the elicitation procedures. The aim of the study was to examine whether the presentation format of the task and the presentation order of probabilities affect the results. The study included 240 undergraduate students, from two universities within the areas of business administration and computer science. The questionnaires with closed questions were tested on four groups with a total of 40 subjects and which was partly redesigned after the test. Four types of questionnaires were used with two different presentation formats (or formulations) of the same problems, that is, there were eight different questionnaires. Each subject answered 7 questions on either chance or risk prospects and the survey was conducted using 8 groups containing 30 students in each group. It was explained that there were no correct answers and this was also stressed in the description of the task in the questionnaire.

The study was designed as follows: Two different types of presentation formats, *Trade for* (TF) and *Choose between* (CB), see Table 1 and Table 2, were used in four types of questionnaires (with increasing and decreasing probability order). The subjects were given a choice between one alternative $\boldsymbol{A_1}$ with a specific probability (of winning or losing a sum of money), and another alternative $\boldsymbol{A_2}$ with a fixed probability, see Table 1 and Table 2. (1 SEK is roughly equivalent to 0.15 USD in purchasing power). Each subject answered 7 questions, and 7 measuring points were used (see Table 3). The probability levels of the 7 measuring points used in Table 3 are in *increasing probability order*. In Table 1 the used measuring points are $A_1(0.65, x_1)$ and $A_2(0.75, x_2)$, and in Table 2 the reversed order of the probability presentation format is found and the used measuring points are $A_1(0.85, x_1)$ and $A_2(0.75, x_2)$.

Original alternative $\boldsymbol{A_1}$: 65% chance to win 2000 SEK	**TRADE FOR?**	Second alternative $\boldsymbol{A_2}$: 75% chance to win one of the following amounts:
		500 SEK
		1000 SEK
		1200 SEK
		1400SEK
		1600 SEK
		1800 SEK
		2000 SEK

Table 1. Presentation format TF.

85% chance to win, $\boldsymbol{A_1}$:	**OR?**	75% chance to win, $\boldsymbol{A_2}$:
2000 SEK		2000 SEK
2000 SEK		2100 SEK
2000 SEK		2500 SEK
2000 SEK		2900SEK
2000 SEK		3400 SEK
2000 SEK		4000 SEK
2000 SEK		4700 SEK
2000 SEK		5500 SEK

Table 2. Presentation format CB.

In the interval of the second alternative $\boldsymbol{A_2}$, an amount that resulted in the corresponding EMV of the first alternative $\boldsymbol{A_1}$ was always available for choice, and the y-axis (in Figure 2, 3 and 4) shows the mapped EMV value of the 7 measuring points. Level 1 on the y-axis represents the EMV-value level. Thus, as can be seen in Figure 2 representing the increasing probability format, the subjects demand a higher EMV for alternative A_2 for measuring points 1 – 3. Thereafter, for measuring points 4 – 7, they accept an EMV for $\boldsymbol{A_2}$ which is lower than for the original $\boldsymbol{A_1}$ alternative.

1	2	3	4
$A_1(0.15, x_1)$ and $A_2(0.25, x_2)$	$A_1(0.25, x_1)$ and $A_2(0.35, x_2)$	$A_1(0.35, x_1)$ and $A_2(0.45, x_2)$	$A_1(0.45, x_1)$ and $A_2(0.55, x_2)$
5	6	7	
$A_1(0.55, x_1)$ and $A_2(0.65, x_2)$	$A_1(0.65, x_1)$ and $A_2(0.75, x_2)$	$A_1(0.75, x_1)$ and $A_2(0.85, x_2)$	

Table 3. The probability levels of the 7 measuring points used, here presented in *increasing probability order*.

The probabilities were either ordered as increasing (as in Table 1 (65→75%)) or decreasing (as in Table 2 (85→75%)) in size and the second alternative was always either 10% larger or smaller than the first alternative. The results from the study show that the presentation format, i.e. the order of the probabilities, affects the results (from both chance and risk perspectives). Figure 2 shows the results displayed for the comparison of the order of probabilities when the presentation format TF is used from the chance perspective and figure 3 shows the comparison of the order of the probabilities when the presentation format TF is used from the risk perspective.

The observed gap

Figure 2 shows one observed result concerning how the subjects' choice behaviour was affected by the order of the probabilities in the TF format and that a gap occurs between the results of the increasing and the decreasing format. The arrow, on the right hand side in the figure, shows the gap that occurs due to the different choice behaviours the subjects display when different elicitation methods are used. This means that subjects demand a lower EMV for the second alternative $\boldsymbol{A_2}$ throughout the whole measuring scale, when the decreasing probability order is used, in comparison to when the increasing probability order is used.

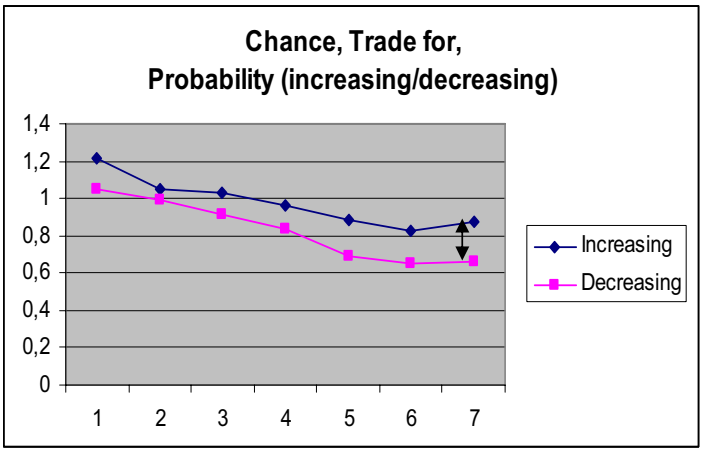

Figure 2. TF presentation format in a chance domain, with increasing and decreasing probability formats.

It should also be noted that this pattern is constant and that the mapped lines on the y-axis do not cross each other. In a paired T-test of the measuring points, the mean difference is 0.15 and the corresponding P-value is 0.000. Figure 3 shows that when studying the *TF* format in a risk domain, we find an even stronger effect in terms of the occurring gap between the different presentation formats (increasing and decreasing). The two mapped lines on the y-axis are completely separated in Figure 3 and the gap between them is even more apparent, i.e. the risk presentation format is more affected by the probability presentation format. Paired T-tests in this case result in a mean difference between the two methods of arranging the probabilities in the *CB* case being 0.09 and in the TF case being –0.22. The corresponding P-values are both 0.000.

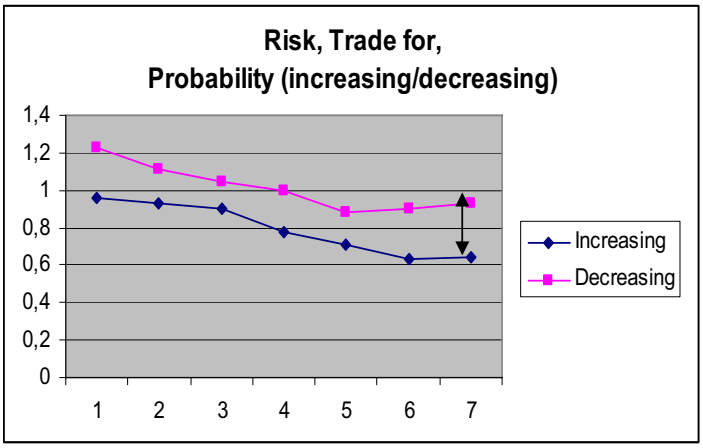

Figure 3. TF presentation format in a risk domain, with increasing and decreasing probability format.

3. Interpretation

The findings from the study discussed above, and similar results from [Riabacke, Påhlman and Larsson 2006] among others, illuminate the importance of developing effective elicitation methods, since no single elicitation method appears to be universally convergent on its own. Obviously, people do not act in accordance with normative rules, and they apparently prefer differently framed prospects in the elicitation process (ibid).
Depending on the perspective, there are three different interpretations of the results of the studies.

(a) From a descriptive perspective, the respondents appear to be victims of framing effects. The effects of framing are widely known within descriptive decision theory, see, e.g. [Kahneman and Tversky 1979; Kahneman, Slovic, and Tversky 1982]. However merely attaching a label to the effects does not change the observed facts and is not particularly helpful from an elicitation point of view. The empirical evidence shows that the respondents provide these answers, even maintaining them after subsequent interviews.

(b) From a normative perspective, the results appear to be simply wrong. The respondents seem unable to communicate a consistent view of the situations encountered, at least from the viewpoint of attempting to elicit single points. This is also somewhat unhelpful from an elicitation point of view.

(c) However by adopting a prescriptive approach, we use the observed gap (called an inertia gap due to respondents' inertia in shifting) to our advantage in proposing a class of elicitation procedures more aligned to the observed behaviour. To emphasize the inertia component, it will be called the GIGA (General Inertia Gap Assessment) class of methods. The core of the proposed GIGA class is to acknowledge the existence of the inertia gap and, as a consequence, not elicit single point numbers.

The consequences of the inertia gap are shown in Figure 4. A problem associated with point-wise methods is that they may elicit a point anywhere within the inertia interval. If a point-wise method elicits point B in the figure, the highest value in the gap, a subsequent sensitivity analysis of the decision problem would consider points outside of (above) the gap, which are points that are not endorsed by the decision-maker.

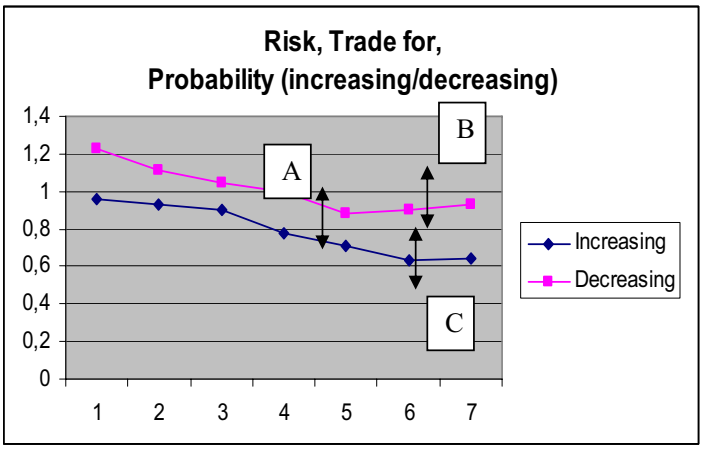

Figure 4. The TF presentation format with increasing and decreasing probability formats.

Similarly, if a point-wise method elicits point C in the figure, the lowest value in the gap, a subsequent sensitivity analysis of the decision problem would consider points outside of (below) the gap. On the other hand, by using an interval-based decision method based on the interval A in a sensitivity analysis and by contracting the interval and studying the stability of the obtained results it can be assured that only the sets of points endorsed by the decision-maker are used. The inertia (unwillingness to shift) effect is present in several elicitation situations. It will only be possible in some cases to reduce the width of the gap to zero, i.e. elicit the same point from oppositely traversing prospects. Consequently, the GIGA class of methods we propose to overcome the gap difficulties described above is to:

1. Use both increasing and decreasing probability presentation formats in the elicitation process, in order to find the inertia interval.

2. Since the elicitation output is based on intervals, to also use intervals in the elicitation process.

3. Use a suitable representation format for storing the elicited information. For this purpose, we introduce an interval representation format.

The first issue is discussed above. The second issue deals with the possibilities associated with also using intervals in the elicitation process itself. This is difficult to do when the output must be a point, but is much easier when the output is a range (interval). This has also been studied in [Riabacke, Påhlman and Baidya 2006]. If we, for instance, offer a prospect where the subject is asked to choose between retaining alternative A_1, a 65% chance to win 2000 SEK, or to trade it for the second alternative A_2 which involves winning a particular amount with a 75% chance (see Table 4), then the subject may choose to trade for the second alternative at 1200 SEK, even though his/her threshold (willingness to trade) lies at 1150 SEK. This means that the true preference for the decision maker, in many cases, simply lies somewhere close to the available alternatives, and that such elicitation methods are rather imprecise and do not provide us with correct assessments of the decision-maker's preferences.

Original alternative A_1: 65% chance to win 2000 SEK	**TRADE FOR?**	Second alternative A_2: 75% chance to win one of the following amounts:
		500 SEK
		1000 SEK
		1200 SEK
		1400SEK
		1600 SEK
		1800 SEK
		2000 SEK

The threshold to trade may, for example, occur at the level of 1150 SEK, i.e. between the available alternatives 1000 and 1200 SEK.

Table 4.

If we start by looking at the presentation format used in Table 4, few people would be able to state that their willingness to trade for the second alternative lies exactly at one of the offered points in A_2 (500 SEK, 1000 SEK, 1200 SEK, etc.), and we would therefore risk ending up eliciting an end-point value within one of their imaginary preferred intervals. Most people would have difficulties stating that I am willing to trade at a value which is, for example, exactly 1154 SEK. It could, however, be easier to say that the sum demanded in the second alternative A_2, which would be willingly traded, must lie somewhere between, for example 1125 – 1175 SEK. So, the offered point values should then be abandoned for values presented as intervals. In Table 5 we find such a suggested interval approach used in order to present the A_2 alternatives.

Original alternative A_1: 65% chance to win 2000 SEK	**TRADE FOR?**	Second alternative A_2: 75% chance to win one of the following amounts:
		400 - 750 SEK
		750 - 1100 SEK
		1100 - 1300 SEK
		1300 – 1500 SEK
		1500 – 1700 SEK
		1700 – 1900 SEK
		1900 - 2000 SEK

Table 5.

Thus, if the threshold for trading A_1 for A_2, for example, occurs at the level of 1150 SEK (between the available alternatives 1000 and 1200 SEK in Table 4), then the subject would choose the alternative presented as an interval between 1100–1300 SEK in Table 5. At this stage there is not only one value, which is the case when using traditional values and only receiving one end point (as the result of using exact values in the presentation format). The next step of the suggested interval elicitation approach could be to use probing and ask the subject for additional information in order to elicit more precise data and narrow (if possible) the chosen interval. The subject may for instance be able to say that his/her preferences lies in the span of 1125–1175 SEK, and he/she might furthermore be able to state that it is more likely that he/she demands a value closer to 1175.

Formal Consistency of Interval Estimates

The third issue is the representation of intervals. The most convenient method is to store the intervals in a format accessible for computer algorithms. In this case, ranges are often stored as pairs of inequalities, i.e. pairs of constraints. If we have a set of elicited ranges of the kind above, then they must be represented in a suitable format. Moreover, for them to be of use, basic checks must be performed in order to ascertain that there are no internal inconsistencies. In principle, we could use any reasonable representation format, but, needless to say, a computationally meaningful one is preferable. The proposed format is an interval representation, interpreting the increasing and decreasing data points as endpoints of an interval describing the user's estimate. The intervals could then be checked for consistency using ordinary linear programming procedures. The *Decreasing* and *Increasing* points for each parameter translate into intervals that are represented by interval constraints, i.e. a pair of inequalities involving a single variable. A reasonable interpretation of such constraints is that the user estimate does not fall outside of the intervals.

Definition 1.

Given an index set I and a set of variables $\{x_i\}_{i\in I}$, a *constraint set* in $\{x_i\}_{i\in I}$ is a set of interval constraints in the variables $\{x_i\}_{i\in I}$. ■

During elicitation, it is important to determine whether the elements in a constraint set are at all compatible with each other. This is checked by determining whether a constraint set has a solution, i.e. if there exist any vector of real numbers that can be assigned to the variables.

Definition 2.

Given an index set I and a set of variables $\{x_i\}_{i\in I}$, a constraint set X in $\{x_i\}_{i\in I}$ is *consistent* **iff** the system of weak inequalities in X has a solution. Otherwise, the constraint set is *inconsistent*. ■

A useful constraint set is consistent, i.e. a set where the constraints are not contradictory. It is consistent if any solution can be found to the set of interval constraints.

Definition 3.

Given an index set I, a consistent constraint set X in $\{x_i\}_{i\in I}$ and a function *f*,
$^{X}\max(f(x)) =_{def} \sup(a \mid \{f(x) > a\} \cup X \text{ is consistent})$. Similarly,
$^{X}\min(f(x)) =_{def} \inf(a \mid \{f(x) < a\} \cup X \text{ is consistent})$. ■

^{X}max and ^{X}min can now be found by a linear programming procedure such as Simplex. If they can be found for each variable, the set is consistent. For a more detailed procedure, see (Danielson and Ekenberg 2007). Furthermore, normalisation constraints of the type where probabilities must sum to one are also easily handled by a linear programming approach by adding the normalisations as additional constraints to the constraint set.

Behavioural consistency of Interval Estimates

The proposed GIGA class of elicitation methods could be considered reasonable only if the intervals are perceived as being at least as representative as points in representing the elicited information. Thus, a reasonable question is whether the use of intervals confuses people and thus makes these methods less suitable. To study some aspects of this problem, a comparative study was carried out at Mid Sweden University in Sundsvall, Sweden, and at Pontifícia Universidade Católica do Rio de Janeiro, Brazil, including a total of 120 respondents from the two countries [Riabacke, Påhlman, and Baidya 2006]. Each respondent answered a questionnaire with 12 questions on prospects with a chance of gain, and they had 20 minutes to fill out the questionnaire. The students were asked to picture themselves in situations described by the prospects. They were also told that they could under no circumstances lose anything and that these situations only occurred once. Four choice settings were used in the study, I)-IV), see for example Table 6 where choice setting III is shown. In each choice setting, four alternatives (A, B, C, and D), again see Table 6, were presented to the respondents and they were asked to choose the alternative they most preferred. Furthermore, each choice setting was presented in two different ways (situations), the uncertainty of each alternative was either presented as a point estimate, p, or as an interval, $[p_1, p_2]$ (where the midpoint is considered to be equivalent to the point estimate of the corresponding alternative, since the centroid of the interval is unknown). In Table 6 the results from one of the above four mentioned choice settings involving the Brazilian students are displayed.

	A	B	C	D
Amount	2500	1500	1000	750
Probability	0,1	0,2	0,4	0,5
Choice Frequency	8%	8%	56%	28%
	A	**B**	**C**	**D**
Amount	2500	1500	1000	750
Probability	0,05-0,15	0,15-0,25	0,35-0,45	0,45-0,55
Choice Frequency	8%	8%	58%	27%

Each choice setting was presented in two different ways (situations). The uncertainty of each alternative was either presented as

a point estimate, p,

or as an interval, (p_1, p_2)

Table 6 Results from the Brazilian respondents in choice setting III.

We can see that the respondents in this choice setting appear to perceive the interval representations as equivalent to point estimates. This was also the case for all the choice settings (I-IV) when choosing between prospects where the uncertainty is expressed as an interval versus prospects where the uncertainty is expressed by point estimates, and the overall p-value was 0.98. Accordingly, the subjects' choice behaviours did not change even though the alternatives in the prospects were presented as intervals. Since there was no perceptible change in behaviour, the inference which can be drawn is that inertia

intervals are a reasonable candidate representation for the user's intended meanings of the parameters subject to elicitation.

We have, in earlier research, suggested that the prospects used in elicitation processes should be presented from several different perspectives, in order to assess the inertia gap in an unbiased manner, since people are affected by the presentation format, etc. [Påhlman and Riabacke 2005; Riabacke, Påhlman, and Larsson 2006]. That is one side of the coin. The other side is that we must be able to prescriptively fine-tune the methods and measuring instruments in order to fit the current situations, different user groups and choice behaviours. In [Riabacke, Påhlman, and Larsson 2006] it has been noted, for instance, that people like to have probabilities presented to them in many different ways. Many of the subjects in the study expressed their evaluation strategy, when choosing from the differently framed prospects, in terms of converting probabilities into frequencies.

If the subjects are familiar with the probability and utility concepts, then it may be possible to ask them in a straightforward manner for their assessments. An advantage of such direct methods is their speed of usage [Påhlman 2006]. It might, however, be difficult for people to assess such values, if they for example are less experienced or are novices within the fields of probabilities and utilities, or in situations where the available alternatives are of a more complex nature. In order to approach less experienced groups of decision-makers in an elicitation process, some sort of measuring instruments [Kirkwood 1997] are required. Several present day tools (e.g. DATA, MSBN, and DPL) supply a graphical probability wheel interface for that purpose, and the use of such wheels, see e.g. [Spetzler and Staël von Hostein 1975; Merkhofer 1987], is the most popular graphical tool used for probability elicitation [Wang and Druzdzel 2000]. The traditional wheels have, however, several disadvantages; a lack of user control being one of them. Wang and Druzdzel (2000) argue, for instance, that since the total probability is always equal to one, automatic adjustments of probabilities are frustrating when an expert merely wishes to modify some of the numbers while retaining others. However, they propose a method in order to circumvent this problem by developing a method that allows the user of a probability wheel to fix some values that must not be changed when other probabilities are modified. The focus of Wang and Druzdzel is, however, on the development of graphical tools for the elicitation of probabilities in conditional probability tables, very close to stage 4 in the process presented in Figure 1. Our gap observation focuses on an earlier stage, namely Stage 2 in the elicitation process.

4. Further Research

The TF and CB formats were employed in the studies for their ease of use in questionnaire situations. This does not necessarily mean that they are the most suitable for elicitation purposes, particularly not for computer tool assisted elicitation. On the contrary, a number of interesting elicitation methods exist in the literature that are promising candidates for inertia elicitation. One research direction is thus to use probability wheels and bars (see Figure 5 and Figure 6) that enable the decision-makers to express their beliefs regarding probability and utility assessments in intervals. The use of these interfaces is supposed to be used in conjunction with other tools in a tool-box (see stage 2 in Figure 1).

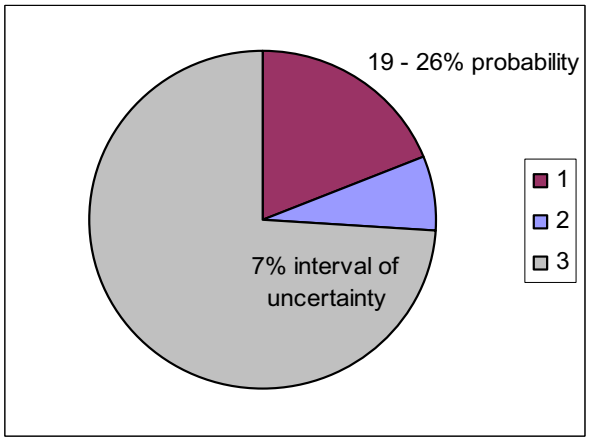

Figure 5. Probability wheel with interval estimations.

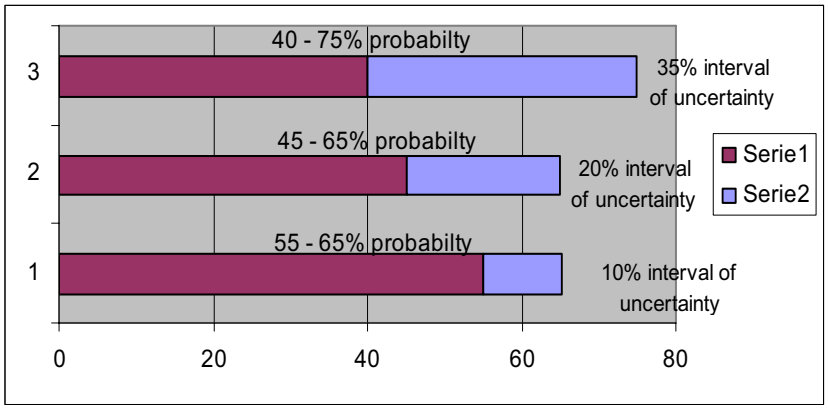

Figure 6. Probability bars with interval estimations.

The probability wheel and the probability bar presented above are early prototypes developed in Microsoft Excel software. The creation of fully functional prototypes for field tests is part of the planned further research. One hypothesis is that it might be more appropriate to use the wheel when eliciting the values for one parameter, while the bar could be better when visualising and eliciting values for a number of parameters at the same time.

5. Concluding Remarks

The fact that most current elicitation methods and computer based decision analytical tools place too high demands on the decision-makers, e.g. by requiring the probability and utility estimations to be expressed as single numbers, makes it difficult for people to use different types of decision aids. In order to discuss the gap between the decision-makers, the elicitation process, and the use of decision analytical tools (when such aids are appropriate to use) we have modelled the elicitation process in four stages, but our main focus is on the second stage (the tool-box). We propose a

class of methods (GIGA) for eliciting data using an interval approach which is more aligned to observed behaviour, i.e. by taking people's natural choice behaviour into account. This behaviour manifests itself as inertia with regards to the shifting of views, thereby creating an inertia gap. In order to overcome some of the identified difficulties that occur, GIGA employs intervals as a basic component in the elicitation process. Further, it uses two complementary presentation formats (in order to narrow the inertia gap). Finally, an interval representation format for storing the elicited information is suggested.

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Appendix

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Interim Report **IR-03-003**

Flood Risk Management Policy in the Upper Tisza Basin: A System Analytical Approach Simulation and Analysis of Three Flood Management Strategies

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Contents

Abstract

This report describes an integrated flood catastrophe model as well as some results of a case study made in the Upper Tisza region in northeastern Hungary: the Palad-Csecsei basin (the pilot basin). The background data was provided through the Hungarian Academy of Sciences and complemented by interviews with different stakeholders in the region. Based upon these data, where a large degree of uncertainty is prevailing, we demonstrate how an implementation of a simulation and decision analytical model can provide insights into the effects of imposing different policy options for a flood risk management program in the region. We focus herein primarily on general options for designing a public-private insurance and reinsurance system for Hungary. Obviously, this is a multi-criteria and multi-stakeholder problem and cannot be solved using standard approaches. It should however be emphasized that the main purpose of this report not is to provide any definite recommendations, but rather to explore a set of policy packages that could gain a consensus among the stakeholders.

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Flood Risk Management Policy in the Upper Tisza Basin: A System Analytical Approach Simulation and Analysis of Three Flood Management Strategies

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1. INTRODUCTION

Rivers and their corridors of flood plains fulfil a variety of functions both for human use and for the natural ecosystem, i.e. they are fundamental parts of the natural, economic, and social system wherever they occur. At the same time, rivers might be the largest threats to entire areas. Besides fires, floods are the most common and widespread of all natural disasters, killing in average yearly 150 people and causing over 3 billion US $ in property damage (FEMA 00). Moreover, national average annual flood losses continue to increase. In recent years, much attention has therefore been given to the management of natural disasters and, in particular, to floods. An event that initiated the discussions was the 1992 flash flood in France, where 42 people were killed in the Vaison-la-Romaine (Samuels 98). However, despite dedicated efforts of governments and the private sector to mitigate flood hazards, problems still remain with current practices, including methods of design and construction of building utilities. Furthermore, driven by the increasing frequency of floods, the need for evaluation and strategic flood planning tools has increased (Evans 00). Consequently, in several countries it is recognized that programs for efficiently and effectively linking private and public responsibility and insurance, as well as loss mitigation, need to be created.

In the Tisza region in the northeastern part of Hungary, there are annual floods. Furthermore, extreme floods are expected every 10-12 years (Vári 99). Financial losses from floods are severe in this region, and costs for compensation to victims and mitigation strategies are increasing. In Hungary, as in other countries, the government is looking for alternative flood management strategies, where part of the economic responsibility is transferred from the public to the private sector. In the design of different flood management strategies, a key interest for the Hungarian government has been to find the balance between social solidarity and private responsibility. Today, most Hungarians perceive that the government should compensate them for the losses, but such a policy is not affordable. Moreover, there are many different interests represented by the tourist industry, other industries, farmers, environmental groups and other NGO's, (non-governmental organizations) that have to be taken into account. Consequently, there is a strong need for other loss sharing policies which different stakeholders, e.g., governments, insurers and individuals, could agree upon. Hungary is

a country where as much as 20 per cent of its 93,000 square meters of territory are at risk for flooding. During the past decades, the central government has spent huge sums on building and maintaining extensive levee systems along the main rivers to protect the endangered land and communities. The government has not only taken the pre-flood responsibility, but also the post-flood responsibility. If a flood occurs in a protected area, this is considered to be the responsibility of the government, and the government has by tradition compensated the victims. For instance, after the recent devastating floods of the river Tisza, in 1999, the government paid full compensation for all damaged private properties.

During 1999, a number of interviews with stakeholders in the Upper Tisza region were performed (Vári 99), with the purpose of identifying realistic flood management strategies considered fair by the different stakeholders in the region and elsewhere. Based on the interviews, three alternative flood management policy strategies were formulated, and this report investigates the effects of imposing these strategies. The strategies are not necessarily optimal in any respect, but are constructed for the purpose of illuminating significant effects of adopting different *insurance* policies. Consequently, a main issue has been to investigate different insurance schemes in combination with level of governmental compensation. In particular, the subsidiary level has been studied, i.e., the amount of money transferred from low-risk areas to high-risk areas as well as from reasonably wealthy property owners to less wealthy ones.

This report is based on a case study of the Palad-Csecsei basin (the pilot basin), which is situated in the Szabolcs-Szatmár-Bereg County in northeastern Hungary and inhabited by 4,621 persons. This region is one of the poorest agricultural regions of Europe, and floods repeatedly strike large areas. In particular, the second largest river in Hungary, the Tisza River, flows trough the county. The pilot basin consists of eleven municipalities, of which primarily two experience flood damages.

Based upon statistical data and interviews, we demonstrate how an implementation of a simulation and decision analytical model can provide some insights on the effects of imposing different policy options for a flood risk management program in the region. We focus herein primarily on general options for designing a public-private insurance and reinsurance system for Hungary. The emphasis is on the multi-criteria and multi-stakeholder issues involved as well as the high degree of uncertainty in the background data.

Section 2 describes a tool for flood consequence simulation applied to the pilot basin with different settings for the three scenarios. Section 3 describes how the results from the simulations can be used from a decision theoretical viewpoint for investigating the relation between the different scenarios taking the different stakeholders into consideration. Section 4 summarizes a number of interviews performed with the purpose of investigating the degree of acceptance of the different scenarios. The interviewees received the simulation results beforehand and made their judgments with this background as a component. Section 5 concludes the report. Finally, there is also a set of appendices. These consists of more elaborated descriptions of the flood simulation model and the decision analytical model as well as transcripts of the interviews.

2. SIMULATING FLOOD FAILURE

Due to the inherent infrequency of natural disasters, it is impossible to predict the time, the location, or the magnitude of a flood. The shortcomings of statistical methods emphasize the role of models for evaluating new policies in presence of dependencies and lack of data, c.f. (Ekenberg 00). Needless to say, this uncertainty can be treated in a multitude of ways, but a quite common approach is to study the uncertainties explicitly by considering the flood-related variables as stochastic variables, in a probability theoretical sense.

Computer based simulations are increasingly used to understand how micro order actions affect the macro order outcome, see for instance (Axelrod 97), (Gilbert 99) and (Conte 97). Simulations are a most convenient approach in this case, since it would be very hard to determine an analytical solution to this problem. The model described below takes such an approach as well using estimated flood failures as stochastic variables in the simulations. A flood failure is something that occurs when the flood overtops a structural flood mitigation measure. The latter could, for instance, be a levee breakage. The reason for restricting the simulations to flood failures only is that insurance companies compensate damages caused by failures, but not damages caused by ground water related floods.

Nine different flood failure scenarios have been implemented in the model. This is based on the assumption that the flood can be of three different magnitudes, and that a failure can occur at three different locations. The financial damages are estimated for all flooded properties for the nine failure scenarios. Thus, in the present version of the model, we use ten different possible scenarios (nine with flood failures and one without), simulated 10 000 times over a period of ten years.

Simulation approaches seem to be the most suitable ones in these kinds of scenarios. The number of different possible outcomes of 10 possible scenarios each year over a period of 10 years is 92378 ($19!/(9!\cdot 10!)$) for each of the three different flood management strategies. Consequently, the number of possible scenarios makes the problem quite complex and not really suited for a more analytical treatment. This is particularly the case when having a decision analytical approach as well.

2.1 THE FLOOD MODEL

The flood model consists of different modules. A brief description of the functionality of the modules is given in the following sections. See Appendix 3 for more detailed information on the flood model and the settings. See also (Brouwers 01) and (Brouwers 02) for a more thorough discussion of the model.

Two stochastic variables are used to represent flood uncertainties. One variable *Magnitude* represents, for each simulation year, whether there is a 100-year flood, a 150-year flood, a 1000-year flood, or no flood. The probabilities for these events are 1/100, 1/150, 1/1000 and 1-(1/100+1/150+1/1000), respectively. The other variable *Failure* represents whether the flood causes a levee failure at one or none of the three locations. The following probability distributions for these 10 possibilities are used.

Magnitude	Failure	Probability
100-year flood	Location 1	0,12
100-year flood	Location 2	0,20
100-year flood	Location 3	0,28
150-year flood	Location 1	0,18
150-year flood	Location 2	0,22
150-year flood	Location 3	0,40
1000-year flood	Location 1	0,19
1000-year flood	Location 2	0,33
1000-year flood	Location 3	0,45
No flood	Location 1-3	0,00

Table 1 Probabilities for failures at different locations (From (VIT 99))

Based on this, the stochastic variables are assigned random values through a Monte-Carlo simulation. These outcomes are passed to the *Catastrophe module*, where the value of the stochastic variable *Failure* is checked. For each of the nine failure scenarios, the Catastrophe module calculates the inundated land area as well as the water level.

The *Spatial module* calculates the vulnerability of inundated land. The module uses a grid representation of the pilot basin with 1551·1551 cells, where each cell represents an area of 10 square meters. For each cell there are several relevant parameters, e.g., soil type, land-use pattern, digital elevation, and property value. In the simulations, only structural flood losses are considered, why agricultural data is omitted.

For each simulated year, when a flood failure has occurred, the financial consequences for the different stakeholders are collected and saved in the Consequence Module. The module calculates, for each inundated cell, the financial consequences, based on property values and vulnerability for all inundated cells. The latter values are received from the Spatial Module. The structural losses are estimated by a loss-function, which considers initial property value and vulnerability as well as level and duration of inundating water.

The stakeholders represented in the flood model are the municipalities, the insurance companies, the individual property owners, and the central government. In the end of each simulated year, the financial situations for all agents are updated (Hansson 01). If there was a failure, the property values are reduced for the affected cells. Premiums are paid annually, but individual property owners can normally choose whether to buy insurance or not. This choice affects the outcome both for the individuals and for the insurance company. The financial consequences also depend on the current flood management strategy, i.e. the compensation level from the government and the insurance companies.

2.2 SIMULATIONS

This section describes the settings for the simulations, and a description of the financial indicators that are being examined. The indicators from the simulations are:

- **Governmental load**: Compensation from government (in addition to subsidies and contribution to re-insurance fund in Scenario 3).
- **Balance for the insurance companies**: Income in the form of premiums for flood insurance, subtracted by the compensation paid to property owners.
- **Balance for entire pilot basin**: Compensation from government in addition to compensation from insurance companies subtracted by property damages and premiums. The individual balances are aggregated for the entire pilot basin (all municipalities).
- **Balance for individual property owners**: Compensation from government in addition to compensation from insurance companies subtracted by property damages and premiums.
- **Balance per municipality**: Compensation from government in addition to compensation from insurance companies subtracted by property damages and premiums. The individual balances are aggregated per municipality.

In this part, only the results concerning the entire basin, the insurance companies and the central government are presented. Full simulation results are provided in Appendix 4.

The results of the simulations of the different flood management strategies are described in terms of financial consequences. For readability, the results are aggregated according to the following distribution of outcomes.

Number of outcomes
8818
431
266
345
140
Total 10000

Table 2

This means that the outcomes are collected in groups in descending order by the magnitude of losses. Thereafter, a weighted mean of the losses is calculated. This will be further explained in section 2.2.2.1 below. The total non-aggregated material is provided in Appendix 4.

2.2.1 Policy Scenario 1: Modified Current Scenario

This scenario is a continuation of the current policy strategy in Hungary, where the government has the main economical responsibility. The assumptions for this scenario are the following:

- The government compensates 60 per cent of property damages.
- 30 per cent of the households have private (bundled) property insurances (in which 2 per cent of the total premium accounts for flood insurance).
- Holders of private (bundled) insurance are compensated by 80 per cent by the insurance companies.
- The insurance premium is not risk-based. It is based on the property value (2 per cent of the property value per year).

2.2.1.1 Governmental Load

The costs for the government equal zero in most 10-year periods (in over 88% of the periods). No flood failures occurred during these decades.

Probability	Weighted loss
0,8818	0
0,0431	-9 372 425
0,0266	-122 222 481
0,0345	-227 255 130
0,0140	-794 509 286

Table 3

However, out of 10 000 simulations, 431 times the costs were greater than zero, but less than 30 million HUF. In 266 cases the costs were between 100 and 150 million HUF. In 345 cases the costs were between 200 and 450 million HUF, were the absolute majority of the outcomes approximated 210-230 million HUF. In 140 cases, the costs were between 800 and 1000 million HUF. See Appendix 4. The right column in Table 3 denotes the weighted costs divided by the number of occurrences within each interval, i.e.,

$$\sum_{i \in I_j} p_i c_i \Big/ \sum_{i \in I_j} p_i \ ,$$

where p_i is the number of occurrences of the cost c_i, and I_j, j=1,…,5, are the respective index sets with 8818, 431, 266, 345 and 140 elements.

2.2.1.2 Balance for Insurance Companies

In the balance for the insurance companies, only premium incomes from the pilot basin are considered. Note that only 30 per cent of the property owners in this region have property insurances as compared to 60 per cent in Hungary in total.

Probability	Weighted loss
0,8818	2 276 800
0,0431	-3 936 425
0,0266	-54 470 117
0,0345	-96 047 548
0,0140	-313 335 200

Table 4

The simulations show that the insurance companies make a small profit in about 88% of the decades. This is because they receive flood premiums (2 per cent of the bundled property insurance premium). In decades with minor flood failures the balance is slightly negative; premiums are not sufficient to cover for compensations. In extreme decades the shortage is even larger, in 231 time-periods the deficit is greater than 100 million HUF. In the 140 decades with most failures, the deficit amounts to over 300 million HUF.

2.2.1.3 Balance for Entire Pilot Basin

The results for the individuals vary considerably; mostly depending on the location of the property. Below the balance for the property owners aggregated over the entire pilot basin is shown.

Probability	Weighted loss
0,8818	-2 276 800
0,0431	-17 932 566
0,0266	-230 715 672
0,0345	-434 214 423
0,0140	-1 540 519 800

Table 5

In most decades the property owner pays premiums without retrieving any compensation, since no flood failure occurs. When a failure occurs, the property owner is compensated by the government by 60 per cent of damages, and is also compensated by the insurance company by 80 per cent of the damages. Because of this double compensation, some property owners gain economically if there is a flood failure. Since the premiums are based on the property value only, the risk of the location is not considered. This means that property owners with insurance in low-risk locations subsidise the premiums for those living in high-risk locations.

2.2.1.4 Summary Scenario 1

1. The governmental load is extensive in this scenario, compensations to individual property owners are high, in extreme occasions up to 1000 millions HUF.
2. Insurance companies in the pilot basin become insolvent when there is a flood failure. As only 30 per cent of the property owners are insured, the risk reserve is insufficient.
3. Property owners with insurance perform very well. They are double compensated; i.e. they are (highly) compensated by the government as well as by the insurance companies. The premiums are not risk based, why a person in a high-risk area pays a subsidised premium. Some individuals in high-risk areas can gain economically from floods.
4. The pilot basin balance is negative in all decades, since costs for premiums are paid. The costs in 140 cases were more than 1 500 million HUF.

2.2.2 Policy Scenario 2: Private Based Insurances

In this scenario, the responsibility is partly shifted from the government to the individual property owner. This is done by lowering the compensation from the government as well as the level of compensation from the subsidised property insurance (called *insurance 1*). Furthermore, an additional risk-based premium insurance (*insurance 2*) is introduced. The assumptions are the following:

- The government compensates 30 per cent of property damages.
- 30 per cent of the households have a bundled insurance, in which 2 per cent of the total premium accounts for flood insurance. This is referred to as insurance 1.
- Holders of insurance 1 are compensated by 40 per cent by the insurance companies.
- The premium of insurance 1 is based on the property value (1 per cent of the property value per year).
- Holders of risk-based insurance 2 are compensated by 100 per cent.
- The premium of insurance 2 is risk-based. It is calculated from the expected damage per municipality, divided by the number of properties in the municipality.

2.2.2.1 Governmental Load

As in the previous scenario, no compensation is paid to the property owners 88% of the decades. In 431 decades the losses were around 4 million HUF. In 266 decades there compensations were about 61 million HUF, etc. The largest load for a decade was 514 millions HUF, which, needless to say, is a considerably smaller load than in Scenario 1.

Probability	Weighted loss
0,8818	0
0,0431	-4 686 212
0,0266	-61 111 241
0,0345	-113 627 565
0,0140	-397 254 643

Table 6

2.2.2.2 Balance for Insurance Companies

The insurance companies receive premiums from two different types of insurances; with subsidised premiums (30 per cent uptake rate in the pilot basin) and with risk-based premiums (5 per cent uptake rate), respectively.

Probability	Weighted loss
0,8818	2 469 598
0,0431	-4 074 660
0,0266	-31 356 868
0,0345	-57 104 532
0,0140	-212 081 938

Table 7

The balance for the insurance companies is calculated from the income in form of premiums, both subsidised and risk-based, subtracted by expenditures in form of compensation. The resulting balance is positive in most decades. In the majority of simulations the balance is about 2.5 millions HUF. The insurance companies manage to stay solvent even for minor flood failures; this can be contributed to the risk-based insurance. When flood failures occur, the insurance companies pay less compensation than in Scenario 1. The reason for this is the low compensation level for the subsidised insurance 1, in combination with the low uptake rate for the risk-based insurance 2. The 140 most severe losses exceeded 200 millions HUF.

2.2.2.3 Balance for Entire Pilot Basin

A property owner, who has both subsidised insurance 1 and risk-based insurance 2, pays large premiums if the property is located in a high-risk area. Premiums for the region amount to almost 2.5 million HUF per decade. When floods occur there is compensation from insurance companies as well as from the government. However, the worst-case losses for the basin are severe.

Probability	Weighted loss
0,8818	-2 469 598
0,0431	-22 480 543
0,0266	-314 940 162
0,0345	-586 785 004
0,0140	-2 039 027 705

Table 8

2.2.2.4 Summary Scenario 2

1. The governmental load is substantially smaller than in Scenario 1. The largest loss is 514 million HUF. The reason for this is that the compensation level is considerably lower.
2. The pilot basin balance shows a more negative result, since risk-based premiums are expensive for the property owner.
3. Insurance companies are showing a more balanced result than in Scenario 1. The incomes are a bit lower and the expenditures are smaller. The major shortage is 272 million HUF.
4. Since only 5% of the property owners are assumed to have risk based insurance, most of them are worse off than in Scenario 1,. Risk-based premiums are very expensive in two of the municipalities. However, when floods strike highly insured households, they receive high compensation. This is because risk-based insurance compensates to 100 per cent in addition to compensation from government and insurance 1. On the other hand, over the entire basin, the effects can be severe with a reasonably large probability of losses over 2 billions HUF.

2.2.3 Policy Scenario 3: Mandatory Fee to Catastrophe Fund

In this scenario, the government compensates flood failure victims from a catastrophe fund. However, it is mandatory for the property owners to pay a fee to that fund. The compensation for losses is 60 per cent. The fee is not risk-based and cross-subsidised in two ways: (i) property owners in high-risk locations are subsidised by property owners in low-risk locations (MUN 01), and (ii) low-income households are subsidised by the government who pays the fees (IIASA 99). The relatively low compensation is intended to stimulate property owners to take own mitigation precautions. If the catastrophe fund

runs out of money, the government reimburses the fund. The assumptions are the following:

- The insurance companies are substituted by a governmentally controlled catastrophe fund.
- A mandatory subsidised fee is introduced.
- The yearly premium for the mandatory insurance is 1.5 per cent of property value.
- The property owners receive 60% compensation.
- The government subsidises insurance premiums (fees) for low-income households. 60 per cent of the property owners in the pilot basin are considered to be low-income households.
- No description of the balance for the insurance companies is included, since insurers are re-insured by the fund.

2.2.3.1 Governmental Load

The governmental load in Scenario 3 consists of the money that is transferred from the government to the fund when the balance of the fund is negative in addition to the premium subsidies for the low-income households. For low-income households, the government subsidises the premiums.

The load of the government is in most cases 2.2 million HUF. This is the mandatory fee from the non-subsidised households (40% of the property owners) in the pilot basin. When the re-insurance fund is unable to cover the claims, the government reimburses these deficits. It occurs in 1182 of 10 000 simulations. However, when this occurs, the magnitude of the loss is at 751 occasions more than 100 millions HUF. In the 140 most extreme decades, the load ranged from -790 million HUF to over -1 billion HUF.

Probability	Weighted loss
0,8818	2 214 540
0,0431	-7 157 885
0,0266	-120 007 941
0,0345	-225 040 590
0,0140	-792 294 746

Table 9

2.2.3.2 Balance for Entire Pilot Basin

In most years, the loss for the basin is just over 2 million HUF. However, the balance for the basin can be severe, with a maximal loss of 2.4 billion HUF.

Probability	Weighted loss
0,8818	-2 214 540
0,0431	-24 083 531
0,0266	-287 400 329
0,0345	-532 476 511
0,0140	-1 856 069 540

Table 10

Note that the balance never becomes positive. This is due to the low compensation level (60 per cent).

2.2.3.3 Summary Scenario 3

1. The balance for the catastrophe fund is rather positive during most decades.
2. The costs for the government are higher than in the other scenarios, due to the cost for contribution to the fund, and aid to the low-income households.
3. The insurance companies suffer no losses whatsoever. Neither, they gain anything in this scenario.
4. The municipalities show a negative balance. The flood compensation is low. Furthermore, in the scenario there is no possibility for the individuals to buy extra insurance.

3. DECISION ANALYSIS OF THE SCENARIOS

Above, we have focused primarily on some quite general options for designing a public-private insurance and re-insurance system for Hungary. As has been noted, this is a multi-criteria and multi-stakeholder problem. This section demonstrates a methodology for further investigating the scenarios from a decision analytical viewpoint.

3.1 The EDM Method

This section is a summary of the description of EDM in Appendix 5. The method used for evaluating the flood risk management policy decision problem in the Upper Tisza Basin (UTB) is based on the Delta method (Danielson 98). It has been further developed and extended to handle a model in which several stakeholders' outcomes can be handled on a per consequence basis. Thus, it is a multi-criteria extension to the basic probabilistic method. Further, the use of multi-level trees in this context, previously only a theoretical possibility, has now been field-tested.

In general, the EDM process is carried out in a number of steps. The first step is a bit special, since there is much information to collect. The initial information is gathered from different sources. Then it is formulated in statements and entered into the

computer tool. Following that, an iterative process commences, where step by step the decision-makers gain further insights. During this process, the decision-makers receive help in realizing which information is missing, is too vague, or is too precise. They might also change the problem structure by adding or removing consequences or even entire alternatives, as more information becomes available.

In some cases, the first information collection phase can be a very long and tedious step. Sometimes, it might take man-months. In other cases, it might only require a few half-day discussions with experts. It is impossible to describe any typical case because the situations are too diverse. In the Upper Tisza Basin case, much work, ranging from interviews to simulation, was required.

After the data collection phase, a modeling task commences where the decision-maker structures and orders the information. Given the set of stakeholders, a smaller number of reasonable courses of action and identification of relevant consequences are compiled. In the UTB case, simulation results were clustered into meaningful sets. There is no requirement for the alternatives to have the same number of consequences. However, within any given alternative, it is required that the consequences are exclusive and exhaustive, i.e. whatever the result, it should be covered by the description of exactly one consequence. This is unproblematic, since a residual consequence can be added to take care of unspecified events.

The probability and value statements plus the weights are represented by interval constraints and core intervals described later. Intervals are a natural form in which to express such imprecise statements. It is not required that the consequence sets are determined from the outset. A new consequence may be added at a later stage, thus facilitating an incremental style of working.

3.1.1 Decision Frames

In EDM, a decision problem is represented by a *decision frame*. The idea with such a frame is to collect all information necessary for the model in one structure. This structure is then filled in with user statements. All the probability statements in a decision problem share a common structure because they are all made relative to the same decision frame. They are translated and collected together in a *probability base*. For value statements, the same is done in a *value base*. Finally, stakeholder weights are also supplied.

In practice, a model of the situation is created with stakeholders, relevant courses of action, and their consequences when specific events occur. A decision frame represents the model. The courses of action are called alternatives in the user model, and they are represented by consequence sets in the decision frame. Following the establishment of a decision frame in the tool, the probabilities of the events and the values of the consequences are subsequently filled in. A part of the user multi-level tree for UTB is shown in figure 3.1. For the first scenario, the three most likely outcomes are shown with their probability and value ranges. The last level contains the local weights of the stakeholders, as described below.

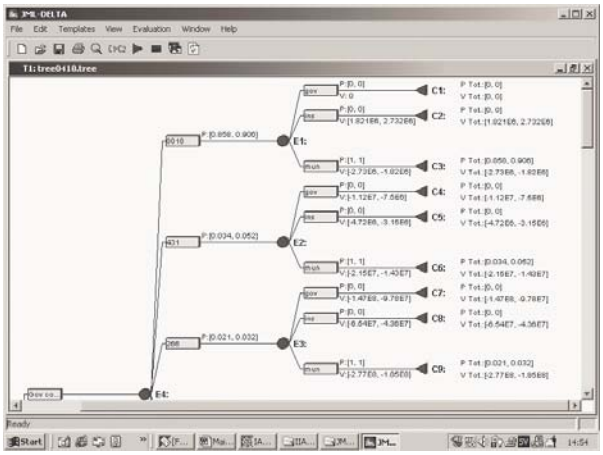

Figure 3.1: A multi-level tree for UTB

A decision frame must capture the structure of the tree internally in the tool once transformed into one-level form. A one-level tree consists primarily of sets of consequences. Then, there are statements of probability and value collected in structures called constraint sets and cores.

A collection of interval constraints concerning the same set of variables is called a *constraint set*. For such a system to be meaningful, there must exist some vector of variable assignments that simultaneously satisfies each inequality in the system. In other words, a consistent constraint set is a set where the constraints are at least not contradictory.

The *orthogonal hull* is a concept that in each dimension signals which parts are definitely incompatible with the constraint set. The orthogonal hull can be pictured as the result of wrapping the smallest orthogonal hyper-cube around the constraint set.

Constraints and core intervals have different roles in specifying a decision situation. The constraints represent “negative” information, which vectors are not part of the solution sets. The contents of constraints specify which ranges are infeasible by excluding them from the solutions. This is in contrast to core intervals, which represent “positive” information in the sense that the decision maker enters information about sub-intervals that are felt to be the most central ones and that no further discrimination is possible within those ranges.

As for constraint sets, the core might not be meaningful in the sense that it may contain no possible variable assignments able to satisfy all the inequalities. This is quite similar to the concept of consistency for constraint sets, but for core intervals, the requirement is slightly different. It is required that the focal point is contained within the core.

Together, constraint sets and cores delimit the shape of the belief in the numerical values for the variables, see figure 3.2.

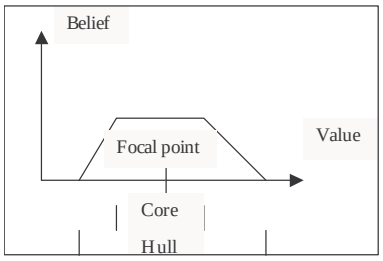

Figure 3.2: The hull, core and focal point for a variable

3.1.2 Evaluations

Which value does a particular decision have? The ultimate comparing rule of an evaluation in EDM as well as in many other methods is the expected value (EV), sometimes instantiated as the expected utility or the expected monetary value. For *s* stakeholders, this leads to the expression

$$EV(A_i) = w_1 (p_{1i_1} v_{1i_1} + \ldots + p_{1i_n} v_{1i_n}) + \ldots + w_S (p_{si_1} v_{si_1} + \ldots + p_{si_n} v_{si_n}),$$

where w_i, i=1,...,s, is the importance weight of stakeholder i.

Fortunately, in the UTB case, the decision trees are symmetrical with respect to the stakeholders, i.e. the trees, the alternatives, the consequences, and thus the probabilities coincide. This leaves us with differing values and weights.

When a rule for calculating the EV for decision frames containing interval statements is established, the next question is how to compare the courses of action using this rule. It is not a trivial task, since usually the possible EVs of several alternatives overlap. The most favorable assignments of numbers to variables for each alternative usually render that alternative the preferred one. The existence of more than one reasonable alternative means that for different consistent assignments of numbers to the probability and value variables, different courses of action are preferable. When this occurs, how is it possible to find out which alternative is to prefer?

Let $\delta_{12} = EV(A_1) - EV(A_2)$ be the differences in expected value between the alternatives. If there are more than two alternatives, pairwise comparisons are carried out between all of them. It makes sense to evaluate the *relative strength* of A_1 compared to A_2 in addition to the strengths themselves, since such strength values would be compared to some other strengths anyway in order to rank the alternatives. The relative strength between the two alternatives A_1 and A_2 are calculated using the formula

$$mid(\delta_{12}) = [max(\delta_{12}) + min(\delta_{12})]/2 = [max(\delta_{12}) - max(\delta_{21})]/2$$

3.1.3 Cutting the Hull

The *hull cut* is a generalized sensitivity analysis to be carried out in a large number of dimensions. In non-trivial decision situations, when a decision frame contains numerically imprecise information, the different principles suggested above are often too weak to yield a conclusive result by themselves. Only studying the differences in the

expected value for the complete bases often gives too little information about the mutual strengths of the alternatives.

A natural way to continue is to consider values near the boundaries of the constraint intervals as being less reliable than the core due to the former being deliberately imprecise. If dominance is evaluated on a sequence of ever-smaller sub-bases, a good appreciation of the strength's dependency on boundary values can be obtained. This is taken into account by cutting off the dominated regions indirectly using the hull cut operation. This is denoted *cutting* the bases, and the amount of cutting is indicated as a percentage β, which can range from 0% to 100%. For a 100% cut, if no core is specified, the bases are transformed into single points, and the evaluation becomes the calculation of the ordinary expected value. It is possible to regard the hull cut as an automated kind of sensitivity analysis. Since the belief in peripheral values is somewhat less, the interpretation of the cut is to zoom in on more believable values that are more centrally located.

In Figure 3.3, the evaluation of the three UTB scenarios is shown as three pair wise comparisons between the alternatives respectively. The x-axis shows the cut in percent ranging from 0 to 100. The y-axis is the expected value difference δ_{ij} for the pairs. The cone (which need not be linear if comparative statements are involved) consists of three lines. For comparing alternatives A_1 and A_2, the upper line is $\max(\delta_{12})$, the middle is $\mathrm{mid}(\delta_{12})$, and the lower is $\min(\delta_{12})$. Thus, one can see from which cut level an alternative dominates weakly, markedly, and strongly. As the cut progresses, one of the alternatives eventually dominates strongly. The cut level necessary for that to occur shows the separability between the expected values.

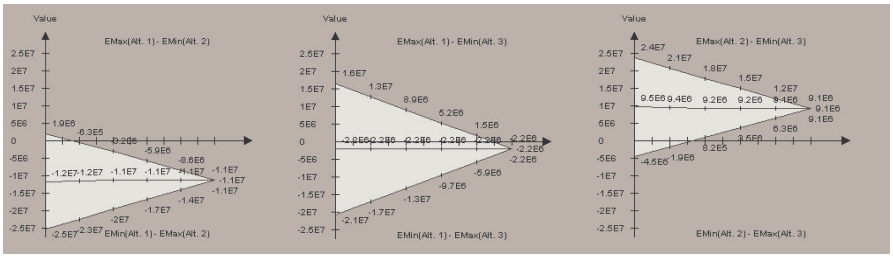

Figure 3.3: Evaluation of the UTB alternatives

The selection procedure then continues with:

(i) Remove all strongly dominated consequence sets

(ii) If more than one consequence set remains

(ii a) Cut the frame until only one consequence set remains

(ii b) Remove the markedly dominated consequence sets

(ii c) A combination of (ii a) and (ii b)

(iii) If only one consequence set remains

(iii a) Uncut the frame until other consequence sets appear

(iii b) Study the markedly dominated consequence sets

(iii c) A combination of (iii a) and (iii b)

Before a new iteration starts, alternatives found to be undesirable or obviously inferior by other information could be removed from the decision process. Likewise, a new alternative can be added, should the information gathered indicate the need for it. Consequences in an alternative can be added or removed as necessary to reflect changes in the model. Often a number of cycles are necessary to produce an interesting and reliable result.

3.2 ANALYSIS OF THE POLICY OPTIONS

Taking the simulation results into account the scenarios are analysed with the decision theoretical tool described in Section 3.1. This analysis incorporates the various costs, criteria and probabilities involved. For the evaluation of the options, the aggregated data in the tables 2-10 have been used.[1]

3.2.1 Modeling Impreciseness in Data

Of great importance here is that the frequency of floods and levee failures used in the described simulations are based on historical data. That is, for instance, they do not reflect the flood increase during recent years. For a number of years, the flood peaks have constantly increased. This may be a result of the change in the land use, for instance forest cutting, urbanization, asphalting and other changes of land use, or it could be a result of global climate changes (CLC 01). Anyway, adequate and precise information is missing to a large extent in the kinds of simulation models described above. Therefore, in the analyses below, ranges of values have been used instead of the values from the simulations. The ranges are 40% intervals centred around the table values as mid-points. Needless to say, this is an arbitrary estimate, but the setting could easily be changed.

3.2.1.1 Probability Estimates

Table 11 shows the used values for the probabilities. These are based on the corresponding values of table 2. In the table, the left value is the minimum value for the probability, and the right value is the maximum value. It should be noted that the values are adjusted such that all values of the intervals are feasible modulo the laws of probability, i.e., there must exist some vector of variable assignments that simultaneously satisfies each statement in the system.

[1] The same principles could have been applied to the non-aggregated data in Appendix 5, but the result would basically be the same.

Min probability	Max probability
0,858	0,906
0,034	0,052
0,021	0,032
0,028	0,041
0,011	0,017

Table 11

3.2.1.2 Cost Estimates

Table 12 shows the interval costs. These are based on the values of Tables 2-10 above. Also here, the left value under each category is the minimum value (80% of the simulated value) for the outcome, and the right value is the maximum value (120% of the simulated value) for the outcome.

Government			Insurers			Pilot basin	
Scenario 1							
0	0		1821440	2732160		-1821440	-2732160
-7497940	-11246910		-3149140	-4723710		-14346053	-21519079
-97777985	-146666977		-43576094	-65364141		-184572538	-276858807
-181804104	-272706157		-76838038	-115257057		-347371539	-521057308
-635607429	-953411143		-250668160	-376002240		-1232415840	-1848623760
Scenario 2							
0	0		1975678	2963518		-1975678	-2963518
-3748970	-5623455		-3259728	-4889591		-17984435	-26976652
-48888992	-73333489		-25085495	-37628242		-251952130	-377928194
-90902052	-136353078		-45683626	-68525439		-469428003	-704142005
-317803714	-476705571		-169665550	-254498325		-1631222164	-2446833246
Scenario 3							
1771632	2657448		0	0		-1771632	-2657448
-5726308	-8589462		0	0		-19266825	-28900237
-96006353	-144009529		0	0		-229920264	-344880395
-180032472	-270048709		0	0		-425981209	-638971813
-633835797	-950753695		0	0		-1484855632	-2227283448

Table 12

3.2.2 Constructing the Decision Tree

The decision tree is constructed from the three policy scenarios, which are considered as alternatives in the tree. Each of these alternatives has the same set of probability nodes, i.e., the five outcomes with the respective probabilities from Table 11. The final outcomes of the five nodes are divided into the three categories: Government, Insurance industry, and Pilot basin. Figure 3.4 shows a sub tree for Scenario 1. For completeness, Appendix 6 shows the entire tree including all scenarios.

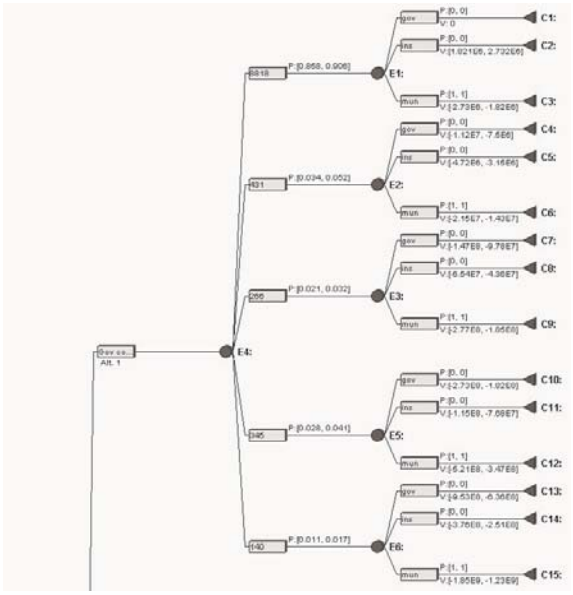

Figure 3.4

The values are mechanically entered into the tool, directly from the simulations. As was explained in Section 3.1, the weights of the stakeholders are modelled at the last level of the tree. The weights sum up to 1 for each of the probability nodes at the next-to-last level. As will be demonstrated in the following sections, the effects of manipulating the weights can then be easily analysed.

3.2.3 Analysing the Scenarios

The following analyses show the result of various evaluations of the decision situation. The following different assumptions have been tested:

- All stakeholders are equally weighted. This shows that the choice is solely a matter of ranking the stakeholders' relative importance.
- Each of the stakeholders is assigned the weight 1. This clearly shows different stakeholder preferences among scenarios.
- The government is considered to be more important than the municipalities.
- The municipalities are considered to be more important than the government.

The perspective of the insurance companies is not taken into account to a large extent in the analysis, even if this easily can be done. It was clear from the interviews (Appendix 2) that a situation where these are considered of most importance would not be publicly acceptable.

3.2.3.1 Equal Weights

It can be seen from Figure 3.5 that all scenarios are equal when the stakeholders receive the same weight, i.e., when all stakeholders are given the weight 1/3. An observation is therefore that to determine the preferred scenario, given the underlying data set, the choice of scenario is obviously a matter of determining the rank between the stakeholders.

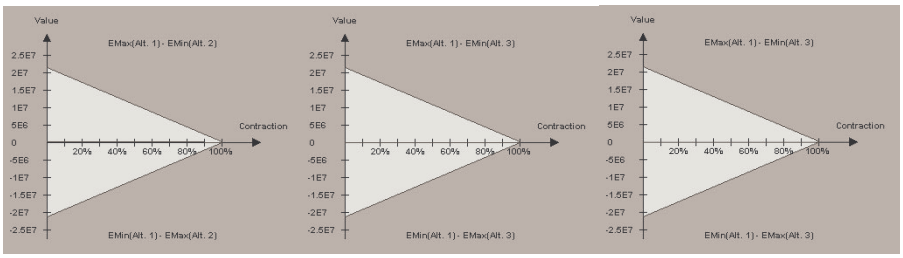

Figure 3.5 The stakeholders' weights are equal

3.2.3.2 Each Stakeholder Dominates

The figures 3.6 to 3.8 below show the results of the situations, when each respective stakeholder has the weight 1.

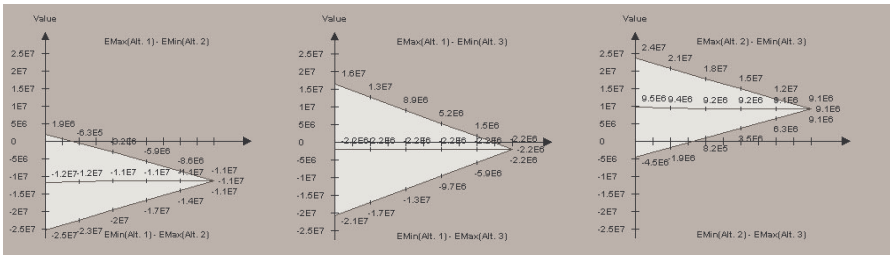

Figure 3.6 The weight of the government is 1

It can be seen from Figure 3.6 that, from the governmental perspective, Scenario 2 is considerably better than the others. Scenario 3 is slightly better than Scenario 1.

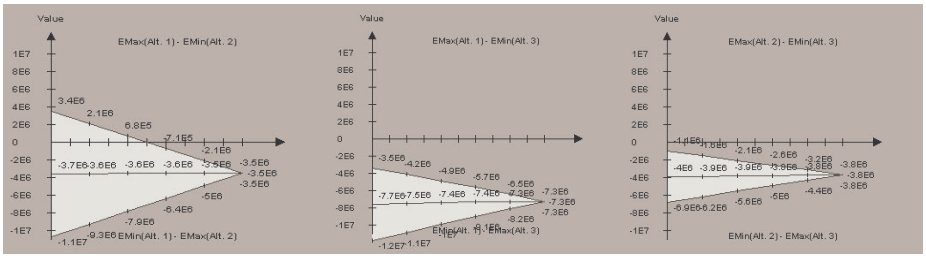

Figure 3.7 The weight of the insurance companies is 1

Figure 3.7 shows that, from the insurers perspective, Scenario 3 is considerably better than the others. Scenario 2 is clearly better than Scenario 1.

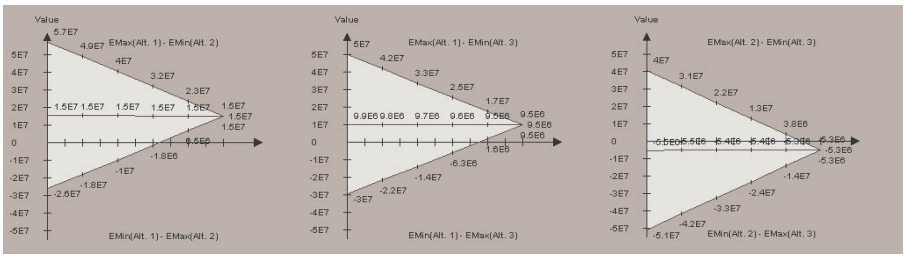

Figure 3.8 The weight of the municipalities is 1

Figure 3.8 shows that, from the perspective of the municipalities, Scenario 1 is better than the others. Scenario 3 is slightly better than Scenario 2.

3.2.3.3 Ranking the Stakeholders

Figure 3.9 shows the analysis when the weight of the government is greater than the weight of the municipalities. Both these weights are greater than the weight of the insurance companies. It can be seen from the figure that Scenario 2 is the most preferred, followed by Scenario 1.

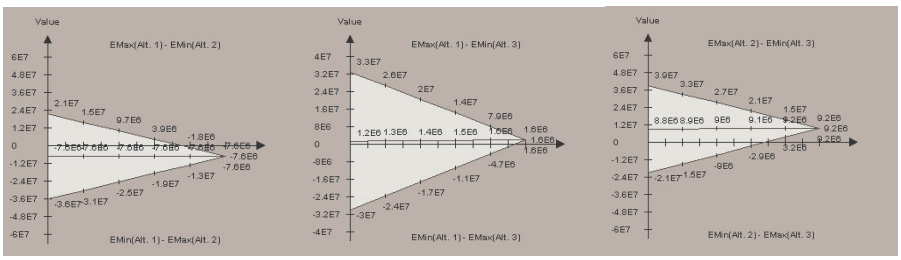

Figure 3.9 Weight of government greater than municipalities

Figure 3.10 shows the analysis when the weight of the municipalities is greater than the weight of the government. As in the previous analysis, both these weights are greater than the weight of the insurance companies. It can be seen from the figure that Scenario 1 clearly is the most preferred, followed by Scenario 3.

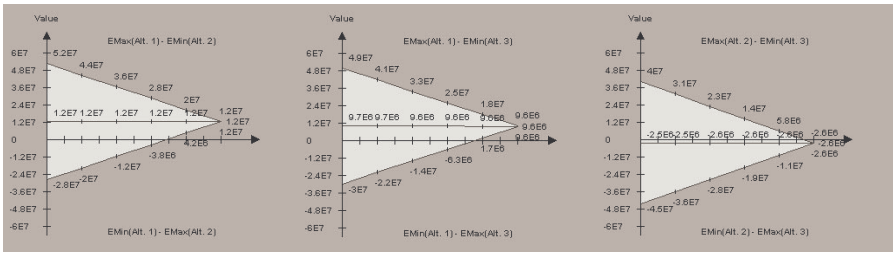

Figure 3.10 Weight of municipalities greater than government

3.2.3.4 Conclusions

The conclusions of these analyses, when only financial losses are taken into account, are the following:

- The choice is a matter of ranking the stakeholders' relative importance.
- From a governmental perspective, Scenario 2 is preferred.
- From the perspective of the insurance companies, Scenario 3 is preferred.
- From the perspective of the municipalities, Scenario 1 is preferred.
- When the government is considered to be more important than the municipalities, Scenario 2 is the most preferred option.
- When the municipalities are considered to be of more importance than the government, Scenario 1 is the most preferred option.

4. INTERVIEW RESULTS

The seven semi-structured interviews were based on an interview protocol (Appendix 1), and the respondents did receive this in advance. The protocol served as a base for the interviews and we also used a probing technique, whenever it was necessary in order to get out more information from the respondents. Each interview lasted between 2 and 3 hours. The participants in the study where not randomly chosen. Instead the selection aimed at securing a broad spectrum of stakeholders.

Strikingly, all local interviewees agreed that people should be able to stay in high-risk areas, and there seems to be more agreement regarding the goals and assumptions than means to achieve these goals. Various reasons are mentioned, e.g., it is more cost-effective than to move people. Furthermore, poor people cannot survive in more expensive areas and most of them have a low standard of education. In the Upper Tisza basin, people can survive on limited resources, e.g., there is no monthly cost for central heating, a cost that is mandatory for apartments in the cities. From the low income

perspective, people can have reasonable lives in the upper Tisza basin, which would not be possible in the cities.

One of the locals said that, “otherwise the whole country should pay for their moving and this would probably be much more expensive”. A local also stressed the fact that if it would be possible for people to stay in a catastrophe-hit region, the system must take into account the indirect losses to the economy and jobs, not only the reconstruction of the dwellings. For example, in the recent Bereg case, when losses to agriculture and other businesses have not been compensated, it is very likely that people will not be able to maintain and operate their beautiful new houses – e.g., they will turn off the gas heating and heat with wood again, etc.

Another local, however, said that there are areas, which must be given up for economic reasons. He also stated that there are limits to economic irrationality; for example, in an extreme case we are protecting 5 billion HUF value with a 30 billion HUF investment.

Others also think that maybe this area cannot maintain all these people, but most agree that *the issue of regional development should be separated (at least politically) from the catastrophe management and compensation issue.*

Assumption 1: All locals emphasize that this is a very poor and backward area. Most people cannot recover without help. If their homes are washed away, most need 100% compensation.

Assumption 2: All locals think that the government has to take responsibility for catastrophes occurring as a result of failure in the primary defence lines. This is because the state has full responsibility in maintaining these lines. Some think that this responsibility should be 100%.

Assumption 3: Mitigation is more cost-effective than loss sharing. The flood risk can and should be decreased (The so called “New Vasarhely iterv” which is currently planned, will reduce the risk significantly. Its estimated cost would amount about less that 100 billion HUF. Implementing this plan is certainly more cost-effective that paying insurance premiums).

Tools: For the above reasons, tools of solidarity are much more emphasized than market-based elements.

All interviewees agree that the recent system has problem, in particular, its unpredictable nature disturbs people. For example, an official of the national disaster management authority said that after the 2001 flood, the government compensated all property owners, even the households who had private flood insurance. When floods happened earlier (1999 and 2000), the governmental compensation-procedure looked different, because the insurance compensation was then deducted from what was compensated by the government. However, the last flood was considered to be the responsibility of the government, as it was a primary levee that burst (earlier this was not the case). Furthermore, political considerations were made – if the governmental compensation was reduced this time, nobody would buy private flood insurance in the

future. Furthermore, some people criticize the fact that people can make money from a catastrophe.

An officer of the regional water management authority gave an example on the latter and said that it is not desirable that people get more than 100% compensation in total. He added that this is a problem with Scenario 1 – because those who have insurance can receive more than 100%. In an extreme case, they can damage their houses – as it really happened in 2001.

Insurance is preferred by locals in the Scenario 3 *non-profit, cross-subsidised form* (which is regarded as a "government insurance" or a catastrophe tax). The idea of a catastrophe fund (similar to the concept of national pool, proposed by (Mitchell 01)), which cannot be used for other purposes, is also supported by most interviewees. (Note that there was such a fund earlier, but the government wanted "free hands" to use it. Therefore, all separated funds were merged in the budget. Separate funds are in contradiction with current centralizing tendencies).

Thus, locals mainly support cross-subsidised premiums, in contrast to the representative of the insurance industry who strongly supports risk-based premiums. However, some would add risk-based premiums for property owners who want to receive more compensation (e.g., the more affluent), or those having summer houses, etc. Furthermore, all locals agree that the government should pay – or at least contribute to - the premiums for people who are poor and cannot pay them by themselves. There are some who claim that the government should pay – or contribute to – the premiums for all properties which are located in high-risk regions.

Mandatory insurance seems to be supported by most locals, but the representative of the insurance industry is very much against it and thinks that it is infeasible. The representative of the Association of Hungarian Insurers, said for instance that, "Mandatory insurance raises bad memories in Hungary – people do not like things that are mandatory".

Most locals think that in case of a large disaster, compensation – paid by the government or by the catastrophe fund - should be 100%. There is one person who would decrease the compensation and add elements, which should encourage people to move. Such elements would be either interest-free loans, or risk-based insurance - a version of Scenario 2. (Note that both would work only for people who are not poor). One of the local mayors mentioned for instance that once when there was a flood, only 100 persons, (out of 1600 persons in the village, and out of 900 in active age), received the loans. The reason was that a term for the loan was that people must have been employed for at least a year. Consequently, the poor would not move anyway – they should be compensated, or their risk-based premiums should be paid.

Most locals do not have strong feelings about government reinsurance, although some are strongly against it (assumption: insurance companies can buy it on the international market). The representative of the insurance industry strongly supports it.

The information below (figures regarding the last flood in the upper Bereg basin) provides us with real data which is valuable when evaluating different insurance scenarios and different ways of compensating losses. The following data are based on the interview with an official of the national disaster management authority:

The reconstruction costs were initially estimated to 25.000 HUF/m2; this figure was finally adjusted upwards to 100.000 HUF/m2. The first estimate of the damages in the Bereg basin was that the direct losses (private households only) summed up to 5 billion HUF (direct losses). Finally, the losses were estimated to 15 billion HUF (this is what government paid, plus insurance companies paid 2,8 billion HUF. The large difference shows that government compensation may have been too generous). If buildings belonging to the central government, crop damages, damages in public infrastructure, etc. are included, the total losses sum up to 50 billion HUF.

There are, however three explanations to why the initial estimation of the losses was much lower than the final figures.

1. The damages of adobe houses are revealed in different time steps; direct damages appear immediately after the flood. Secondary damages appear when the house dries up; these can be cracks in the walls etc.
2. People who made the first estimates were not real experts. If insurance companies had made it, estimates would have been much closer to real costs. In addition, first estimates were made at the time of flood protection.
3. Reconstruction costs were much larger than what was originally expected. A consortium consisting of five construction companies was assigned the task of reconstructing the damaged houses.

The government offered following compensation alternatives after the last flood (Bereg basin):

1. The property owner receives a new house in the same location, built in a material better suited to stand future floods (concrete house, standing on a 1,5 meter high foundation – this flood was about 1 meter high). Applied for: Severely damaged houses (destroyed).
2. The house is renovated on the expense of the government. Applied for: Moderately damaged houses.
3. The property owners could choose to leave the basin and buy a house of similar standard in other municipalities (but only within the county), with less flood risk. The old damaged house was then taken down. The government paid for the new house, controls were made to assure that the new house was of similar standard etc. Applied for: Severely damaged houses (destroyed) and for moderately damaged houses.
4. The property owners were given cash economic compensation; the size of the compensation handed out was lower than renovation costs for the house (25 000 HUF/m2 for adobe house, 50 000 HUF/m2 for non-adobe house).
5. One restriction that was introduced was that people who received new houses must not sell them for 15 years.

Since 206 people bought other houses, demand and real estate prices went up. (However, the market value of the new houses is still about the half of the reconstruction costs.) People have to spend much more money for the utility fees in these large, new houses (e.g., gas central heating, closed septic tanks – technically better

solutions, but expensive). The property owners with damaged houses made the following choices (based on 98 % of the households):

- 766 house owners received a new house on the same location
- 1719 house owners had their homes renovated
- 206 house owners choose to move out
- 183 house owners received cash economical compensation

Regarding the insurance options, according to the interviewee the third scenario is preferred, but without making the fee mandatory (since this would be infeasible anyway, he said). The government should help to make insurance more attractive (for example, insurance fees could be deducted from tax). It would be desirable that more people have insurance. Currently, insurance companies pay 1% of their profit (1,5 billion HUF in total) to the government. This money is used for fire protection purposes. Such system could be extended to natural catastrophes. Catastrophe funds would be a good idea. It has existed before.

5. CONCLUSIONS

Based on earlier interviews performed in the Palad-Csecsei basin (Vari 01, 01b), this report discusses three alternative flood management policy strategies. We have investigated the effects of imposing these for the purpose of illuminating significant effects of adopting different insurance policies. The main focus has been on insurance schemes in combination with level of governmental compensation.

The analyses of the different policy strategies have been based on a model where the flood failures are simulated and where geographical, hydrological, social, and institutional data have been taken into account. The generated results are thereafter automatically transposed to decision trees under three stakeholder perspectives. Thus, taking the simulation results into account, the scenarios have been analysed with a decision theoretical tool for evaluating the various costs, criteria and probabilities involved.

However, of great importance here is that the frequency of floods and levee failures used in the described simulations are based on historical data and does not, for instance, reflect recent years increase of flood peaks. In general, these kinds of simulations, dependent of quite a large number of input data, are also very sensitive to various types of errors. Consequently, there seem to be significant reasons for discriminating between measurable and immeasurable uncertainty in this context. Since an actual and precise uncertainty measure is lacking, the simulations have been used merely as a basis for a more elaborate sensitivity analysis, considering both probabilities for floods and the estimates of losses.

We have also, to some extent, validated the approaches using stakeholder interviews. A main issue is that all local interviewees think that people should be able to stay in high-risk areas, and there seems to be more agreement regarding goals and assumptions than means to achieve these goals. This motivated the entire scenario construction approach. Furthermore, it was emphasized that tools of solidarity are much

more emphasized than market-based elements. This was the motivation in selecting the criteria for the analyses.

It should be noted that we have refrained from making any definite conclusions as to which of the three policy scenarios is the best; the preferences concerning level of solidarity/private responsibility is the single most important perspective that affect this choice.

In the next phase, a stakeholder workshop will be conducted where the stakeholders can debate and promote the different policy strategies. The stakeholder workshop will take place during September 2002. Other activities within the research project are also to scale up the results of the pilot basin to the entire county. More policy strategies are being identified and implemented, for instance re-naturalization by taking down sections of the levee upstream the villages. This step is quite controversial, since much arable land would be sacrificed to save the villages. It can also be seen as a more holistic flood management strategy; floods are really a natural part of the riverine system.

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LIST OF APPENDICES

APPENDIX 1: INTERVIEW PROTOCOL

TISZA River Interview Guide

<u>OPTIONAL INTRO:</u> The project "Flood Risk Management Policy in the Upper Tisza Basin: A System Analytical Approach" is an international research project with collaborators from Austria, Hungary, and Sweden. The project is funded by the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning. The research project is aimed at understanding the flood risk management problem in the Upper Tisza region.

The background information for this study is provided in the attached documents and the suggested decision trees for choosing insurance policies and mitigation measures are also provided.

We would like to take this opportunity to point out that all your responses will be treated in the strictest confidence. None of your responses will be directly attributed to you or to your institution.

A. PROLOGUE

1) Which flood related areas do you deal with, or responsible for?

2) How did you get to be in this position?

- *Academic/professional background*
- *Career path*

B. IMPORTANCE OF DIFFERENT AGENTS

1) What is your view on how flood insurance and mitigation policies should be handled?

- *The flood-fighting approaches should focus on "top-down" decision-making*
- *The success of future mitigation strategies will depend on putting some control in the hands of the communities.*
- *Other*

2) **Please rank the following with respect to responsibility for compensating flood losses.**

- *The Hungarian government*
- *The local/municipal governments*
- *Property owners*
- *The upstream countries*
- *Insurance companies*
- *Other*

3) **Who are the most important actors to involve when formulating and implementing insurance and mitigation policies? Rank the following with respect to importance.**

- *State actors (ministries, civil servants, executive agencies, etc.)*
- *Political actors (ministers, advisers, spokespersons of political parties)*
- *Interest representation and NGOs (environmental groups, specialised interest groups, etc.)*
- *Private sector actors (insurance companies, banks, firms, etc.)*
- *Research actors (universities, think-tanks, research organisations, etc.)*
- *Property owners*
- *Others*

4) **In general, who do you consider to be the most trustworthy for evaluating flood losses and mitigation measures? Rank the following.**

- *Experts of water management*
- *Experts of municipal governments*
- *Experts of the Hungarian government*
- *University teachers and researchers*
- *Experts of the Hungarian Academy of Sciences*
- *Experts of international intergovernmental organizations (e.g., E.U.)*
- *NGOs and environmental group experts*
- *Other*

C. INSURANCE POLICIES

C1. CONSEQUENCE STRUCTURE

1) Demonstration and discussion of a tentative decision tree with probability and value estimates.

2) In the document provided, a consequence tree is suggested. Please modify this tree according to your perception of events that may occur as consequences of major floods. You may want to consider categories like the following.

- *Roads, utilities, and public buildings are damaged*
- *Farming activities become impossible*
- *Homes, summer houses are damaged*
- *The income from farming activities becomes highly uncertain*
- *People get distressed, and often become ill*
- *Property values decrease in the endangered areas*
- *Strain on families removed from their home environments*
- *Altered social relationships*
- *Personal vulnerability and loss of control*
- *Other*

C2. VALUE ESTIMATION

1) Please estimate the consequences in the finalised tree with respect to values. If possible, try to estimate the values precisely, in intervals, or by just ordering them. You may want to consider categories like the following.

- *Distribution of costs, i.e., the risk groups pay for their costs vs. taxpayers in low-risk areas subsidise those in high-risk areas*
- *The possibility that large groups cannot afford to pay insurance premiums*
- *Separate treatment of owners of vacation homes or well-to-do businesses*
- *Less consideration of victims who have built their homes in high-risk areas without a permit*
- *Encouragement of neighbors and others to help one another*
- *Villages should be protected at all costs*
- *Insurance companies may go bankrupt after a very serious flood*

2) **Could you see any activities that reduce the severity of the consequences? If this is the case, how does it affect the decision tree? You may want to consider categories like the following.**

- *Take into consideration particularly vulnerable groups*
- *Take into consideration critical aquatic life and wildlife habitat vulnerable to damage from flooding*
- *Consideration of options to protect better the basin from contaminants during future floods*
- *Consideration of options to protect critical habitat*
- *Conversion of marginal agricultural land of the floodplain into a greenway, park, forest preserve or other use not subject to much damage*
- *Tightening zoning ordinances to restrict the kinds of development permitted in flood-prone areas.*
- *Information available to individuals, government, and non-government organizations and others gathered and made available at a central basin-wide archive or archives*
- *Possible compensation for villagers choosing to relocate*
- *Low-income persons are assisted in purchasing insurance*
- *Property owners taking more responsibility*
- *Insurance companies assisting governments in building flood defences*
- *Insurance companies might not insure poor persons living in very high risk areas*
- *Insurance companies might not insure all flood risks*
- *Insurers charge the same insurance premium for people living in low-risk areas*

C3. PROBABILITY ESTIMATION

1) **Please estimate the consequences in the finalised tree with respect to probabilities. If possible, try to estimate the values precisely or by using intervals.**

2) **Could you see any activities that change the probabilities of the consequences? If this is the case, how do they affect the tree? You may want to consider categories like the following.**

- *Developing or improving arrangements for warning of imminent flooding*
- *Developing or improving flood preparedness plans*

- *Working with governmental or local agencies to provide or improve structural protection for the area*
- *Providing technical and/or financial assistance to property owners in flood proofing or otherwise protecting their property against flooding*
- *Establish sufficient information centres prior to and during a flood event*
- *Better organised decision management at central and local governments*

D. MITIGATION MEASURES

D1. CONSEQUENCE STRUCTURE

1) **Demonstration and discussion of a tentative decision tree with probability and value estimates.**
2) **In the document provided, a consequence tree is suggested. Please modify the tree according to your perception of events that may occur as consequences of major floods. You may want to consider categories like the following.**

- *Roads, utilities, and public buildings are damaged*
- *Farming activities become impossible*
- *Homes, summer houses are damaged*
- *The income from farming activities becomes highly uncertain*
- *People get distressed, and often become ill*
- *Property values decrease in the endangered areas*
- *Pollution is spread by flood waters*
- *Drinking water reserves become polluted*
- *Tourism is decreased*
- *The ecosystem becomes unbalanced or damaged*
- *Wildlife and vegetation is damaged*
- *Strain on families removed from their home environments*
- *Altered social relationships*
- *Personal vulnerability and loss of control*
- *Other*

D2. VALUE ESTIMATION

1) Please estimate the consequences in the finalised tree with respect to values. If possible, try to estimate the values precisely, in intervals, or by just ordering them. You may want to consider categories like the following.

- *Distribution of costs, i.e., the risk groups pay for their costs vs. solidarity*: taxpayers in low-risk areas to support those in high-risk areas
- *Large groups cannot afford to pay insurance premiums*
- *Separate treatment of owners of vacation homes or well-to-do businesses*
- *Special consideration of victims who have built their homes in high-risk areas without a permit*
- *Encouragement for neighbours and others to help one another*
- *Villages should be protected at all costs*
- *Insurance companies may go bankrupt after a very serious flood*
- *Other*

2) Could you see any activities that reduce the severity of the consequences? If this is the case, how does it affect the tree? You may want to consider categories like the following.

- *Compensation for villagers choosing to relocate*
- *Low-income persons are assisted in purchasing insurance*
- *Each jurisdiction with responsibilities for evacuation within the basin establishes an evacuation protocol within its emergency operation plan*
- *Clarity and public dissemination of the protocols to help prevent confusion at the time of evacuation*
- *Plans take into consideration the specific requirements of vulnerable groups, such as nursing home residents*

D3. PROBABILITY ESTIMATION

1) Estimate the consequences in the finalised tree with respect to probabilities. If possible, try to estimate their values precisely or by in intervals.

2) Could you see any activities that change the probabilities of the consequences? If this is the case, how does it affect the tree?

Thank the respondent and Close

APPENDIX 2: INTERVIEWS

Officer of the Upper Tisza Reginal Water Authority
26 February, 2002

Goal/1: We do not want that people make a profit from a catastrophe. This means that it is not desirable that people get more than 100% compensation in total. This is a problem with Scenario 1 – because those who have insurance can receive more than 100%. In an extreme case they can damage their houses - as it really happened in 2001.

Goal/2: We want to keep people in risky areas. Otherwise the whole country would have to pay for them moving and this would probably be much more expensive. Therefore, we have to help people in high-risk areas to recover after major floods.

Goal/3: The overall risk should be decreased. Houses should be built in safer locations, with better technologies.

Considering the above goals, Scenarios 1 and 3 both have large solidarity elements, while Scenario 2 is more market oriented and it would lead to an outmigration from high-risk areas (because of less than 100% compensation and high risk-based premia). Scenario 3 is somewhat better than the other because 100% compensation can be assured, and in addition, damages do not have to be estimated and paid via two channels, insurance experts can be used to estimate the damages.

At the same time, mechanisms are needed that would make people interested in decreasing the damages. For example, building permits should not be issued for deep areas which are frequently flood by seepage from river or standing water from precipitation. Another solution: existing houses demolished and people moved to "social" apartments. This happens in Belgium.

To reach the above goals, the interviewee combined the various scenarios and proposed the following two alternative policies:

A. Modified version of Scenario 3: Mandatory insurance, with less than 100% compensation, and government support to the poor by paying the premia. To start all over in case of a large catastrophe an interest-free loan is offered. It can be used to build new houses in less risky locations with more advanced technologies.

B. Modified version of Scenario 2: Three pillars where the first two pillars add up to 100%, plus risk-based insurance can be bought as well. The poors get their premia paid by the government.

The interviewee suggested that discharge data for the 100 years and 1000 years flood should be considered with caution because they are very uncertain. Sensitivity analysis were proposed where both discharge and probability data could be manipulated.

Mayor of a city in the Bereg region
February 27, 2002

Scenario 1: It is basically OK. Protecting the people from flood is the responsibility of the government. Therefore he thinks that *100% government compensation* in case of a dyke failure is fair and it is government responsibility. In addition, people who have insurance should be compensated by the insurance companies. In previous years, insurance was deducted from the government compensation, but this sent a wrong message to those who insured their homes.

He talked about the anomalies of the property values – the market values of the old houses were about 1-2 MFt, but if the government had paid this amount, people would not have been able to rebuild their houses. New houses were built for 8-10 MFt, but if somebody would like to sell them, they would be worth 3-4 MFt. Differences are less in the city, but larger in the small settlements.

Scenario 2: Government has either to guarantee 100% compensation, or *help paying insurance* premia to the insurance companies on behalf of the inhabitants of the high-risk regions. But he cannot support the option where government pays premia for households in low-risk areas. According to him the government should pay (fully or partially) the premia for people living in high-risk regions, because government is responsible for protecting such areas. (NOTE: This makes sense only if premia are risk-based, otherwise people living in low-risk areas have to pay more than people living in high-risk areas, which is nonsense!)

He also spoke about the premia received by insurance companies. For AEGON (the largest insurer) the yearly total premia in the Bereg region is 200 MFt. In 2001 they had to pay 1,5 billion Ft for the damages which occured in Bereg. In January 2002 they started to pull out, and cancelled the flood-insurance from 12 000 contracts in the Upper and Mid-Tisza flood basins. (The other six companies operating in the region paid 1,3 billion Ft in total in 2001. Most of them are willing to offer flood-coverage, although with some restrictions, e.g., some companies do not want to cover adobe houses which have no foundations).

He concluded that mitigation is cheaper than loss sharing. The so called „New Vasarhelyi-terv" which is currently planned, will reduce the risk significantly, and its estimated cost would amount to less than 100 billion Ft. Implementing this plan is certainly more cost-effective than paying insurance premia

Scenario 3: He could support scenario 3 if Government paid premia in high-risk regions (see above), and if some of the risk was taken by the insurance companies – like in the French system, but he *does not think that government reinsurance would be necessary*, because small companies can find reinsurance at large companies.

Mayor of a village in the Szatmar area
27 February, 2002

The heavy metal pollution that occurred only weeks after the cyanide spill, does still have large impact on the tourism industry in the region. The water tourism (boating, canoeing, etc.) still visits the area, but the stays are shorter then before. Elderly people used to spend the entire summer there, but this doesn't happen any longer. The amount of fish has been affected; even tough this part of the river was not contaminated by the cyanide spill. The heavy metal spill, that did pollute this part of the river, did not kill the fish. As the fish was reduced upstream, in the Samos tributary, many anglers and fishers moved to this part of the river instead. Fish implantations were not made in this part of the river.

Scenario three seemed interesting according to the interviewee, but he identified a number of potential problems:

1. Some people can benefit from the floods, by getting new houses from the government. The system must assure that the compensation is limited so no overcompensation can happen. If a new house is built it should have a standard similar to the old one.
2. Even the 40 per cent that are not considered 'low-income household' could need subsidised premiums. He did not think that private responsibility needed to be encouraged. Households should pay according to their economical situation, but still take responsibility.

Insurance Companies

The insurer (Aegon) that pulled back recently did only have a number of contracts in the region. The other insurers (3) are still active in the region. The price of the premiums depends on the material of the house (concrete, wood, clay, etc.). The location of the building does not make any difference in the size of the premium, they are not risk-differentiating within the Tisza river basin. In general, adobe houses are three times as expensive to insure as concrete houses. Adobe houses are old-fashioned and built by clay-bricks.

Interest-free Loans

Out of 1600 persons in the village (900 in active age), only 100 received the loans, one term for the loan is to have been employed for at least one year.

Re-location

Many of the people are low-educated, which would make the re-location alternative very costly, as it would lead to unemployment. In this Upper Tisza basin, people can live and survive on very little money. There is no monthly cost for central heating for instance, a cost that is connected with apartments in the cities. From the low incomes,

people can lead reasonable lives in the upper Tisza basin, which would not be possible in the cities.

Unemployment

Neither tourism nor agriculture is enough for anybody to live on.

Tourism

The tourist-season only lasts two months a year: Some restaurant-owners try to survive the rest of the year by preparing food for schools and companies, but it is difficult. They cannot afford to renovate the their buildings.

Agriculture

The production in this area is not high, but it is not very low either. Especially the fruit production is quite reasonable. The problem is that the farmers are unable to sell their fruit and vegetables since they don't cooperate with any larger chains. The distribution-channels are still under-developed, which leads to those large amounts of fruit and vegetable rot that cannot be sold to the cities. Due to distribution problems and uncertainties regarding the price-levels for different crops, many farmers choose not to cultivate their land or to recreate the live-stocks (?).

Director of a regional Environmental NGO
February 28, 2002

Goal: People should not leave the area, but of course, there are areas which must be given up for economic reasons. There are limits to economic irrationality, for example, in an extreme case we are protecting 5 billion Ft value with a 30 billion Ft investment.

Scenario 1: The most important is to change the current system. There are a lot of uncertainties in the current system. The insurance system is problematic as well, but government compensation is even more problematic because it is completely unpredictable. Another problem is that buildings are strongly under-insured.

Scenario 2: Government has to play a role, because people cannot pay high risk-based insurance premia in the high-risk regions.

Scenario 3: Cat-fund is a good idea, but it should not be operated by a government authority. I do not prefer large government bureaucracies, rather a profit-oriented organization should operate it. Certainly these funds should not be located in a ministry.

If the insurance companies run the system, it will be more effective – private business is more profit-oriented and rational, chance of corruption is much smaller than in the government sector.

Mandatory insurance is problematic, people would not be willing to pay it. Cat-fund is a good idea, but I do not see how it could be collected. It could be collected as a tax, but I am not sure that there will be a political will for this. Another option would be to get insurance companies to collect it. For people who cannot pay premia, the government should pay them.

This would be a good business for the insurance companies, therefore their duties should be much more clearly regulated. Insurance should pay for seepage, standing water, etc. if it is related to riverine floods. And this system would be good for the government because they could get rid of the risk.

On the other hand, regulations should guarantee that houses are built with appropriate technologies, so they wouldn´t get to damaged. Regulation and control should be more stringent. Authorities can do a lot, but individuals cannot do much to decrease the losses.

This system should first be built up for private residences, but later they should be extended for community properties, and also private businesses (jobs are erased by the flood!).

Recently premia were raised severely. In the Upper Tisza they doubled. But still, it is crucial that buildings should not be under-insured. If they are under-insured, it is impossible to reconstruct the buildings from the compensation. Risk-based premia would be too high for the people, but if the govt. has to pay it, that is efficient, because they have to decide if they should pay higher premia, or protect the region.

Risk-based premia should be applied on the level of settlements, then people would move to higher points. But the reality is that people cannot leave the whole Bereg area behind.

If people cannot pay the high risk-based premia in high-risk areas, they would move, but this is not necessarily good. He would not propose to young people not to move there, because then only the old and the Roma population would stay there, because they cannot sell their houses, or if they could sell them, they would not get much out of it. The situation would get worse and worse.

However, there should – and will – be major changes. Soil is not good for agricultural production. Also, the EU accession means that less land will be used for agricultural production. Agro-land could be reduced and wetland be created. This would be good for mitigation.

150 years ago it was possible to pass a long area by canoeing on the streams, not only on the Tisza. There was a large wetland there. In the Hortobagy National Park, there are large areas which can be turned into wetlands. In these large unpopulated areas it is easier than in the Upper Tisza region where there are many small settlements near the river. When deciding about renaturalization, many factors have to be taken into consideration.

Advantages of complex land-use: not only ecological, but also economical. Intensive production 100 000 Ft/ha, complex use: 4-500 000 Ft/ha estimated income!! But changes from intensive use to complex land-use will be slow and gradual.

Representative of the Szabolcs-Szatmar-Bereg County Chamber of Agriculture
February 28, 2002

Goal: The system should make it possible to people in a catastrophe-hit region to be able to recover. If people are not able to start all over again – especially in a case of a large damage concentrated to one region - then life there will be impossible. Moreover, it is not only the dwellings that should be important, because there are indirect losses to economy and jobs, these should also get reconstructed. For example, in the recent Bereg case, where losses to agriculture and other businesses have not been compensated, it is very likely that people will not be able to maintain and operate their beautiful new houses – e.g., they will turn off the gas heating and heat with wood again, etc.

Scenario 3 preferred. Proposed change: 100% compensation – indirect losses are still a severe load on the communities. The reason for this proposal is the poor situation, the high level of unemployment, and the bad quality of land in this county. Therefore, people do not have sufficient reserves, and in case of a catastrophe they cannot recover without external help.

The cat-fund is a good solution. The organization which handles the cat-fund should work on a non-profit basis. The government should pay at least 90-95% to the insureds that are poor. Such a fund should have been created a long time ago.

What kind of premia? He does not agree with risk-based premia, he would support cross-financing. If such a catastrophe-insurance is mandatory, it is like a property-tax. For poor people this tax is waived, or paid by the government. And it should be broader than just flood, it should cover various catastrophes. But the fund covers only homes, not *summer houses (these should be insured on the private insurance market).*

Reinsurance by government: AEGON would like government reinsurance because they have problems on the international reinsurance market. He has no opinion on this issue.

Q: But should people be encouraged by the compensation to stay here and build homes over and over again?

R: If we want people to leave that should not be tied with decisions on compensation. These two issues should be kept separated. Regional development decisions should be made by the government for long-term, and it should be decided what kind of activities should be encouraged, and how many people should stay. For example, there is an increasing emphasis on multi-functional land-use, e.g., maintenance of pastures, forests, wetlands, recreation, as opposed to production by itself. The question is how many people should be involved in these activities, how should they be compensated for the

decreased production, where should the others go? And if we want that some of them leave, they should receive some funding for this. In case of floods, they should be able to receive money as compensation and move. Young people have started to move anyway.

The Socialist Party's program includes the idea of a catastrophe fund and that this concept should be developed. They are also working on a fund that should cover agricultural losses. Recently this is uninsurable loss (agricultural flood-loss).

Representative of the Association of Hungarian Insurers
March 1, 2002

Recent events: AEGON is pulling out from flood insurance in the risky area. The main reason for this is the difficulty of finding reinsurance for catastrophe risks. Other 8 companies are replacing AEGON which for the time being have no such problems (they have less contracts in the property insurance field).

Evaluation of the various solutions:

Scenario 1: If business as usual continues, other insurance companies will be likely to pull out. To prevent these, premia have to be raised significantly in high-risk areas.

Scenario 2: *Risk-based insurance* is a good idea, he would like to see it more. In high-risk areas premia could be one magnitude higher than now, the government should *pay the difference between cross-financed premia and risk-based premia for the insurers*. (This could mean in an extreme case that government pays 100% of flood insurance premia for *all people* living in high-risk areas which is financially equivalent with 100% compensation after floods).

Scenario 3: *Mandatory insurance* raises bad memories in Hungary – people do not like things that are mandatory. This kind of mandatory insurance does not exist in Europe – except for France.

Cat-fund would be a good idea, but he assumes that it will be accumulated from insurance taxes (3-4-5%), which have been proposed already three times. (The interviewee talked about insurance tax, a top-tax that is added on top of the premia.) This would not be fair because people who have already insured themselves would need to pay additional tax i.e., payments will be distributed among the insured rather than among all taxpayers. This may also make many people to cancel their insurance .

The amount of compensation paid to clients is always the reconstruction cost. If a low-standard house, an adobe house for instance, is destroyed, then it is compensated by a house of the same size but of a higher standard. This explains why the compensation is larger than the original property value of the house.

Under-insured houses are only compensated to certain per cent of it reconstruction cost. Wether a house is under-insured or not, if yes to what degree, is based on how large the coverage is, the insurance companies have records on the property values for all clients.

The cost for rebuilding of houses (from last flood of 2001) was 10 – 12 million HUF, but the market value of the new houses was only 5 – 6 million HUF.

Insurance contracts for adobe houses were cancelled from January 1st. This was said to have happened to 10 000 households. The government intervened with OTP and ordered them to offer flood insurance. The OTP wanted to keep the customers but get rid of the flood insurance.

Important info: There are about 7 million property insurance contracts in Hungary:

Administration and profit amounts cca. 30-35% of price.

Officer of the Ministry of Interior National Directorate General for Disaster Management
March 1, 2002

Figures from the last flood:

The reconstruction costs were initially estimated to 25 000 HUF/m2; this figure was finally adjusted upwards to 100 000 HUF/m2.

The first estimation of the damages in the Bereg basin was that the direct losses (private households only) summed up to 5 billion HUF (direct losses). Finally, the losses were estimated to 15 billion HUF (this is what government paid, plus insurance companies paid 2.8 billion HUF. The large difference shows that government compensation may have been too generous). If buildings belonging to the central government, crop damages, damages in public infrastructure, etc. are included, the total losses sum up to 50 billion HUF.

There are three explanations to why the initial estimation of the losses was much lower than the final figures.

4. The damages of adobe houses are revealed in different time steps; direct damages show immediately after the flood. Secondary damages show when the house dries up, these can be cracks in the walls etc.
5. People who made the first estimates were not real experts. If insurance companies had made it, estimates would have been much closer to real costs. In addition, first estimates were made at the time of flood protection).
6. Reconstruction costs were much larger than what was originally expected. A consortium consisting of five construction companies was assigned to the task of reconstructing the damaged houses. Mr The interviewee let us understand that it probably wasn't the cheapest way to rebuild the houses.

After the 2001 flood, the government compensated all property owners, even the households who had private flood insurance. When flooding happened earlier (1999, 2000) the governmental compensation-procedure looked different, the insurance compensation was then deducted from what was compensated by the government. But this last flood was considered to be the responsibility of the government, as it was a primary levee that burst (earlier this was not the case). Furthermore, political considerations were made – if the governmental compensation was reduced this time, nobody would buy private flood insurance in the future.

The government offered following compensation alternatives after the last flood (Bereg basin):

6. The property owner receives a new house in the same location, built in a material better suited to stand future floods (concrete house, standing on a 1.5 meter high foundation – this flood was about 1 meter high).

   Applied for: Severely damaged houses (destroyed).

7. The house is renovated on the expense of the government.

   Applied for: Moderately damaged houses.

8. The property owners could choose to leave the basin and buy a house of similar standard in other municipalities (but only within the county), with less flood risk. The old damaged house was then taken down. The government paid for the new house, controls were made to assure that the new house was of similar standard etc.

   Applied for: Severely damaged houses (destroyed) and for moderately damaged houses.

9. The property owners were given cash economic compensation; the size of the compensation handed out was lower than renovation costs for the house (25 000 HUF/m2 for adobe house, 50 000 HUF/m2 for non-adobe house).

People who received new houses must not sell them for 15 years.

Impacts: Since 206 people bought other houses, demand and real estate prices went up. (But the market values of the new houses are still about the half of the reconstruction costs). People have to spend much more money for the utility fees in these large, new houses (e.g., gas central heating, closed septic tanks – technically better solutions but expensive)

The property owners with damaged houses made the following choices (when 98 % of the households had made their choices):

1. 766 house owners received a new house on the same location
2. 1719 house owners had their homes renovated
3. 206 house owners choose to move out
4. 183 house owners received cash economical compensation

Opinion about the insurance options: The French system is preferred, but without making the insurance mandatory (this would be infeasible anyway). The government should help to make insurance more attractive (for example, insurance fees could be deducted from tax). It would be desirable that more people have insurances.

Currently, insurance companies pay 1% of their profit (1.5 billion HUF in total) to the government; this money is used for fire protection purposes. Such system could be extended to natural catastrophes. Cat-fund would be a good idea, as it has existed before, but the current government dismantled it.

About the author

Ari Riabacke, who was born in 1965, has both a B.Sc. and a M.Sc. in Business Administration and Economics, and, in addition, completed his Lic.Ph. in Computer Science and Systems Analysis in 2003. He has been employed as a university lecturer at Mid Sweden University since 1994. Moreover, he has been involved in a variety of development projects over a number of years and has acted as a consultant in the private sector. In 2000, he started his research within the Fibre Science and Communication Network project at Mid Sweden University. During his time as a Ph.D. student, Ari has also spent three months working at the International Institute of Applied Systems Analysis (IIASA), in Laxenburg, Austria, where the main focus was on flooding problems in the upper Tisza Region in Hungary. Furthermore, he spent three months in Brazil, at Pontifícia Universidade Católica (PUC) in Rio de Janeiro, studying contextual effects on decision making.

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