COMPUTER BASED PRESCRIPTIVE DECISION SUPPORT

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I am based on a true story.
To my wife Malin,
our children Mi and Philippa
and to Isak the proud big brother.
Abstract

The overall aim of this thesis is to study in what type of decision situations (involving risk and uncertainty) managers encounter problems and pitfalls, and to propose formalised methods for handling such situations. Traditionally, at least from an academic perspective, utility theory and the principle of maximising the expected utility has had a great influence on decision-making in such contexts. Even though this principle is often useful when evaluating a decision situation, it is not necessarily, despite what has often been claimed, the definition of rationality. And other approaches are definitely worth considering. The thesis has three main components. It develops a compilation of normative, descriptive and prescriptive theories within the area of risk taking and decision-making. Thereafter follows an empirical study examining some aspects of how managers define risk, how they handle risk, how they make risky decisions and how the organisational context affects the decision-making processes. This part contains an analysis of how managers make their choices from different risky prospects. Taking this into account, the third part brings attention to some of the problematic features of evaluation through utility theory and tries to constructively relax the demand for precise data in situations where only imprecise data are available.
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1. Introduction

Decision theory has become a multidisciplinary subject involving knowledge from a wide range of areas such as economics, sociology, statistics, philosophy, politics, mathematics, organisational theory, computer science, artificial intelligence, behavioural science, computational feasibility, among others. See for example early work by statisticians Wald (1950) and Savage (1954). Bacharach and Hurley (1991), Gärdefors and Sahlin (1988), Harper and Skyrms (1988) and McClennen (1990) provide current discussions of principles for decision-making within philosophy. Wittgenstein (1953) and Searle (1969) are at the forefront of decision-making and games. The field of economic decision theory have a long history and much of the work in the field has been done by Simon (1955, 1976), Simon and March (1958) and Lindblom (1959). For general surveys, see Bacharach and Hurley (1991) and 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, for example, Hogarth (1987), Kahneman et al. (1982), Payne et al. (1992), Sutherland (1992) and Wright and Ayton (1994). Thus, many argue that it is of great importance to have different approaches for studying risk taking (Bell et al., 1988). During the last 40 years, or so, risk has been studied from many different perspectives, see for example research focusing on capital asset theory of evaluating investments, Markowitz (1952, 1959) and Sharpe (1964), research in finance examined investors perception of risk, Cohn et al. (1975), Gooding (1975) and 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. However, the greatest amount of research on recognising risk has been done in the area of nuclear energy and other technological hazards, and leaders in this field have been Starr (1969, 1984), Slovic et al. (1976, 1978-1981, 1983), Olson (1976), Kates (1978), Keeney (1980), Keeney et al. (1984), Vlek and Stallen (1981) and Kunreuther et al. (1984).

Many of the issues discussed over the years have 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.

The distinction between the normative and the descriptive approach is a traditional classification in the literature on risky choices and decision-making. On one hand the normative theory describes how decision-makers should make choices when considering risk. We know, however, that many of
the normative rules are not sufficient, for different reasons. One such reason, for example, is that the normative rules are not able to handle all types of risky decisions, and another problem is that the decision-makers do not always act in accordance with the suggested rules. The descriptive theory, on the other hand, focuses on how people make decisions regarding risk in real settings; and it tries to come up with models that explain how real decisions are made, i.e. how we do decide. The descriptive theory tells us, for example, that decision-makers do not act in a rational manner, and that they, for instance, when confronted with real problems construct simplified models of the real situations. Nowadays, however, 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, to guide real decision-making (Bell et al., p.5).\(^1\) 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), Fishburn and LaValle (1989), Keeney (1992), Kleindorfer et al. (1993), Roy (1993), Watson and Buede (1987) and White (1975), or further reading regarding the prescriptive analyses using normative models to guide the decision-maker see, for example Brown and Vari (1992), Dempster (1985), French (1996), French and Smith (1997), French and Xie (1994) and Payne et al. (1992).

So, the effort of the prescriptive decision theory is to help decision-makers solve real decision problems and to focus on one problem at the time, not a whole class of problems, as e.g. the normative theory does (Keeney, 1992).

However, in order to develop prescriptive decision aid there are also other aspects of the decision-making process that must be taken into consideration. Namely the fact that decisions are made in organisations, with different types of structures, different types of cultures, at different levels in the hierarchies and concerning different types of problems. Are the decisions, for example, made in highly centralised organisations with low level of trust in subordinates or are they made in decentralised organisations with high level of trust in subordinates? In other words, we must examine the structure as well as the culture of the organisations since they both to a great extent influence the decision-making processes. “No decision takes place in vacuo: there is always a context” (French and Rios Insua, 2000, p.7). It is important to define the decision-making context since it affects the form of decision analysis in many ways, and the way decisions are made, see e.g., French and Liang (1993), House and Singh (1987) and Lee et al. (1999).

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1 Note that French earlier in his writing has used “normative” and “prescriptive” interchangeably: see, for example, French (1986a, 1989).
A good introduction to the ideas in organisation theory can be found in several sources. These include Mintzberg (1979) and 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 (Ungson and Braunstein, 1982) which contains a number of useful papers, and Clough (1984) who gives us a good general outlook of both the theory and the practice of organisational decision-making as well as a good summary of other theories in his book. Furthermore, some useful reading concerning the organisational structure is provided by many writers including Emery and Trist (1965), Woodward (1965), Perrow (1967), Thompson (1967), Lawrence and Lorsch (1967), Scott (1987) and Morgan (1986). The culture in organisations has been studied by among others Hofstede (1980), Handy (1993), Mintzberg and Quinn (1991) and Schein (1992). So, in order to guide the decision-makers toward better decision-making and to be able to provide prescriptive decision aids we need to study the organisation and the decision-making context where the decision-making takes place. We also need to interview people within the organisations in order to assess the way they think, the way they actually make decisions and the way they deal with risk; in order to be able to identify the way they think that the organisations expect them to act. Furthermore, in order to be able to identify the attitudes of the managers towards risk, we need to study the way they make real decisions and the way they choose from risky prospects.

Consequently, this thesis has multiple aims. The first aim is to develop a compilation of normative, descriptive and prescriptive theories within the area of risk taking and decision-making. The second aim is to carry out a study in order to examine; how managers in the Swedish forest industry define risk, how they handle risk, how they make risky decisions and how the organisational context affects the decision-making processes. And finally, it also aims to analyse how managers make their choices from different risky prospects. The overall aim is thus to study in what type of decision situations (involving risk and uncertainty) the managers encounter problems and pitfalls, and to propose formalised methods for handling such situations. With a few exceptions, mainly focusing on models that requires precise data, very little has been done in this borderland between how real decisions, based on imprecise information, are made and the formalisation of decision-making processes. 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, and how can computer-based prescriptive decision support be useful when modelling risky decisions where only vague information is available?
Sometimes, when entering a new research area where little has been done previously (as in this case), it is difficult to predict how to design the entire study. Therefore, to be able to proceed it is sometimes necessary to see the research problem from a pragmatic point of view. Most researchers have faced problems when choosing research strategies and methods. Morgan (1983, p.370) describes this as follows, “different research strategies do different things, and […] as far as their contributions and knowledge claims are concerned, we should follow Feyerabend (1975) and conclude that “anything goes”. Since little research has been done in this field and few studies have focused on managerial decision-making, this study can be viewed as a pilot study. The research method can be characterised as explorative, since the main aim of the thesis is to identify and specify problem areas, which are somewhat obscure at present.

The theoretical framework, in chapter 2 - Risk modelling, has two purposes: (1) to enable the empirical study, and (2) to introduce the audience to the presentation of the subject and the problems concerned. The twelve semi-structured interviews, presented in chapter 3 - How do managers make risky decisions?, were based on an interview protocol (see attachment 1), 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. 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 last part of the thesis, chapter 4 - Computerised risk modelling, is a product of the findings made in the empirical study in chapter 3 - How do managers make risky decisions?, and it focuses on how computer-based decision support can be useful when modelling prospects containing risk and uncertainty.
2. Risk modelling

2.1. Definition of Risk

In the *Oxford English Dictionary* we find that *risk* is defined as “Hazard, chance of, or of bad consequences, loss”. One interesting aspect is that three of the above definitions emphasise the negative consequences of action taken, such as loss. This risk definition is, however, too narrow when looking at risk from the perspective of risk taking, even if the definition in many cases fits in with the notions scientists have when talking about risk (Shapira, 1995). This has led to many studies attempting to deal with this problem and examining the role of risk in their respective fields. Moore (1983) states that risk means different things to different people, and French (1993, p.27), moreover, says that: “risk is a much overused word; indeed, it has been used in so many senses as to become virtually meaningless.” Luce and Raiffa (1957, p.13), however, 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:

- **Certainty**, where each action is known to lead invariably to a specific outcome.

- **Risk**, where each action leads to one of a set of possible specific outcomes, each outcome occurring with a known probability.

- **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. In this study we will see that most decisions are made in the realm of uncertainty.

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2.2 Normative theory

The literature on risky choice can in most cases be classified as being a part of the normative or the descriptive approach. This part of the thesis will explain how the normative theory guides decision-makers to make decisions under risk and uncertainty. It will then point out that people do not always act in accordance with the rules suggested by the normative theory, and so criticism against normative theories of decision-making under risk will be presented.

2.2.1 Normative rules for choice subject to risk

The expected value rule\(^3\) and the expected utility rule\(^4\) are the two main normative rules for choice under risk (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.\(^5\)

Let us look at two examples to illustrate the differences.

In the first example (i) we face a problem where we have to decide if we want to accept a business proposal where we can either gain $10,000 with a probability of 0.7 or lose $20,000 with a probability of 0.3. The expected value is then \((10,000 \times 0.7) + (-20,000 \times 0.3) = 1000\). However, this $1000 gain will not occur since we will either gain $10,000 or lose $20,000. If we were to repeat the decision a great number of times the outcome should be $1000 on average, but this is not the case if we do this only once. The expected value rule is therefore only an average of the two monetary values taking into account the probabilities, and it does not take into consideration the attitude of the decision-maker concerning the risk, i.e. can we afford to lose $20,000. This is an important concern since many economic decision problems are risk analysis problems in one way or another. In analysing real decision problems we must take into account the uncertainty aspects of the decision-making since nothing is absolutely certain; uncertainty is always present (French, 1988).

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\(^3\) I use the abbreviation EMV (expected monetary value) since this is the most commonly used interpretation of the expected value rule, among others by economists.

\(^4\) I use the expected utility rule and the subjective expected utility rule (SEU) interchangeable.

\(^5\) The statistical decision theory suggests that expected value is the best rule for choice under risk (Raiffa, 1968). French (1988) discuss the problem with expected value as a normative rule for choice under risk. French states that expected value is simply a weighted average sum of two consequences and that it does not consider the aspects of risk in the decision-making. He suggests the expected utility rule to be the criterion for decision-making under risk.
In the second (ii) example we then move from the expected (monetary) value rule to the \textit{principles of maximising the expected utility} and the \textit{utility function}. Von Neuman and Morgenstern (1944) proposed the expected utility rule as the optimal criterion for choice under uncertainty since it takes into account individual risk tendencies. The risk tendencies can be compared to the situation where we flip a fair coin, if you guess right you win $10 and if you guess wrong you get nothing. The expected value of the gamble is $5 and the two outcomes are of equal probability. The offer made to a person is to play this game or alternatively to receive a certain $5 (without gambling). If the person is \textit{indifferent} as to which alternative to choose, expected value $5 or the $5 payment, he is defined as \textit{risk neutral}. However, many people prefer to receive a certain $5 to taking part in such gamble, i.e., they prefer a guaranteed cash equivalent to a gamble with the same expected value, and are defined as \textit{risk averse}. Finally we have \textit{risk seeking (or risk prone)} individuals who prefer a gamble with a particular expected value to a guaranteed payment equal to the expected value.

Nevertheless, precise objective probabilities are seldom available in decision-making situations,\textsuperscript{6} so to be able to use the expected utility principle, probabilities have to be estimated.\textsuperscript{7} Such estimates can only be subjective and since most risky choices refer to future states of the world, subjective estimation of probabilities is a fundamental part of the risk taking process (Shapira, 1995). 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 explained below, the decision method is called Bayesian.\textsuperscript{8} Subjective, in this sense, means that the values reflect the decision-makers 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 (Ramsey, 1931).

It is easy to explain \textit{utility functions} using a diagram (see figure 1) and thus see that; a risk-averse person has a \textit{concave} utility function (1), a risk-seeking person has a \textit{convex} utility function (2), and, a risk-neutral person’s utility function is \textit{linear} (3) (Arrow, 1951).\textsuperscript{9} Nevertheless, it is worth noticing that

\textsuperscript{6} See for example Keeney and Raiffa (1972).
\textsuperscript{7} Bell \textit{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.”
\textsuperscript{8} Named after the eighteenth-century English clergyman Thomas Bayes.
\textsuperscript{9} See also French (1986a).
utility functions may exhibit other shapes than those described above. We must also notice that example (ii) above only describes one way of assessing the utility function and the attitude to risk, and that there are also other methods for this purpose.\textsuperscript{10}

Figure 1

Many empirical studies have suggested that an individual’s utility for money changes as the sums involved increase, i.e., the utility passes through regions of convexity and concavity, with risk proneness changing to risk aversion (see for example Tversky and Kahneman, 1972). An individual’s utility function for money and his/her risk attitude is undoubtedly related to his/her total assets. Thus in assessing a decision-makers utility, it is usual to integrate monetary outcomes into his/her final level of wealth (French and Rios Insua, 2000).

However, when several individuals are involved in a decision-making process there will be different opinions and values. Furthermore, individuals often differ in their subjective probabilities of events and their utilities of outcomes. How should these differences be solved, and what are the problems we might face when trying to do so?

2.2.2 Mathematical aggregation

Ferell (1985, pp.112) provides us with an excellent overview of mathematical aggregation as well as other aggregation methods. His example will be used when the mathematical methods of aggregation are briefly described below. These methods are, for many reasons, attractive for practical decision-making because of their relative ease of use and apparent simplicity. There are a number of advantages to gain when using mathematical aggregations to combine the judgements of the individual members of a group. The individuals do not need to meet and can be reached by mail, telephone etc. This might also lead to influences of dominant group members being avoided and factors such as status and personality not affecting the way individuals decide. The simplicity, however, according to Ferell (1985, p.112) “is, in part, only apparent because the mathematics of aggregation can produce complexities and paradoxical results in decision situations.” In table 1, for example, we can see how complex aggregations can affect decisions and cause serious problems. The decision matrix includes a group of three members. On the basis of their respective expected utility each of them prefers a different action. It seems sensible to aggregate their respective utility to reach a decision for the entire group. However, this is not the case, as we can see in the matrix, different formal methods give different results. This means that if we take the average of the probabilities and sum the individual’s utilities, as in table 2, Action A3 is preferred on the basis of the expected group utility. However, in table 1 we can see that Action A2 wins if the members decide to vote on pairs of actions or sum the ranks or their individual preferences (based on their own utilities). But, if the members, on the other hand, agree to accept the average of their probabilities as the best estimate for the group and recalculate their own utilities it will lead to person A’s opinion not changing, but B’s and C’s ranking completely changing. Finally, if they vote or sum the average result of everyone’s expected utility for each action and choose on the basis of the highest average, Action A1 would win.11
Table 1 Hypothetical Decision Matrices for Individuals

### Person A

**Action**

<table>
<thead>
<tr>
<th>State</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>0</td>
<td>.5</td>
<td>1.0</td>
<td>.3</td>
</tr>
<tr>
<td>B2</td>
<td>1.0</td>
<td>0</td>
<td>.5</td>
<td>.2</td>
</tr>
<tr>
<td>B3</td>
<td>.5</td>
<td>1.0</td>
<td>0</td>
<td>.5</td>
</tr>
</tbody>
</table>

| Expected Utility | .45 | .65 | .40 | 1.0 |

| Rank | 2   | 1   | 3   |

### Person B

**Action**

<table>
<thead>
<tr>
<th>State</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>0</td>
<td>1.0</td>
<td>.75</td>
<td>.1</td>
</tr>
<tr>
<td>B2</td>
<td>1.0</td>
<td>.5</td>
<td>0</td>
<td>.6</td>
</tr>
<tr>
<td>B3</td>
<td>.5</td>
<td>0</td>
<td>1.0</td>
<td>.3</td>
</tr>
</tbody>
</table>

| Expected Utility | .75 | .4  | .375| 1.0 |

| Rank | 1   | 2   | 3   |

### Person C

**Action**

<table>
<thead>
<tr>
<th>State</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>0</td>
<td>.5</td>
<td>1.0</td>
<td>.55</td>
</tr>
<tr>
<td>B2</td>
<td>.5</td>
<td>1.0</td>
<td>0</td>
<td>.15</td>
</tr>
<tr>
<td>B3</td>
<td>1.0</td>
<td>0</td>
<td>.5</td>
<td>.30</td>
</tr>
</tbody>
</table>

| Expected Utility | .375| .425| .7  | 1.0 |

| Rank | 3   | 2   | 1   |

---

11 See also Raiffa (1968) when he exemplifies that the paradoxes can arise even when all the members agree in preferring one action.
Table 2 The Group Decision Matrix Obtained by Averaging the Individual Probabilities and Summing the Individuals Utilities from Table 1.

<table>
<thead>
<tr>
<th>State</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>0</td>
<td>2.0</td>
<td>2.75</td>
<td>.317</td>
</tr>
<tr>
<td>B2</td>
<td>2.5</td>
<td>1.5</td>
<td>.5</td>
<td>.317</td>
</tr>
<tr>
<td>B3</td>
<td>2.0</td>
<td>1.0</td>
<td>1.5</td>
<td>.367</td>
</tr>
</tbody>
</table>

Expected Utility | 1.527 | 1.477 | 1.580 | 1.0 |

Rank | 2 | 3 | 1 |

“We conclude that there is still no satisfactory quantitative method for determining group preferences by some mathematical operation on the expressed preference of individuals. So attempts to apply decision theory to an organization by the mathematical aggregation of individual beliefs will encounter difficulties.”

(Watson and Buede, 1987, p.109)

2.2.3 Aggregating preference judgements

The measurements of both utility and probability depend on it being possible to articulate a preference order regarding the options. While a person acting on his/her own may be able to do this, this may not be possible within an organisation in which there may be different opinions. People might think that the preference order of an organisation would be easily determined by a traditional method of majority voting. This might however lead to paradoxical results, such as an example, originally discovered by Condorcet (1785). Arrow (1951) demonstrates in the “majority voting paradox” that aggregating individual preferences through democratic means will not always arrive at one clear preference. In The Economist (1978) one can find a good example of this paradox, which will be used in the illustration below.
Three members of a group attempt to rank three mutually exclusive policy alternatives: (a) environmentalism (b) efficiency and (c) goodheartedness. The hope was to reach some social function upon which policy decisions could be based.

The ranking went as such:

<table>
<thead>
<tr>
<th></th>
<th>1st choice</th>
<th>2nd choice</th>
<th>3rd choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. Econut</td>
<td>(a)</td>
<td>(b)</td>
<td>(c)</td>
</tr>
<tr>
<td>Mr Tycoon</td>
<td>(b)</td>
<td>(c)</td>
<td>(a)</td>
</tr>
<tr>
<td>Rev. Goodchappe</td>
<td>(c)</td>
<td>(a)</td>
<td>(b)</td>
</tr>
</tbody>
</table>

The result is thus that (a) is preferred to (b), (b) is preferred to (c), but we also have that (c) is preferred to (a), which means that the preferences of the group are not transitive. This also means that no rational policy decision based on a social welfare function is possible in this hypothetical situation. So, since majority voting is not a satisfactory method for determining group preferences, we must therefore ask if there is one? This is the question Arrow (1951) asked, and to which he got the unconventional answer that there is none. He established four conditions that he considered should be met by a satisfactory procedure for determining a group’s preferences between a set of options. Arrow’s conditions can be stated as follows:

- Whatever the preference of the group members, the method must produce a group preference order for the options being compared.
- If every member of the group prefers option \( A \) to option \( B \), then the group also must also prefer \( A \) to \( B \).
- The group choice between two options, \( A \) and \( B \), depends only upon the preferences of members between these options and not on preferences for any other option.
- There is no dictator. No individual is able to impose his/her preferences on the group.

Arrow proved that there is no such procedure that meets all these four conditions,\(^\text{12}\) and his work was “concerned with the combination of preference orders, and does not use the intensity of preferences of individuals,\(^\text{12}\)

\(^{12}\) For a wider discussion concerning the proof of this theorem see Sen (1970).
nor, more significantly, interpersonal comparison of utility." (Watson and Buede, 1987, p.108). Keeney and Raiffa (1976) have, however, put forward a particular approach to constructing a group utility function, as a function of individuals. In their work they imagine a “supra-decision-maker” who is supposed to construct a utility function for a number of individuals, and they explore the conditions under which the group utility function can be a weighted sum of the individual utility functions.¹³

¹³ For an interesting contribution to this debate see Brock (1980) who points out that there is no consensus on whether this procedure, or others that have been suggested, make sense even at the theoretical level.
2.2.4 Criticism against the normative theories

2.2.4.1 The expected value theory

The expected value theory fails to take into account the attitude to risk of the decision-maker, and in 1738 the mathematician Daniel Bernoulli (1700-1782) published a paper and rejected the criterion for monetary pay off as a decision rule.\textsuperscript{14} In what is called the \textit{St. Petersburg paradox}, Bernoulli offered a gamble where a coin will be tossed until a head appears for the first time. When this happens you will be paid $2, if a head appears again on the second throw you will be paid $4, if a head appears on the third throw you will be paid $8 and so on. The expected returns on the gamble are: $2 \times (0.5) + $4 \times (0.25) + $8 \times (0.125) + \text{etc.} \text{ which equals } 1 + 1 + 1 + \ldots \text{ infinity, so the expected return will be infinity large.}

How much should a rational decision-maker be willing to pay in order to play this game? Not many people would be prepared to pay a limitless amount of money, in accordance to the expected value criterion. It should also be noted that the EMV criterion assumes that the decision-maker’s value function for money is linear, i.e. that increasing returns from $0 to $1 million will be as preferable as an increase from $9 million to $10 million. Bernoulli, however, pointed out the \textit{subjective preferences} as essential to the decisions to be made and said that the objective methods such as EMV were inadequate. He said:

"To make this clear it is perhaps advisable to consider the following example: Somehow a very poor fellow obtains a lottery ticket that will yield an equal probability of either nothing or twenty thousand ducats. Will this man evaluate his chance of winning at ten thousand ducats? To me it seems that the answer is negative. On the other hand I am inclined to believe that a rich man would be ill-advised to refuse to buy the lottery ticket for nine thousand ducats. If I am not wrong then it seems clear that all men cannot use the same rule to evaluate the gamble [...] the value of an item must not be based on its price, but rather on the utility it yields. The price of the item is dependent only on the thing itself and is equal for everyone; the utility, however, is dependent on the particular circumstances of the person making the estimate." (Bernoulli, 1954, p.24).

\textsuperscript{14} I use the presentation by Bernoulli (1954), Econometrica 22, pp.23-36.
Bernoulli was the first person to identify the difference between the objective economic outcome and the value of consequences.\(^\text{15}\) Since EMV only focuses on money as the attribute it has an additional limitation. We should, nevertheless, point out that the EMV criterion is still used in practice and that many people argue that it is an appropriate criterion to follow if it is done consistently since people make a large number of decisions and the returns will therefore still be maximised.

2.2.4.2 The expected utility theory

The 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).\(^\text{16}\) There are a multitude of suggestions as to how to motivate the expected utility rule using an axiomatic approach.\(^\text{17}\) However, even if 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 involved when constructing the proofs. The problem is that the elicitation of utilities takes the decision-maker away from the real problem, i.e. the real world, into a world of hypothetical lotteries. It is easy to say you are prepared to accept a 3% risk to lose $5,000 if it is a part of a lottery or a game, but should you take the same risk facing a real problem? Tocher (1977, p.433) says:

\(^{15}\) As stated above, D. Bernoulli explicitly defined a logarithmic utility function that depended on the present wealth of the evaluator. This function was in itself considered adequate for almost two hundred years. In 1927, however, Karl Menger presented a paper to a reluctant Viennese Economic Society, in which Bernoulli’s function was shown to be completely ad hoc. The function was shown to be unsatisfactory already on purely formal grounds. For the evaluation of additions to a fortune by any unbounded function, there exists a game related to the St. Petersburg Game, in which the subjective expectation of the risk taker on the basis of this value function is infinite (Menger, 1934, p.264). This states that it is possible to provide a paradox, in all important respects equivalent to the St. Petersburg paradox, but not resolved by the introduction of Bernoulli’s function. In the process, Menger also showed the inadequacy of mathematical utility functions suggested by Bernoulli’s contemporary Gabrial Cramer, and others. The respect for Bernoullis’s original work was such that it was only in 1934 that Manger’s article could be published. By this time, the theory of probability had come to the attention of economists and psychologists, and decision theory was no longer a strictly mathematical subject. It was therefore natural for Menger to focus on normal behaviour in games of chance (own remark).

\(^{16}\) Schoemaker (1982) provide us with a survey of different interpretations of the utility principle and the principles of maximising expected utility, focusing on its descriptive and predictive capabilities.

\(^{17}\) See for example Ramsey (1931), von Neumann and Morgenstern (1947), Savage (1972), Herstein and Milnor (1953), Suppes (1956), Luce and Krantz (1971) and Jeffrey (1983).
“Such experiments in the mind offer no guarantee as to the subject’s reaction when faced with a similar real choice; we all know from bitter experience that men do not act as they say that they will.”

This might cause the erroneous behaviour that the decision-maker’s judgements do not correspond to what he/she would have done in a real decision situation. Others argue that if expected utilities only can be measured approximately then it is not always worth the trouble to assess them since the value function is easier to assess and can therefore serve as a good enough approximation (e.g. von Winterfeldt and Edwards, 1986). Raiffa (1982, p.155) has made an interesting point concerning the problem above when he says that;

“Many analysts assume that a value scoring system-designed for tradeoffs under certainty can also be used for probabilistic choice (using expected values). Such an assumption is wrong theoretically, but as I become more experienced I gain more tolerance for these analytical simplifications. This is, I believe, a relatively benign mistake in practice.”

Some argue that it will never be possible to formalise the decision process with all reasonable risk attitudes by a utility function. Hence, any attempt to capture risk attitudes varying with the decision context would be doomed to failure, and, critics point out that most mathematical models of decision analysis are oversimplified. If mathematical models, for instance, were the only criteria for gambling, no games would be arranged. Since, if the rules, make it advisable for the gambler, then the arranger should not offer this to the gambler. Nevertheless, people do arrange and participate in games. At a roulette wheel people might happily bet one dollar with an 18/38 probability of winning two dollars. Such behaviour, in fact, violates some of the more naive decision theories that do not take psychological factors into account.

It has also been argued that people tend to disregard very small probabilities, even in games with finite mathematical expectations, and that, in the case of very high probabilities, a gambler is unwilling to risk anything (Menger, 1934).

It appears, in the opinion of many people that the principles of maximising the expected utility are not enough to model all risk attitudes and Dreyfus (1984), moreover, argues that real decision-makers are not interested in the analytical approach of decision-making.\textsuperscript{18}

\textsuperscript{18} For an interesting reply on this statement see Brown (1984).
2.2.4.3 Allais’ paradox

Many people believe that the independence axioms, i.e., the sure-thing principle,\(^19\) 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)\(^20\) discussed it more thoroughly.\(^21\) The Allais’ Paradox is, as the St. Petersburg paradox, not a paradox in the formal sense of the word. Rather it is an observation of the way we humans reason, detecting a certain kind of inconsistency.

To illustrate this, consider following example based on two decision situations each involving two gambles.

**Situation 1. Choose between**

<table>
<thead>
<tr>
<th>Gamble 1.</th>
<th>$100,000 with probability 1; and</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamble 2.</td>
<td>$500,00 with probability 0.1,</td>
</tr>
<tr>
<td></td>
<td>$100,000 with probability 0.89,</td>
</tr>
<tr>
<td></td>
<td>status quo with probability 0.01.</td>
</tr>
</tbody>
</table>

**Situation 2. Choose between**

| Gamble 3. | $100,000 with probability 0.11,   |
|           | status quo with probability 0.89; and |
| Gamble 4. | $500,000 with probability 0.1,     |
|           | status quo with probability 0.9.   |

The SEU model implies that individuals should choose either the pair 1 and 3 or the pair 2 and 4. Most people, however, choose gamble 1 in the first situation and gamble 4 in the second situation. In the first case people seem to argue that why gamble when I can be certain of receiving $100.000? And in the second case most people argue in favour of the larger amount since the

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\(^{19}\) 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. Moreover (provided he does not regard B as virtually impossible) if he would definitely prefer g to f, knowing that B obtained, and, if he would not prefer f to g, knowing that B did not obtain, then he definitely prefers g to f.” (Savage, 1972, p.21)

\(^{20}\) Allais own reaction against Savage’s argument can be found in Allais (1979, p.534).

\(^{21}\) For further reading see Allais (1953), Savage (1972), Raiffa (1968) and for a discussion about the Allais’ example from both a normative and descriptive standpoints, see MacCrimmon and Larsson (1979) and Slovic and Tversky (1974).
probabilities for both options are nearly the same? However, in choosing gamble 1 and gamble 4 the judgements are in conflict with the utility concept or, in particular, the sure-thing principle.

The pair of preferences above implies the following inequalities for any hypothetical utility function. \( U($100,00) < 0.1U($500,00) + 0.89U($100,000) + 0.01U($0), \ 0.1U($500,000) + 0.9U($0) < 0.11U($100,000)+0.89U($0); \) and these are evidently incompatible (Savage, 1972).

This example suggests that people do not always choose in accordance with the expected utility combination rule when given alternatives. Instead they exhibit strong preferences for the certainty in gamble 1. Many psychological studies have shown that substantial numbers of people choose 1 and 4, even in the face of convincing arguments that they should choose otherwise (see for example Slovic and Tversky, 1974).

Without losing any generality, situations 1 and 2 can be pictured as a lottery with 100 tickets.\(^{22}\) In option B, for instance, there will be one ticket marked with “$0” (assume this is ticket number 1), ten tickets marked with “$500,000” (tickets 2-11), and eighty-nine tickets marked with “$100,000” (tickets 12-100), see table 3.

Table 3.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2-11</th>
<th>12-100</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$100,000</td>
<td>$100,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>B</td>
<td>$0</td>
<td>$500,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>C</td>
<td>$100,000</td>
<td>$100,000</td>
<td>$0</td>
</tr>
<tr>
<td>D</td>
<td>$0</td>
<td>$500,000</td>
<td>$0</td>
</tr>
</tbody>
</table>

The table clearly shows that both these situations only differ in their respective options for tickets 1-11; for tickets 2-100 the result is the same. So, the only difference between situation 1 and 2 is that for tickets 12-100 the gain is $100,000 and $0 respectively. Otherwise, the situations are identical. Therefore, the mindful gambler would choose A in situation 1 and C in situation 2, and the more adventurous gambler would choose B and D, respectively. It is, thus, inconsistent to choose A and D, as well as B and C.

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. This can for example be done either by comparing the outcomes.

\(^{22}\) I use the presentation from Savage (1972, p.102). Raiffa (1968, pp.80-86) presents similar arguments.
(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). The purchase of both insurance and lottery tickets are real-life situations that partially mimic these situations. These situations, characterised as high consequence-low probability events, have been confusing economists for a long time, because the same person may buy both insurance and lottery tickets.23 “The former being a display of risk aversion and the latter of risk seeking.” (ibid., p.11).

2.2.4.4 Irrelevant contextual effects

It seems that people in many risky-choice situations do not act in accordance with the rules of maximisation of the expected utility. Empirical studies have shown that people remain inconsistent in their method of choosing even though they have been taking part in the results above (Slovic, 1974), and even if they realise that their suggested decision was premature. So, why are so many people inconsistent in this respect? One thesis is that irrelevant contextual effects influence people. Tversky and Kahneman (1981) gives an example by offering a choice between two programmes (see below) which aim to fight an Asian disease that is expected to kill 600 people.

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23 An interesting notation in this realm is that Shapira and Venezia (1992), when studying the purchase of state lottery tickets, found that the demand for the lottery tickets where related to the size of the first price but not to the expected value.
Program 1
A. Exactly 200 will be saved
B. A 1/3 probability that 600 will be saved, and a 2/3 probability that none will be saved.

72% out of 152 persons preferred program A. 155 persons were then offered the same choice but with a different formulation:

Program 2
A. Exactly 400 will die
B. A 1/3 probability that nobody will die, and a 2/3 probability that 600 will die.

This time 22% preferred program A. The idea is to show that irrelevant contextual effects may influence a decision-maker.

Among others, McNeil et al. (1982), Slovic et al. (1983) and Tversky and Kahneman (1981) 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. Therefore, these framing effects cause significant problems to the normative theory of risky choice since it only emphasises the statistical basis for decision-making (Shapira, 1995).

The normative theories however totally rule out such behaviour, nevertheless these results are important for those who try to understand how people think and perhaps even more importantly for those who try to use normative principles under such conditions (Bell et al., 1988). Hence it is very important to handle the framing process cautiously when supporting people to make better decisions.24 We will return to this theme in Section 2.3 when discussing this issue from a descriptive point of view and go a step further by bringing this subject into the field of prescriptive theory in Section 2.4.

We have now seen that the suggested normative rules, the expected value rule and the expected utility rule, do not always serve as a good foundation for decision-making under risk and uncertainty. The EMV rule, for example, fails to take into account the attitude towards risk of the decision-maker, and can therefore only serve as an average sum of two consequences (French, 1988). The EMV rule, furthermore, assumes that the value function for money is linear. Bernoulli (1954), however, pointed out that subjective preferences are essential when making decisions and he said that the EMV method was therefore inadequate.

The expected utility rule, on the other hand is criticised by, among others, Tocher (1977) since the model, according to him, takes the decision-maker

away from the real world into a hypothetical world of lotteries. Others argue that it is difficult to measure the expected utilities and state that if it can only be measured approximately it is better to use the value function (e.g. Winterfeldt and Edwards, 1986).

The Allais’ paradox is another, often cited, criticism that has been used against the utility theory. Allais (1953) shows that people are inconsistent and do not always act in accordance with the expected utility rules or, equivalently, the sure-thing principle, when choosing from different alternatives. People, however, often remain inconsistent in their way of choosing even though they have been informed about their inconsistency (Slovic and Tversky, 1974). One thesis to confirm this phenomenon is that irrelevant contextual effects influence people (Tversky and Kahneman, 1981). These framing problems, that people may choose in opposite ways and end up with contrary results when data are presented in different, but mathematically equivalent, ways, cause significant problems to the normative theory of risky choice (Shapira, 1995).

It appears, in the opinion of many people, that the principles of maximising the expected utility are not enough to model all risk attitudes and Dreyfus (1984), moreover, argues that real decision-makers are not interested in the analytical approach to decision-making.

Hence, we must raise the questions; how do people actually make decisions and how do they act when choosing from a set of risky prospects?

The aim of studying the descriptive field of decision-making is to identify the discrepancies between the way people actually make decisions and the way the normative rules suggest people act. It is not enough to provide rational (normative) procedures for decision-making without knowledge about how the decision-making “out there” actually takes place.
2.3 Descriptive theory

The normative theory suggests rules for the decision-makers and states how they should make decisions; the descriptive theory on the other hand, tries to explain how real decisions are made, i.e. how we actually do decide.

The classical decision-making approaches regard decision-making as a rational process. The assumption is that individuals think and act with complete objectivity and that the rational decisions are those where; the problems and the goals are clearly defined, all alternatives and outcomes are known, preferences are clear, constant and stable, there are no constraints, and the final choice will maximise results for the individual and the organisation (Lee et al., 1995). But this is not always the reality, March (1994, pp.8-9) state that;

“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.”

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25 The descriptive approach to risky choice stems from the early work by Edwards (1954) when he showed that people did not use the rules of expectation when choosing among risky prospects.

26 Rational theories of choice assume that decision processes are consequential and preference-based. They are consequential in the sense that action depends on anticipations of future effects of current actions. Alternatives are interpreted in terms of their expected consequences. They are preference-based in the sense that consequences are evaluated in terms of personal preferences (March, 1994, p.2).
2.3.1 Descriptive approach to risky choice

This section will explore what we know at present about how decisions are carried out in organisations and what the foundations of the organisational decision-making theory are.\(^{27}\) Weber’s ideal model (bureaucracy) was built on a well-defined hierarchy of positions for people to occupy, where there were fixed jurisdictional areas and the management and the decision-making was prescribed by well-defined procedures (Weber, 1947). Many of the critics of Weber’s ideal model argue, however, that the result of following all the rules can often fail to achieve a reasonable conclusion. The work that Weber did, however, provides us with a framework for studying the nature of organisations and their formal structure,\(^ {28}\) but it did not concentrate on the decision-making within them. This was, however, done by Simon.\(^ {29}\) In 1955 Simon came up with his classical work, about *bounded rationality*, and argued that people do attempt to be rational but since they have a limited information-process ability they can not be completely rational.\(^ {30}\) Simon states;

- firstly, people do not have a complete knowledge of the consequences of their acts,

- secondly, they either do not have complete knowledge of the alternative courses of action available to them or they cannot afford to obtain that knowledge, which means that people do not create complete lists of alternatives before making every decision (and even if they tried to, the list would not be complete). Therefore, people simplify problem choices and consider only a subset of the entire set of alternatives, and then choose one alternative that seems “good enough”. Hence, the process does not necessarily end up with the optimal solution, i.e. the best alternative may not be selected,

- thirdly, even if the individual has several alternatives, he or she would not be able to rank them in terms of preferences nor be sure

\(^{27}\) As a good introduction to the ideas of organisation theory one can read; 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 (Ungson and Braunstein, 1982) which contains a number of useful papers, and Clough (1984) who gives us a good general outlook of both the theory and the practice of organisational decision-making as well as a good summery of other theories in his book.

\(^{28}\) Others who have studied organisational structure from a several different points of views; Emery and Trist (1965), Woodward (1965), Perrow (1967), Thompson (1967), Lawrence and Lorsch (1967), Scott (1987) and Morgan (1986).

\(^{29}\) See for example Simon (1955, 1957a,b, 1960, 1976).

\(^{30}\) See also Lindblom (1959).
which is the most desirable and which one is the least desirable (Simon, 1976). This, *satisficing principle*, is about searching through a limited set of alternatives until one arrives at a satisfactory alternative to choose.

So, when people are confronted with real decision problems they construct simplified models of the real situation, they conduct a limited search for alternatives from a well-worn path, and they do not examine all possible alternatives. They rather select the first satisfactory one that comes along and invoke solutions they have used before (March and Simon, 1958).31

An important idea is that bounded rationality will not only recognise parameters but will also be influenced by the decision-makers environment, internal as well as external (Lee *et al.*, 1999). Simon says that the individuals have decisions made “subject to the influences of the organization group in which he participate.” (Simon, 1976, p.79). This is done through the division of labour, the authority system, channels of communication, standard practices, and training and indoctrination (ibid.).32 The result, however, is that the individuals are made to “adapt their decisions to the organization’s objectives” and for that purpose they are provided with information needed to make correct organisational decisions (Simon, 1976, p.79). Simon states that the ”behaviour of individuals is the tool with which organizations achieve its purposes” (ibid., p.108) and that the individuals are the tools of the organisation.

In 1959 Lindblom came up with the idea that the decision-making processes of organisations is based on “*muddling through*”. He said that decision-making happens incrementally, and that policies, for instance, are compared with slightly different ones but not with all possible ones. Jansson and Taylor (1978) agree with Lindblom’s approach and state that this is a correct way to describe how policy-making actually takes place in organisations. In the field of social psychology we also find contributions as to how decisions are reached in organisations. Within group decision processes Janis (1972) has identified a phenomenon he has termed

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31 “March and Simon illustrate their satisficing model with the example of looking for a needle in haystack – you do not search for the sharpest needle, only one sharp enough to sew with. But the example is not apt; no economist (who is supposed to deal only with completely rational people) would argue that you search for the sharpest needle. The real reason why the Simon formulation is so useful is that the costs of search are usually unknown to individuals. They do not know if there is a sharper needle or how long it would take to find it. Therefore, they cannot take into account the cost of search in many cases. At any rate, Simon does not say that all behavior ignores cost or search, or does not seek maximum solutions, but only says that it is impossible to do so all or most of the time.” (Perrow 1986, p.122.)

32 These are the cornerstones of the Weberian model, but March and Simon dismiss the Weberian model in a couple of paragraphs as too mechanical (March and Simon, 1958, pp.36-37).
“groupthink”. He argues that if a decision-making group is: (1) highly cohesive; (2) insulated from many external influences; (3) lacking in procedures for systematically evaluating alternatives; (4) subject to a directing leader; and (5) in accordance of high stress; then there is a concurrence-seeking tendency which he calls groupthink. He also states that some of the symptoms of groupthink are:

- Excessive optimism and risk-taking - the group collectively makes riskier decisions than its individual members might have done. This is sometimes referred to as the ‘risky shift’ phenomenon.

- An illusion of the invulnerability of the group to error, the group ignores the external environment or outside warnings.

- A common belief in the morality of the group. As the group becomes more cohesive, its members often tend to think along similar lines, and their opinions become more convergent.

- Direct pressure on dissenters to conform. Deviation from the group norms are not accepted - the more cohesive the group, the greater demand for conformity.33

There have, however, been very few laboratory tests on Janis’ theory and one of the main reasons is because researchers have found it problematical to achieve high level of cohesiveness, a primary antecedent of groupthink. Another way of verifying the theory has, however, been to study the case history.34 Janis and Mann (1977) have also identified two other types of social pressure that affect the decisions made by individuals. The first one is what they called “anticipatory regret”. Which is our tendency to worry about how disappointed we, and others, might feel after that we have made a wrong decision,35 and secondly, threats, or constraints, imposed by others.

Since these are important influences on decision-making they must be borne in mind when prescribing how to use decision theory in group decision-making (Watson and Buede, 1987). Two conclusions that can be made about decision-making in organisations are; firstly that decisions made by organisations are not made in the same way as by an individual, and secondly

33 Other studies have also demonstrated the tendency of members of cohesive groups towards excessive conformity, even when this conflicts with the individual’s rational or moral judgement, see for example Asch (1951) and Millgram (1974).
34 One such study has been made by Esser and Lindoerfer (1989) when they analysed the decision to launch the space shuttle Challenger on 28 January 1986.
35 See also Bell (1982) when he discusses a similar phenomenon that he calls regret aversion.
that prescriptions regarding how decisions are made in organisations are needed (ibid.). However, since the decision-making by individuals and organisations, of course, are not completely separated one should also pay attention to the descriptive aspects regarding how individuals make decisions.
2.3.2 Prospect theory - an alternative to the expected utility theory as a descriptive model

Kahneman and Tversky (1979) rejected the expected utility theory as a descriptive model, and they proposed an alternative account of choice under risk. Their empirically based descriptive model is called prospect theory. They show that most people violate the SEU model even in situations where there is no vagueness about uncertainties (ibid.). Below we can see that the prospect theory consists of three elements; (a) a value function, (b) a decision weight function and (c) the editing rule.

- Firstly, the theory defines values as deviation from a certain reference point. Kahneman and Tversky describe this by comparing an individual’s attitude to money to a book where each page represents the value function for changes at a particular asset position. They say that clearly, the value functions described on different pages are not identical: they are likely to become more linear with increases in assets (ibid.).

- Secondly, in the theory both gains and losses diminish in value and this suggests that people are more sensitive to changes around the reference point. The difference in value between a gain of 100 and a gain of 200 seems to be greater than the difference between a gain of 1100 and a gain of 1200. We can identify the same pattern if we compare a loss of 100 and a loss of 200 which appears to be greater than the difference between a loss of 1100 and a loss of 1200. The weighting function implies that the value of each outcome is multiplied by a decision weight, and the decision weights are inferred from choices between prospects. However, the decision weights are not probabilities and they should not be interpreted “as measures of degree or belief” (ibid.).

- Thirdly, a very important characteristic of prospect theory is the editing rule, which later was transformed into the concept of framing (Tversky and Kahneman, 1981). This phase consists of a preliminary analysis of the prospect on offer, and also that the decision-makers “edit” the problem until they arrive at simplified

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36 The value function plays the role of utility function in utility theory.
37 Compare with the EMV criterion, which assumes that the decision-makers value function for money is linear (own remark).
38 See also March (1994, p.12).
well-organised alternatives that can apply either in the domain of gain or the domain of loss.

As we will see in following examples people often perceive outcomes as gains or losses and since many problems can be presented in either a positive or negative frame, this will lead to risk-prone or risk-averse behaviour (see also figure 1, and figure 2). An important notion is that gains and losses are defined in relation to a neutral reference point. The location of this reference point, and the coding of outcomes such as gains and losses, can also be affected by the way the offered prospect is formulated and by the decision-maker’s expectations (Tversky and Kahneman, 1979).

Allais’ paradox,39 previously presented in this paper, is the best-known counter-example to expected utility theory. The paradox illustrates the problem of the certainty effect, and the prospect theory model accounts for paradoxes such as Allais’.

Consider the following example, which offers someone the choice of one gamble in problem 1 and one gamble in problem 2.40

Problem 1: Choose between
A: 2500 with probability 0.33,  B. 2400 with certainty
2400 with probability 0.66, 0 with probability 0.01.
N = 72  (18)  (82)

Problem 2: Choose between
C: 2500 with probability 0.33,  D. 2400 with probability 0.34,
0 with probability 0.67. 0 with probability 0.66.
N = 72  (83)  (17)

This certainty effect shows us that people give undue weight to outcomes that are certain as compared to outcomes that are merely probable (Tversky and Kahneman, 1979). The pattern in the above example violates the expected utility theory in the way described by Allais.

So, the first preference, with \( u(0) = 0 \), implies \( u(2400) > 0.33u(2500) + 0.66u(2400) \) or \( 0.34u(2400) > 0.33u(2500) \) and the second preference implies the reversed inequality.

39 Allais (1953).
40 The number of respondents answering each problem is denoted by \( N \), and the percentage choosing each option is given in brackets.
It should be noted that problem 2 (above) is obtained from problem 1 by reducing the probability of winning 2400 by 0.66 from both options.

Kahneman and Tversky (1979, p.186) state that; “evidently, this change produces a greater reduction in desirability when it alters the character of the prospect from a sure gain to a probable one, than when both the original and the reduced prospects are uncertain.”

Let us consider that the outcomes are changed and that gains are replaced by losses, what happens then? Kahneman and Tversky (1979) use an example to illustrate what they call the reflection effect. The example below is a simplification of the same phenomenon as presented above.

Let us have a look at a gamble involving only two outcomes.

Problem 3:
A: (4000, 0.80) or B: (3000)
N = 95 (20) (80)

Problem 4:
C: (4000, 0.20) or D: (3000, 0.25)
N = 95 (65) (35)

We can see, above, that more than half of the respondents violated the expected utility theory, as they also did in the first example. However, the reflection effect appears when we replace the gains by losses, see below.

Problem 3’:
A: (-4000, 0.80) or B: (-3000)
N = 95 (92) (8)

Problem 4’:
C: (-4000, 0.20) or D: (-3000, 0.25)
N = 95 (42) (58)

The conclusion is that the reflection of prospects around 0 reverses the preference order and we face a mirror image between the positive and the negative prospects, see figure 2.
When analysing the data we can see that risk aversion in the positive domain switches to a risk prone behaviour in the negative domain. Others, including Markowitz (1952), have noted the tendency of risk seeking in choices between negative prospects. Fishburn and Kochenberger (1979) and Riabacke (2000) identified a similar prevalence of risk prone behaviour in choices between risky prospects in loss domains. Williams (1966) also made similar findings when he found that translation in outcome causes a *shift from risk averse to risk prone behaviour*. When studying different groups of professionals Riabacke (2000) identified a strong correlation between income and the way the respondents chose from a set of risky prospects. Individuals with a lower salary appear to be more risk averse than those with a higher salary. Thus, the explanation for the results could be that the individuals, implicitly or explicitly, use their respectively incomes as a reference point when they choose an option.

For the last 30 years or so, the evidence of the incompatibility of the two theories, normative and descriptive, has been growing. Also as we have seen above, we have the normative theory on one hand trying to tell people how they should make decisions; and the descriptive theory on the other hand attempting to clarify how people actually make decisions.

The descriptive theory assumes that the decision-makers do not have complete knowledge about the consequences of their actions, they do not have all the information needed to create a complete list of alternatives and they do not know which alternatives that actually are available for them (among other things). So, when confronted with real decision problems, people construct simplified models of the real situation and choose one alternative that seems good enough (Simon, 1976). Hence, people conduct a limited search for alternatives among a well-known path and select the first satisfactory one that comes along (March and Simon, 1958). An interesting notion has also been made by March (1994), when he states that people consider different

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41 Riabacke studied 5 different groups of professionals (university lecturers, professional dancers, computer technicians, cleaners, and insurance company employees), and the study included 39 persons.
alternatives sequentially rather than simultaneously, due to their limited capacity for handling large quantities of information.

Kahneman and Tversky (1979) use the examples of the certainty effect and the reflection effect (among others) to invalidate the expected utility theory as a descriptive model. The certainty effect shows us that people give undue weight to outcomes that are certain compared to outcomes that are merely probable. The reflection effect points out that people tend to be risk averse in a positive domain and then switch to being risk prone in a negative domain. The conclusion is that the reflection of prospects around 0 reverses the preference order and we face a mirror image between the positive and the negative prospects (see figure 2).

So, depending on how a problem is presented it might cause different reactions, i.e., if a problem is presented in a positive frame it will lead to risk averse behaviour and if a problem is presented in a negative frame it will lead to a risk prone behaviour.

Many decision analysts initially hoped that it would be good enough to study and document biases in the normative theory, for example those presented above, and then point them out to decision-makers, but it did not solve the problem. However, Bell et al. (1988) noted that the evidence accumulated so far suggested that it is necessary to develop normative, descriptive and prescriptive models to achieve improvements in decision-making. This confirms that it is of great importance to study risk taking and the decision context from several perspectives, and that the decision problems will not be solved by one single universal axiom. We must be able to identify pitfalls that occur in different decision situations, such as framing problems, certainty effects, etc., and we must establish a mutual understanding regarding what we are going to do. It is not sufficient for only the decision analyst to understand “what is going on”; all parties must be actively involved in the process. Developing prescriptive decision aids is one step in this effort.
2.4 Prescriptive theory

We have, in the recent past, seen an increasing interest in the interaction between normative, descriptive and prescriptive theories of decision-making,\textsuperscript{42} and in order to develop decision aids it is of great importance to know the similarities as well as the differences between the three theories.\textsuperscript{43}

Examining the criteria by which they are evaluated can illustrate the differences between the three models of choice.

- \textit{Empirical validity} is the criterion used when evaluating descriptive models, i.e. to what degree they correspond to observed choices.

- \textit{Theoretical adequacy} is the criterion used when evaluating normative models, i.e. to what degree they provide rational choice; and

- \textit{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 (Bell \textit{et al.}, 1988).

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 (ibid.) provides us with a useful framework to visualise the features of the discussed choice models, see table 5.


In table 4 we can see that these two ways of describing the theories, discussed above, correspond to the criterion column. Keeney (1992), however, goes a step further in his classification when he divides the theories into different classes of problems:

- 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 way.

- 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 analysis focuses on *one decision problem* at a time and the focus is therefore on the cell that addresses a specific decision problem.

So, let us have a look at an example that will illustrate the differences between the three viewpoints. 44

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44 I use the presentations by McNeil *et al.* (1982) and Bell *et al.* (1988).
2.4.1 An example of prescriptive theory in which all three theories are used

The authors, McNeil et al. (1982), investigated how variations in the way information was presented influences the patient’s choice between alternative therapies. Data was presented to 238 patients with different chronic medical conditions, to 491 graduate students and to 424 physicians and the subjects were asked to imagine that they had lung cancer. They had to choose between two therapies on the basis of given probabilistic assessments. The subjects had to choose either treatment A or treatment B and the relevant questions (see below) were presented to one group in terms of survival.

- Of 100 people having treatment A, 90 live through the treatment. A total of 70 people are alive by the end of the first year and a total of 38 people are alive by the end of five years.

- Of 100 people having treatment B, all live through the treatment. A total of 79 people are alive by the end of the first year and a total of 26 people are alive by the end of five year.

The second group had the data presented to them in terms of mortality rates rather than the survival rates (e.g., “of 100 people having treatment A, 10 die during the treatment,” etc.). The data was also shown to each subject in the form presented in table 5. Each subject was shown frame 1 or frame 2, not both.

Table 5 Alternative frames for choice selection

<table>
<thead>
<tr>
<th></th>
<th>Frame 1 Cumulative chance of death</th>
<th>Frame 2 Cumulative chance of survival</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment A</td>
<td>Treatment B</td>
</tr>
<tr>
<td>During treatment</td>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>By year 1</td>
<td>30%</td>
<td>21%</td>
</tr>
<tr>
<td>By year 5</td>
<td>62%</td>
<td>74%</td>
</tr>
</tbody>
</table>

The results were dramatic and there were large differences in how they responded depending on whether the data was presented in terms of survival or in terms of mortality. Observe that the data presented to the subjects are identical in formational content in both cases. When data was presented in terms of survival 61% of the subjects preferred treatment B to A but when data
was presented in terms of mortality only 37% of the subjects preferred \( B \) to \( A \). Hence, the format seems to affect the process of thought and the way people actually choose between different alternatives. So, it is obvious that the framing of the question can, and does affect the way people choose (Tversky and Kahneman, 1981, 1982, 1986).

However, these framing problems are still not a part of the normative theory (Fischer, 1989). Nevertheless, these are the descriptive realities and these 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 prescriptively important if we are to attempt to help people make their choices (French and Rios Insua, 2000).

So, in order to make the decision situation more easily understood we continue with an illustration from a prescriptive point of view. In table 6 we can view the summarised data that gives the relative frequency of each outcome. This gives the patient a better view of the different alternatives and hopefully makes it easier to choose the appropriate therapy.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Treatment A</th>
<th>Treatment B</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0)</td>
<td>Not surviving treatment (i.e., dying during treatment)</td>
<td>10%</td>
</tr>
<tr>
<td>(0, 1)</td>
<td>Surviving treatment but dying before end of first year</td>
<td>20%</td>
</tr>
<tr>
<td>(1, 5)</td>
<td>Surviving 1 year but dying before end of fifth year</td>
<td>32%</td>
</tr>
<tr>
<td>(5+)</td>
<td>Surviving at least 5 years</td>
<td>38%</td>
</tr>
</tbody>
</table>

We continue this prescriptive analysis by setting up a situation where we offer a hypothetical decision-maker, Ms Jones, an urn with 100 balls; each ball having a label A, a label B or both label a A and B on it. In table 7 you can see the possible markings on the 100 balls corresponding to the relative frequencies in table 6.
Table 7

<table>
<thead>
<tr>
<th>Number of balls</th>
<th>A-label</th>
<th>B-label</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>(0,1)</td>
<td>(0,1)</td>
</tr>
<tr>
<td>32</td>
<td>(1,5)</td>
<td>(1,5)</td>
</tr>
<tr>
<td>26</td>
<td>(5+)</td>
<td>(5+)</td>
</tr>
<tr>
<td>1</td>
<td>(0)</td>
<td>(0,1)</td>
</tr>
<tr>
<td>9</td>
<td>(0)</td>
<td>(1,5)</td>
</tr>
<tr>
<td>12</td>
<td>(5+)</td>
<td>(1,5)</td>
</tr>
</tbody>
</table>

The decision to be made can be viewed as follows: Ms Jones has to choose between A and B and then draw a ball that will show the outcome. In order to help Ms Jones we can simplify the decision situation even more by getting rid of the 78 balls that have both A and B labels, since they are not actually involved in the problem and only focus on the choice between the remaining 22 balls. The original and the simplified problem are shown in table 8.

Table 8

<table>
<thead>
<tr>
<th>Event</th>
<th>Original Treatments</th>
<th>Reduction Treatments</th>
<th>Modification Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>A'</td>
</tr>
<tr>
<td>(0)</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>(0, 1)</td>
<td>20</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>(1, 5)</td>
<td>32</td>
<td>53</td>
<td>0</td>
</tr>
<tr>
<td>(5+)</td>
<td>38</td>
<td>26</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>100</td>
<td>22</td>
</tr>
</tbody>
</table>

Hence, in the reduced problem we only have 22 balls left and the argument is that the choice between A and B should be the same as the choice between A’ and B’. Perhaps, someone might chose differently between these two versions, but they are in fact the same but in a different form. Now, assume that Ms Jones wants her choice between A’ and B’ to rule her choice between A and B and that she is inclined to choose A’ over B’, but is not sure. We therefore modify the choice between A’ and B’ to a choice between A” and B” (see the last two columns in table 8) and offer her the following proposal: “If you were certain of the outcome (1, 5); would you take a 50-50 chance of getting (0) or (5+)?” If she says, “yes I would take that chance” she should also prefer A’ to B’ and consequently she should prefer A to B.
These examples above handle the *framing process* which is one of the main problems the SEU model has in order to provide an appropriate basis for prescriptive analysis (ibid.). The normative theory 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, as we have previously seen, several *reference effects* lead to violations of the “independence principle” of SEU. These effects include among others the tendency to become risk averse for gains but risk seeking for losses (see Fishburn and Kochenberger, 1979, Markowitz, 1952, Riabacke, 2000 and Williams, 1966), and the tendency to weigh losses more heavily than equivalent gains (Kahneman and Tversky, 1979, 1984). Another *reference effect* includes *regret aversion*, which may occur when the risky choice turns out to be “wrong” (Bell, 1982). Nevertheless, the normative theory faces several problems concerning the beliefs and judgements about uncertainty. The SEU model claims that decision-makers should hold beliefs about uncertainties that are in accordance with some probabilistic measure (Bell *et al.*, 1988). But this is not the reality and several examples show that people do not act as the SEU model expects us to do. The “*conjunction fallacy*” for instance, shows that many individuals register beliefs that hint, for them, that the event (*A* and *B*) is more likely than the single event *A* (Tversky and Kahneman, 1983). Bell *et al.* (1988, p.26), gives us a illustrative example of this phenomenon;

“The probability of a nuclear war starting by a terrorist act is assessed as being more likely than a nuclear war starting.”

Among others, the problems discussed above, are what the prescriptive intervenor has to deal with. This is very much what the prescriptive theory is about, to identify the discrepancies between real and idealised behaviour in decision-making and to help people make better decisions.

As we have seen, in table 5, the normative theory *focuses on all kinds of decision-making*, whereas descriptive theory *focuses on classes of problems* and prescriptive theory *focuses on a specific problem*. In the example, where all three theories are used, we can see that the framing of a question can, and does, affect the way people choose (Tversky and Kahneman, 1981, 1982, 1986). Framing problems are one of several important issues to take into
account when developing prescriptive decision aid in order to help people make better decisions. However, this is far from sufficient and we must do a lot more. In order to provide decision aid we must also be aware that “people are different, with different psyches and emotions, capabilities, and needs, 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). This is very important because if the decision analyst and the decision-maker do not understand each other it will lead to difficulties in being able to generate successful decision aid. A good example is if “individuals who think one way have to interact with experts who think along different paradigmatic lines, as, for example, between a rational decomposer and a holistic intuiter” (ibid., p.17).

Therefore, in order to be able to gain a holistic understanding for the decision-making process we moreover need to study the objective factors that affect the decision-making, i.e., the organisational culture and the structure of the organisation, since these components more or less implicitly control and guide the decision-makers (Simon, 1976).
2.5 The decision-making context

Since the decision-making context affects the decision-making in several ways, it is of great importance to pay attention to the context in which decisions are made. The normative theory, for instance, does not take these kinds of issues into account when suggesting rules for decision-making. The importance of the framing process is one problem (Tversky and Kahneman, 1981, 1982, 1986), among others, that must be thoughtfully handled with respect to the culture as well as the structure when developing decision aid. When examining descriptive theory we can see that people do not act in accordance with the rules suggested by the normative theory. Instead we can see that people act in accordance with the prevailing organisational conditions, and that the environment influences the bounded-rationality behaviour, i.e. the way decisions are made (Simon, 1976). Thus, it is important to study these aspects of the decision-making process in our effort to provide decision-makers with sustainable decision aid.

So, the way decisions are made by individuals very much depends on the prevailing culture and how the organisation is structured. The next sections of this thesis focus on the internal decision-making constraints, structure and culture.

2.5.1 Organisational structure

Mintzberg (1983, p.2) defines organisational structure as, “...the sum total of the ways in which its labour is divided into distinct tasks and then its coordination is achieved among these tasks.”

According to Galbraith (1987) the term organisational structure refers to the formal configuration between individuals and groups regarding the allocation of tasks, responsibilities, and authority within organisations. But, the structure of an organisation is not visible since it is an abstract concept. However, in an organisational chart the connections between various clusters in the organisation can be visualised, and the chart can be considered to be a representation of an organisation’s internal structure (Greenberg and Baron, 1997). The organisational chart also provides us with information such as who

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46 See for example March and Simon (1958), Tversky and Kahneman (1979) and Simon, (1976).
47 Others who have studied organisational structure from a several different points of views; Emery and Trist (1965), Woodward (1965), Perrow (1967), Thompson (1967), Lawrence and Lorsch (1967), Scott (1987) and Morgan (1986).
reports to whom, known as the hierarchy of authority (ibid.). The organisational chart will moreover determine the way individuals make decisions and participate in the decision-making process (Lee et al., 1999). As Lee puts it “One key aspect of organisational structure is the way in which it should outline and facilitate decision making”, and it 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 (ibid., p.10).

2.5.2 Mechanistic and organic organisational structure

In a classic investigation by Burns and Stalker (1961) scientists identified that organisations can be categorised depending on the degree of structured formality that exists within the organisation. Burns and Stalker defined organisations as either “mechanistic” or “organic” in nature. The mechanistic structure very much describes the “bureaucratic” approach (Weber, 1947), and the organic structure is what Mintzberg (1983) called an “adhocracy”. One should notice that these two forms are extremes and that organisations can be relatively mechanic, relatively organic or, something in between. We can in figure 3 see the associated degree of decision-making freedom in each form (Lee et al., 1999).

Figure 3

<table>
<thead>
<tr>
<th>MECHANISTIC</th>
<th>ORGANIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Bureaucracy)</td>
<td>(Adhocracy)</td>
</tr>
<tr>
<td>Highly centralised decision-making</td>
<td>Decentralised decision-making</td>
</tr>
</tbody>
</table>

In the mechanistic structure the decision-making is highly centralised, and in the organic structure the decision-making is highly decentralised (Burns and Stalker, 1961). The mechanistic structured organisations were identified to be suitable in a stable, unchanging environment, and the organic structured organisations were considered to be suitable in an unstable, turbulent environment (ibid.). The significant difference between the mechanistic and the organic organisations can be measured by the degree of freedom given to the individuals in the organisations, especially regarding the decision-making. However, the structure itself does not make any decisions; it is the people within the organisation who make the decisions. These people are subject to a
wide range of influences within an organisation, from where the structure begins to dictate what is expected of them through to the general culture of the organisation.

Lee et al. (1999, p.14) state that “it is important therefore, to consider the impact of organisational culture on the way in which individuals make decisions as structure and culture are invariably linked.”

2.5.3 Organisational culture

Organisational culture has been defined by many writers including Hofstede (1980), Handy (1993), Mintzberg and Quinn (1991) and Schein (1992). Schein (1992, p.12) provides us with a definition of culture which can serve as a basis for discussing the link between organisation culture and decision-making;

“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.”

So, if culture is portrayed as the “correct way to perceive, think and feel” then the implication of this definition is that it will influence the way people in fact perceive their role in the decision-making process. Since the working norms are defined by the organisational culture, the culture can include or exclude individuals from the decision-making process (Lee et al., 1999).
2.5.4 Autocratic and democratic culture, and levels of culture

In figure 4 we can see that in the autocratic culture the management is highly centralised and that the decision-making is not entrusted to the employees, apart from programmed decisions. In contrast we can see that in the democratic culture the employees are entrusted with decision-making power (ibid., p.16).

Figure 4

<table>
<thead>
<tr>
<th>MECHANISTIC (Bureaucracy)</th>
<th>ORGANIC (Adhocracy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly centralised decision-making</td>
<td>Decentralised decision-making</td>
</tr>
<tr>
<td>(Autocratic culture)</td>
<td>(Democratic culture)</td>
</tr>
<tr>
<td>Low levels of trust in subordinates</td>
<td>High level of trust in subordinates</td>
</tr>
<tr>
<td>with little or no freedom</td>
<td>with high degree of freedom</td>
</tr>
</tbody>
</table>

The culture, however, can be analysed at different levels, and it is important to do so, otherwise it might be complicated to define where the cultures derives from. The level term refers to what degree the cultural phenomenon is visible to the observer. In figure 5 we can see the different levels that Schein (1992, p.17) uses in his discussion concerning Uncovering the Levels of Culture.

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48 Programmed decisions are highly routine decisions made according to pre-established organisational routines and procedures. Nonprogrammed decisions are made about highly novel problems for which there are no pre-specified courses of action (own remark).
The level of *artifacts*, on the surface, includes everything that you see and feel when you encounter a new group with a different culture. It includes visible products of the group such as its language, its technology and products, its style embodied in clothing, manners of address, etc. The most important fact regarding this level of culture is that it is easy to observe and hard to decipher.

The *espoused values* are the values that are put forward by the organisation, and if these values are put into practice and work well, they gradually start a process of *cognitive transformation*. Firstly it will be transformed into a *shared value or belief* which ends up as a *shared assumption* (ibid.). This is, nevertheless, not always the case. If the espoused values, for instance, welcome and support employee involvement in the decision-making process, but at the same time the truth is somewhat different, it will have an impact on the relations between the organisation and the individuals (Lee *et al.*, 1999). However, if the espoused values continue to be successful, a set of values can become embodied in an ideology or organisational philosophy. Thus, they can serve as “*a guide and as a way of dealing with the uncertainty of intrinsically uncontrollable or difficult events*” (Schein, 1992, p.20).

Furthermore, Schein states that it is even more important to understand the basic assumptions in order to get a deeper level of understanding and to be able to predict future behaviour correctly. The basic assumptions relate to the assumptions that are incorporated in the way people view the organisation, and it will therefore determine the behaviour of the individuals within the
organisation. “In fact, if a basic assumption is strongly held in a group, members will find behaviour based on any other premise inconceivable” (ibid., p.22). These basic assumptions are similar to those that Argyris (1976) has identified as “theories-in-use”, the implicit assumptions that guides behaviour and tell people how to perceive, think about, and feel about things. Since we do not debate or confront basic assumptions, or “theories-in-use”, it is extremely difficult to change them. To learn something new, in this realm, you must go through what Argyris calls a double-loop learning or frame breaking.49

Culture, as a set of basic assumptions, tells us what to do in different situations, and how to react emotionally to what is going on (Schein, 1992). Once we have developed an integrated set of basic assumptions, that can be called a thought world or mental map, we will feel comfortable with other people who share the same set of assumptions and very uncomfortable and vulnerable in situations where other assumptions operate. The reason for this is that we either do not understand what is going on or we misinterpret what other people are doing (Douglas, 1986).

As, we have seen, the decision-making process is to a great extent influenced by the organisational structure as well as the culture of the organisation. These aspects are, however, often neglected when developing decision aid. The normative theory, for instance, does not bring up such problems when suggesting rules for decision-making, which is a fatal error. The structure creates boundaries within which people are expected to act, and the culture influences people in their way of acting and thinking when making decisions. The structure of an organisation can, for instance, either be mechanistic (Weber, 1947), organic (Mintzberg, 1983) or something in between. On the basis of such facts we can elicit some information concerning the degree of freedom given to the individuals regarding the decision-making (Lee et al., 1999). Thus, it is not sufficient, to only study the specific decision problem in order to help the decision-makers. One must also study the formal structure of the organisation and the prevailing culture. Otherwise it will become difficult to come up with solutions that will suit the specific situation. Therefore, is it important to become familiar with the current circumstances, i.e. the structure and the culture of the organisation, to be able to “speak the same language” in order to be able to provide sustainable decision aid.

49 See e.g. Argyris, Putnam and Smith (1985) and Bartunek and Moch (1987).
2.6 Discussion

Many books have been written 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). But what happens when people are confronted with real decision problems that do not arrive ready packaged into decision trees, decision tables or influence diagram representations?

“Normative science, typified by statistical decision theory, characterizes ideal inference or decision processes, without assurance that the ideal conditions are met by the humans who must implement them. Descriptive science, on the other hand, typified by psychological and organizational theory, characterize how people actually do infer and decide. Both are well established and thriving fields of research. Prescriptive science, in contrast to both, supports the development of inference and decision aids which are to be used and useful, i.e., aids which humans can effectively supply the input to and use the output from” (Brown and Vari, 1992).

2.6.1 Normative, descriptive and prescriptive theories

We have seen that the normative theory suggests people use different rules for decision-making. We are offered the expected value rule (or the expected monetary rule, EMV, when the decision involves monetary outcomes), and the subjective expected utility rule (SEU) when the decision situation involves risk. We know, however, that people do not always follow the normative rules when making decisions. The SEU model which takes the risk aspect into consideration has been criticised since many argue that by measuring the utilities this takes the decision-maker away from the real world, into a hypothetical world of game and lottery situations (Tocher, 1977). Additionally there has been criticism of this theory since people do not always act in accordance with the rules of utility theory, and Allias’ paradox is, for instance, one example that has been used for this purpose. The normative theory, moreover, in most cases ignores different aspects of decision-making such as the decision-making situation, psychological aspects of decision-making, the decision-making context and the human tendency to act on the basis of given conditions such as time constraints, lack of information etc.
The *descriptive theory*, on the other hand, intends to explain how real decisions are made, why people make decisions the way they do and why people do not always follow the normative rules for decision-making. The descriptive theory also tries to explain why people who attempt to be rational end up being non-rational or at least less rational than they wish to be. Simon (1955, 1976) argues that people have limited information-process ability and that they therefore can not be completely rational. Simon says that people do not have complete knowledge about the consequences of their acts and that people do not have complete knowledge about the alternative courses of action available to them (or they can not afford to attain that knowledge). Simon also states that people do not make a complete list of alternatives before making a decision, instead they simplify choice problems, consider only a subset of the entire set of alternatives and on those grounds they choose one alternative that seems “good enough”. People also search for alternatives among a well-worn path (March and Simon, 1958). According to March (1994), the limited information-process ability forces decision-makers to consider only a few alternatives, instead of considering all the alternatives, and to look at them sequentially rather than simultaneously.

The *bounded rationality* behaviour will also be influenced by the decision-makers environment, internal as well as external (Lee et al., 1999). Simon (1976) says that individuals have decisions made “*subject to the influences of the organization group in which he participate.*” (p.79). This is done through division of labour, the authority system, channels of communication, standard practices, and training and indoctrination (ibid.). So, all in all, Simon states that the "*behavior of individuals is the tool with which organizations achieve its purposes*" (ibid., p.108) and that the individuals are the tools of the organisation. Furthermore, people do choose differently from risky prospects depending on the *framing process*, i.e. the tendency for people to make different decisions based on how the problem is presented to them (McNeil et al., 1982, Slovic et al., 1983 and Tversky and Kahneman, 1981, 1982, 1986). Another situation when people violate the expected utility theory is when the gains are replaced by loses in the risky prospects50 (Markowitz, 1952, Fishburn and Kochenberger, 1979, Riabacke, 2000 and Williams, 1966). The normative theories, however, do not pay any attention to these problems even though these results are very important in order to understand how people think, and to gain understanding of why people act the way they do (Bell et al., 1988).

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50 This phenomenon is called the *reflection effect*. 
The prescriptive theory attempts to help people make better decision by identifying the discrepancies between real (descriptive) and idealised (normative) behaviour in decision-making. While the normative theory focuses on all kinds of decision problems and the descriptive theory on a class of decision problems, the prescriptive theory focuses on one specific decision problem at a time (Keeney, 1992). To be able to provide decision-makers with successful decision support the analyst and the decision-maker must understand each other and “speak the same language” (French and Rios Insua, 2000).

It is of great importance that the decision analyst has a good understanding about the individuals in the organisation in order to provide the decision-maker with methods that are practically useful and that are transparent to them. Thus, we must capture the way people think, the way people actually make decisions, and of course how the organisation expects them to act.

This is important since the prevailing culture and structure of the organisation very much controls and guides the decisions made by individuals (Simon, 1976), and one key aspect of the organisational structure is the way it should outline and facilitate decision-making. (Lee et al., 1999)

2.6.2 The structure and the culture

The structure will thus set the rules by which individuals should make decisions, and, furthermore, it will create the boundaries within which people are expected to act (ibid.). The structure of an organisation can of course be constituted in many different ways. One notable difference is, for example, between organisations that are mechanistic and organisations that are organic (Burns and Stalker, 1961). These two forms are extremes and many organisations lie somewhere in between. These two forms of structure seem to dictate different types of decision-making climate, in the mechanistic organisations the authors identified a highly centralised decision-making and in organic organisations they identified highly decentralised decision-making (ibid.). So, it seems that the degree of decision-making freedom differs depending on which type of structure the organisations possess. People within the organisations are thus subject to a wide range of influences when making decisions, i.e. the way the structure dictates what is expected of them and

51 See table 4.
what the culture of the organisation “tells them to do”. Since structure and culture are linked to each other it is also very important to consider the impact of culture on the way in which people make decisions.

Schein (1992) has defined culture as the correct way to perceive, think and feel, and the implication of the definition is that it will influence the way people actually perceive their role in the decision-making process. It is important to notice that culture itself can be analysed at different levels (see figure 5), such as the level of artifacts, the level of espoused values, and the level of basic underlying assumptions. Schein (1992) states that it is, for instance, very important to understand the basic assumptions, in order to gain a deeper level of understanding and to be able to predict future behaviour correctly. “In fact, if a basic assumption is strongly held in a group, members will find behaviour based on any other premise inconceivable” (ibid., p.22).

In figure 4 we can see the link between structure, culture and levels of trust and freedom. In the autocratic cultures we find a highly centralised decision-making, with low levels of trust in subordinates. In contrast, we find that democratic cultures entrust employees with decision-making powers and that they have a high level of trust in subordinates.

Hence, we have seen that in order to make better decisions by identifying the discrepancies between real (descriptive) and idealised (normative) behaviour in decision-making, we must adopt a holistic approach to the decision-making processes.

Brown and Vari (1992) suggest that one promising line of prescriptive research, among others, is field research.

So, in order to achieve a holistic view of the decision-making process we must study; how managers actually make real decisions? How managers define risk? What are the attitudes of the managers toward risk? Are they risk averse, risk prone or risk neutral? How do the managers manage situations when they are confronted with a risky decision? How do they attempt to manage risk? However, this is not enough. To be able to prescriptively help the decision-makers we must also pay attention to the organisational context.

We need, therefore, to study what type of organisations the decisions are made in, i.e., are they made in highly centralised organisations with low levels of trust in subordinates or are they made in decentralised organisations with high levels of trust in subordinates? What level are the decisions actually made at? In other words, we must examine the structure as well as the culture of the organisations since both, to a great extent influence the decision-making processes. Therefore, to be able to answer the above questions we must study real decision-making in real settings. In the next part of this thesis
results from a study carried out in the Swedish forest industry will be presented.
3. How do managers make risky decisions?

3.1 Background

During the last 40 years, or so, risk has been studied from many different perspectives. However, with the exception of a study by MacCrimmon and Wehrung (1986), and a study by Shapira (1995), empirical research has not generally focused on the conceptions of risk and risk taking held by managers. Since the empirical research has not focused on managerial behaviour concerning risk taking, the area still remains relatively murky. This study was carried out in two major Swedish forest companies and includes interviews with twelve managers. The semi-structured interviews were based on an interview protocol (see attachment-1), 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. 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.

Studies like this, where manager’s risk-behaviour is studied in parallel with analysis of their taken action, have not been previously carried out in the forest industry, or in any other business. Decision-making and risk taking is context dependent (March and Shapira, 1987), and it is therefore necessary to study risk taking in realistic settings, i.e. the context where the action takes place. Today we know by experience that very few people make decisions on the basis of well-deliberated calculations. 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 examples concerning the reasons 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 (see e.g. Simon 1958, 1976). People, for instance, make decisions by following well-known paths and by following well established and built in norms. There is reason to believe that in the Swedish forest industry we may

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52 See Section 1 (Introduction in this thesis).
53 See e.g. Schein (1992) and his discussion concerning Basic Underlying Assumptions.
find similar patterns regarding the decision-making processes. This pilot study, therefore, aims to identify discrepancies between idealised (normative) and real (descriptive) decision-making,\textsuperscript{54} and to point out weak elements in the decision-making process. The results from the study will then be used in order to develop and propose computer based formal methods for how to handle risky situations in a more conscious manner.

\textsuperscript{54} See also Brown and Vari (1992).
3.2 Attitudes towards risk

Cyert and March (1963) conclude that managers avoid risk, rather than accept it. It is also, in the classical literature, widely accepted that most people are risk-averse and that risk and return are positively related (Shapira, 1995). Some studies, however, point out that managers may not necessarily believe that risk and return are positively related, and in a study, made by Shapira (1995), 73% of the managers believed that risk was manageable. The next part of this thesis will analyse the interview answers by examining the following questions. How the managers perceive risk - are they risk-prone or risk-averse? How they perceive the correlation between risk and uncertainty and how do they try to manage risk? How do the structure and the culture affect the way managers make decisions under risk and uncertainty?

3.2.1 What is risk?

When asking the managers how they defined risk, most of them distinguished between different type of risks, such as fire risk, financial risk, technical risk, commercial risk, and investment risk. It is interesting to see that risk means different things to them and that they perceive risk in different ways depending on what area they are working within. The managers did not talk of risk as a general phenomenon; rather it was related to specific situations and specific contexts. Without explicitly being asked about the relationship, several of them perceived uncertainty as a risky element. One of them said, “Risk is an uncertain outcome, some sort of uncertainty in the future.” Another said, “Risk is a decision situation where you deliberately make a decision on basis of uncertain facts”, and he added, “You will never have all the necessary information available. Almost all decisions are made with an eye in to the future and that makes decision-making a risky business. It is also important to remember that “non-decisions” also are risky decisions.” Another manager gave an additional example of the relation between risk and uncertainty and he said, “Uncertainty contributes to the risk and the risk corresponds to the profit.” Half of the respondents also defined risk as something that turns out wrong, i.e. when things do not turn out the way you have planned. These answers correspond to Luce and Raffia’s (1957) definition of a risky situation (see also Section 2.1). They say that a risky situation is a situation where the outcome is unknown to the decision-maker,

55 See for example Pratt (1964), Arrow (1965) and Ross (1981).
i.e. he/she is not sure which outcome will occur and the uncertainty leads to erroneous choices.

### 3.2.2 Risky situations

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 in new 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. When you have made that mistake a couple of times, i.e. entered the market as number one, you learn the lesson and let others take the risks next time.” Another risky area pointed out by a manager was that they were very vulnerable concerning issues related to information technology and he had asked himself, “Who can we trust when dealing with these kinds of issues since we are so dependent on the experts?”

- (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 refuse the figures they have and base their decisions on their “gut reaction”. The main problem, however, according to most of the respondents is the fact that it is not possible, in advance, to see into the future. Thus the uncertainty seems to be one major risk factor.
3.2.3 Risk and return – are they related?

According to Sharpe (1964) 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, some others, e.g. Bowman (1980) and Fiegenbaum (1990), show that there may be a negative correlation between accounting measures of risk and return. In Shapira’s study (1995) 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.58

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 said, explicitly, 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 maximising the return, and in order to do so we must take risks all the time”, “Higher risk corresponds to higher potential profit.” Also “I believe that if you are not willing to take any risk at all you will not receive a good profit either.” However, at the same time as 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 minimise the risks and not take too great a risk. Two of them also said that they are not

57 See also Section 2.2.
58 The remaining 9% felt that risk and return were definitely not related.
gamblers and that they therefore are very careful when taking risks and this was a recurring statement during the interviews.

The managers were also asked to rate the relation of risk and return on the following scale.

1                      2         3           4     5

| Strong Negative Relation | Negative No Relation | No Positive Relation | Strong Positive Relation |

The average of their choice was slightly over 4, i.e. that risk and return had a positive relation. An interesting fact in this context is that none of the respondents rated the correlation negative, and only two of them rated the correlation below 4 (3,5). All twelve 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 said. Two of the others said, on the other hand, that if you have better knowledge about the market (in comparison to your competitors), then it is sometimes possible to achieve good results without taking risks. However, one of them also said that it is difficult to achieve the “little extra” without taking risks and he added, “you must bet to win.”

### 3.2.4 Risk and uncertainty – are they related?

Four of the managers regard risk and uncertainty as almost the same thing and furthermore think 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 don’t!, 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 to risk, and according to them, the level of uncertainty could in many cases be reduced if the actual case was analysed in an orderly fashion. When asking them more specifically what they thought best described the relation between risk and uncertainty six of them felt that uncertainty led to risk, three of them felt that uncertainty and risk were always related, and four of them felt that uncertainty and risk were only sometimes
related. Hence, we can see that the majority of the managers perceive uncertainty as one significant variable that caused a great deal of risk.

### 3.3 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 aspect of the problem, (d) actively work on the problem and in due time (e) delay the decision. The least preferred alternatives are (a) avoid taking risks and (f) delegate the decision. Several of the respondents expressed the view that they disliked alternatives (a) and (f) and one of them said, “I would like to cancel alternatives (a) and (f) since you can never avoid risk taking or delegate a risky decision.” Three of the others explicitly said that alternative (a) was not a realistic option at all, since risk was always present when making decisions and one manager said that if you do not like decision-making then you should work with something else. The majority of them agreed that taking risks was necessary for the organisation. However, four of them stressed that they would avoid taking risks if the consequences could be “catastrophic”, i.e. if the organisation could not manage the situation if it turned out wrong, and one of them said, “We would never take risks that can jeopardise the whole company.” 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.

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59 The sum is the average of the answers (1 was the most preferred alternative and 6 was the least preferred alternative).
3.3.1 Can risk be managed?

Several studies show that managers do not accept that the risks they face are inherent in the situation and, furthermore, they avoid accepting risk by considering it as subject to control (Strickland et al., 1966). Rather, they believe that using skills to control the dangers can reduce risk. In Shapira’s study (1995) 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). When asking the managers in this study 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 and sufficient knowledge about the problem, and if you are experienced in the field it concerns. One manager said, “The key to success in these matters is that you must learn more all the time about what is going on” and another of them said that you could work on the problem and thus reduce the risk. Most of them, once more, emphasised 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 (see Section 3.3). Those three alternatives are obviously linked to each other and often used in order to manage the risky elements in a decision-making situation.

Simon (1976), however, points out that people do not have, and can not afford to attain, all the necessary information to make optimal decisions. He also says that people, when confronted with real decisions, simplify the choice problems and therefore only consider a subset of the entire set of alternatives and then choose the alternative that seems to be “good enough.”

One additional problem when collecting data (see, e.g., Keeney and Raiffa, 1972 and Shapira, 1995) is the fact that precise objective data is very seldom available (see Section 2.2.1). This means that many situations, where the decision-maker does not have all the necessary information available, must be subjectively estimated. 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 the future states of the world. One of them stated it in following terms, “when you have been working on a problem through a whole process it is possible to make the decisions on the basis of your gut feeling.” Another manager stresses the importance of using intuition and said, “using your intuition is a ability that has been developed during a
long process over many years.” 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 buying a new machine for example (i.e. let the supplier take part of the risk and make this clear in the purchase contract).60

The risk estimates made by the managers were often based on what they identified as experience and intuition, and one of them said that he has an “all together” feeling that guides him. He also added that he used to make a sensitive analysis to check “how great a mistake they could afford to make.” Only one of the managers explicitly expressed that he tried to calculate and quantify the risk. Five of the respondents said that they tried to collect as much information as possible to be able to make better risk estimations. One of them, however, said, “A few times people have tried to subjectively quantify probability estimations – which I do not like… I do not find subjectively made estimations useful at all…” Bell et al. (1988, p.27), however, states that “many, if not all, real decision problems cannot be analyzed adequately using purely objective probabilities.” (see also Section 2.2.1, and Keeney and Raiffa, 1972).

### 3.3.2 Is it possible to identify risk-prone and risk-averse persons?

In Shapira’s study (1995) the interviewed managers were asked if they could identify risk-prone and risk-averse managers, and they responded with unequivocal, clear descriptions. “Risk-prone managers were described as innovative, those who “always try to make changes and improve things,” “transaction oriented,” and “deal makers.” They were also characterized as “confident,” “outgoing,” “outspoken,” and “achievement oriented,” although “slightly messy” and also “aggressive.” Some described risk-prone managers as “open mouthed” and “egocentric.” In contrast, risk-averse managers were depicted as “chicken,” “nervous,” “unsure,” “passive,” “slow,” “yes men,”

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60 The manager who suggested this risk reducing procedure also said, “a project standard must be added to such a contract, and this document should contain the rules about how the work should be done, who is responsible for different phases of the job and who has the over all responsibility, etc.”
“pessimistic,” “reserved,” “spineless,” and other pejoratives.” (ibid., p.55). Furthermore the managers said that a major difference between risk-prone and risk-averse managers is the perceived speed of their managerial work, and many of them also felt that a manager who failed to take risks should not be in the business of managing.

According to five of the respondents in this study 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 – “they do not have to ask about everything.” Several of the managers considered risk-prone persons as those who are willing to make a decision without having “everything” perfectly clear and who are able to make what they called fast decisions. Two of them said that risk-prone individuals are more willing to attempt different kind of changes and are also better prepared to test new things. One of them said, “Some managers want to create new organisational units, while others try to keep the old structure of the organisation as long as possible.”

Other characteristics that were identified among risk-prone individuals;

- their risk behaviour has to do with their personality, and less with their background and education,
- self-confident people are more risk-prone than others,
- those “who are risk-prone are not afraid of making mistakes”
- those higher up in the organisation were more risk-prone.

An interesting angle is that, even though both risk-prone and risk-averse behaviour are desirable qualities in different situations, the managers thought that risk-prone behaviour was something positive and that risk-averse behaviour was something negative. One manager said for instance, “It is always better with someone who takes risks in comparison to those who try to avoid risk taking in every situation.” And another manager said, “A risk-prone person is someone who really wants to make progress and that’s 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 that category. Furthermore, in contrast to the risk-prone, risk-averse people were labelled as those who “complain about innovations” and as those “who do not like any kind of changes.” Risk-averse people were also, according to two of the respondents, those who strive to have control of everything before making decisions, which is not possible and the consequences of this are that the decision-making process in many cases is delayed. Two other managers gave
examples of how managers who delay unpleasant decisions act. One of them gave an example when a manager said, “We will act in this manner…, but we must be sure that we can also do this or this…” and the other managers gave an example when a risk-averse person delivered basic data for decision-making and, as he said, “included 7000 alternatives for it…” These kinds of “back-up” or “save your back” solutions make the decision-making process much more difficult and time consuming than is necessary.

3.3.3 What do the managers think of themselves - are they risk prone or risk averse?

The managers were asked if they saw themselves as a (a) risk-averse person, (b) risk-neutral person, (c) risk-prone person or (d) something else. Two of them chose alternative (a), i.e. they do not like risk taking, four of them chose alternative (b), i.e. they consider themselves neither one way nor the other, and finally the remaining six of them chose alternative (c), i.e. they like risk taking. So, we can see that 50% of them labelled themselves as risk takers and only 16.7% of them label themselves as risk-averse people. A later section (Section 3.5) in this thesis will analyse the choices the managers made when choosing a risky prospect to identify whether the figures above correspond to their actual behaviour. This is interesting for many reasons, one being that one of the managers who labelled himself as a risk-neutral person, when he was confronted with the above question, several times during the interview stressed that he definitely was a risk-prone person…

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

Most of the managers answered “no” when they were asked the above question. 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 modelling investments when doing investment calculations and also when following up as to whether investments had succeeded. The overall impression we got was, nevertheless, that the managers are not familiar with computer based decision tools and that they do not work in “such a way” when solving decision problems and estimating risks (see also Section 3.3.1). Why is it like this, 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.”

3.4 The decision-making context

3.4.1 The organisational structure and the decision-making culture

“One key aspect of organisational structure is the way in which it should outline and facilitate decision making” (Lee et al., p.10), and, therefore also 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 (see Section 2.5.1).

The managers in this study were asked, “How do you perceive the structure of the organisation?”

(a) Bureaucratic with highly centralised decision-making.
(b) Organic with decentralised 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 decentralised, and there has been a lot of progress made during the past ten-years.” So, one can say that the picture of the organisational structure is not easily stated. However, half of the respondents, irrespective of whether they chose (a) or (b), had one opinion in common. Namely that they agreed that decentralised 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 organisation is organic and centralised at the “factory level”, but very bureaucratic above that level – which is unpleasant.” Moreover one of the middle level managers said, “many of us are afraid of making decisions that “daddy” perhaps may approve 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 organisation is decentralised as those higher up in the hierarchy thought. One of them, who had difficulties in deciding whether the organisation was autocratic or democratic, said that it is somewhere in between. However, he also added, “there is often an obvious distance between the directors and others which also affects the flow of information – or more precisely the lack of informal information.”

In 1961 Burns and Stalker identified that organisations can be categorised depending on the degree of structured formality that exists within the organisation (see Section 2.5.2). They defined organisations as either “mechanistic” or “organic” in nature. The mechanistic structure describes the “bureaucratic” approach (Weber, 1947), and the organic structure is what Mintzberg (1983) called an “adhocracy”. One should notice that these two forms are extremes and that organisations can be relatively mechanistic, relatively organic or, something in between. In figure 3 we see the associated degree of decision-making freedom in each form.61

![Figure 3](image)

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 organisations were mechanistic or organic. The organisations were rather, according to the managers, a mixture of both. And it could perhaps be explained by the fact that several of the managers perceive the organisations 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 organisation, concerning the level of trust in

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61 In the mechanistic structure the decision-making is highly centralised, and in the organic structure the decision-making is highly decentralised (Burns and Stalker, 1961). The mechanistic structured organisations were identified to be suitable in a stable, unchanging environment, and the organic structured organisations were considered to be suitable in an unstable, turbulent environment (ibid.). The significant difference between the mechanistic and the organic organisations can be measured by the degree of freedom given to the individuals in the organisations, especially regarding the decision-making.
subordinates. The alternatives were: (a) Autocratic with a low level of trust in subordinates, (b) Democratic with a high level of trust in subordinates. They had also a third alternative (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 less unconscious and taken-for-granted beliefs that guided them when they made different kinds of decisions. Three of them made statements such as 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 organisational 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/loose their job (see Section 2.5.4). He also added, “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.” Schein (1992, p.12) provides us with a definition of culture which can serve as a basis for discussing the link between organisation culture and decision-making;

“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.”

So, if culture is portrayed as the “correct way to perceive, think and feel” then the implication of this definition is that it will influence the way people in fact perceive their role in the decision-making process. It seems to me that there are lots of unwritten rules that guide the managers in their way of making decisions and that the basic underlying assumptions are strong (see Section 2.5.4, and Schein, 1992). These basic assumptions are similar to what Argyris (1976) has identified as “theories-in-use”, the implicit assumption that guide behaviour and tell people how to perceive, think about, and feel about things.
Since we do not debate or confront basic assumptions, or “theories-in-use”, it is extremely difficult to change them. To learn something new, in this realm, you must go through what Argyris call double-loop learning or frame breaking. Several of the managers 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, “People have a tendency to follow a well-worn path in the organisation. 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.”

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62 See also Argyris, Putnam and Smith (1985) and Bartunek and Moch (1987).
3.5 An analysis of how the managers choose risky prospects

The interview part of the study included twelve managers. One of the managers could not participate in this part, answering the questionnaire containing risky prospects. The eleven managers were asked to act (answer the questions) as they would have done if they had been facing the offered prospects in real decision-making situations (see attachment 2). The aim of this study was to show how the managers chose between the different prospects, if they for instance acted in accordance with the expected utility rules or if they chose inconsistently. The amount of money in the offered prospect varied since the aim was to examine if the behaviour of the managers changed when the sums become larger. Furthermore, they were offered the same type of prospects with a negative outcome in order to be able to study how they acted in loss contra win domains.

3.5.1 Certainty effect

In utility theory the utilities or outcomes are weighted according to their probabilities. In situation 1.1, however, we can see that a majority (82%) of the managers overweight alternative B which was certain, in preference to alternative A (18%), which was merely probable. This phenomenon is called the certainty effect and shows us that people overweight outcomes that are certain to outcomes that are merely probable (Kahneman and Tversky, 1979). Situation 1.2 is then obtained from situation 1.1 by eliminating a 66% percent chance of winning 240.000 SEK from both alternatives and we can see that a change in the character of the prospect completely changed the way the managers chose between the alternatives.

63 This counter-example to the expected utility theory, introduced by the French economist Maurice Allais (1953), is already once mentioned in the introduction of this paper (see Section 2.2.4.3).
Situation 1:
1.1 Which of following would you prefer?
A. 250,000 SEK with probability 33% or B. 240,000 SEK with certainty
240,000 SEK with probability 66%
0 SEK with probability 1%
(18%) (82%)

1.2 Which of following would you prefer?
A. 250,000 SEK with probability 33% or B. 240,000 SEK with probability 34%
0 SEK with probability 67% 0 SEK with probability 66%
(82%) (18%)

We should also notice that the expected values in 1.1A and 1.1B are practically the same, which is also the case in 1.2A and 1.2B. In situations 2 and 3 we find additional examples of the same problem, i.e. the certainty effect. And we can once again state that the managers do not act in accordance with the expected utility theory (see also Section 2.2.4). We find another example of the same phenomenon when we analyse 2.1. Even though the expected value in alternative A is 3,200,000 SEK and 3,000,000 SEK in alternative B, 73% of the managers choose alternative B.

Situation 2:
2.1 Which of following would you prefer?
A. 4,000,000 SEK with probability 80% or B. 3,000,000 SEK with certainty
(27%) (73%)

2.2 Which of following would you prefer?
A. 4,000,000 SEK with probability 20% or B. 3,000,000 SEK with probability 25%
(91%) (9%)

Situation 3:
3.1 Which of following would you prefer?
A. 400,000 SEK with probability 80% or B. 300,000 SEK with certainty
(36%) (64%)

3.2 Which of following would you prefer?
A. 400,000 SEK with probability 20% or B. 300,000 SEK with probability 25%
(91%) (9%)

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64 The expected value for 1.1A is 240,900 SEK and for 1.1B the expected value is 240,000 SEK.
65 The expected value for 1.2A is 82,500 SEK and for 1.2B the expected value is 81,600 SEK.
66 Situations 2 and 3 differ from situations 1.1 and 1.2 since they have only two outcomes.
We also, when comparing situation 2.1 with 2.2, observe that a reduction in the probabilities to win from 100% to 25% has the opposite effect to the reduction from 80% to 20%. An explanation for such an effect could be, according to Kahneman and Tversky (1979), that people prefer prospects that have small variance and high expected value. So, in situation 2.1 for instance we can see that 2.1B (3.000.000) has no variance at all and that 2.1A (4.000.000, 80%) has a large variance and therefore the former prospect would be chosen despite its lower expected value. However, when reducing the prospects the variance between (4.000.000, 20%) in 2.2A and (3.000.000, 25%) in 2.2B may be insufficient to overcome the difference in expected value and the managers therefore chose the alternative that offered the largest possible outcome. In situation 4.1 and 5.1 we face another type of situation where the managers have an obvious tendency to choose the alternative where winning is more probable, without taking into account how large the possible outcome is. In these situations we can see that most of the managers, respectively 82% in 4.1B and 100% in 5.1B, chose the alternative with the highest probability, even though the expected value is the same in 4.1A and 4.1B, respectively in 5.1A and 5.2B.

Situation 4:
4.1 Which of following would you prefer?
A. 600.000 SEK with probability 45% (18%) or B. 300.000 SEK with probability 90% (82%)

4.2 Which of following would you prefer?
A. 600.000 SEK with probability 0.001% (82%) or B. 300.000 SEK with probability 0.002% (18%)

Situation 5:
5.1 Which of following would you prefer?
A. 6.000.000 SEK with probability 45% (0%) or B. 3.000.000 SEK with probability 90% (100%)

5.2 Which of following would you prefer?
A. 6.000.000 SEK with probability 0.001% (82%) or B. 3.000.000 SEK with probability 0.002% (18%)

However, when analysing situation 4.2 and 5.2 we can see that the managers considerably have changed method of choosing between the offered

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67 See also Allais (1953), Markowitz (1959) and Tobin (1958).
alternatives, instead of choosing the alternative with highest probability they now chose the alternative with the lowest probability. Why? The answer to this phenomenon could be that when the probability for winning has dramatically decreased and the chance of winning was possible but no longer probable, people then chose the alternative that offered the largest gain.\textsuperscript{68} So, in this case the managers did not pay that much attention to the probabilities, but rather focused on the possible outcome.\textsuperscript{69}

3.5.2 The reflection effect

So far in this thesis only the preferences between positive prospects have been analysed, i.e., where the outcome is always a win situation. What happens if we replace the wins by losses? When analysing and comparing the prospects in situations 6-9, we can identify a phenomenon called the reflection effect (see also Section 2.3.2). The reflection effect, however, does not appear in the comparison of situation 6.1 and 6.2. This will be discussed later in the thesis. As we can see the reflection effect does imply that risk aversion in the positive domain is replaced by risk seeking in the negative domain.\textsuperscript{70} We can also see that the reflection of prospects around 0 reverses the preference order and we face a mirror image between the positive and the negative prospects, see figure 2.

Figure 2

\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{reflection_effect.png}
\caption{Reflection effect between positive and negative prospects.}
\end{figure}

\textsuperscript{68} See Kahneman and Tversky (1979).
\textsuperscript{69} MacCrimmon and Larsson (1979) have reported similar results.
\textsuperscript{70} Markowitz (1952) early noted the tendency of risk seeking in choices between negative prospects. Fishburn and Kochenberger (1979) and Riabacke (2000) identified similar prevalence of risk-prone behaviour in choices between risky prospects in loss domains. Williams (1966) also made similar findings when he found that translation in outcome cause a shift from risk-averse to risk-prone behaviour.
Situation 6:
6.1 Which of following would you prefer?
A. 400.000 SEK with probability 80% or B. 300.000 SEK with certainty
< (36%) (64%)
6.2 Which of following would you prefer?
A. -400.000 SEK with probability 80% or B. -300.000 SEK with certainty
< (45%) (55%)

Situation 7:
7.1 Which of following would you prefer?
A. 400.000 SEK with probability 20% or B. 300.000 SEK with probability 25%
> (91%) (9%)
7.2 Which of following would you prefer?
A. -400.000 SEK with probability 20% or B. -300.000 SEK with probability 25%
< (27%) (73%)

Situation 8:
8.1 Which of following would you prefer?
A. 4.000.000 SEK with probability 80% or B. 3.000.000 SEK with certainty
< (27%) (73%)
8.2 Which of following would you prefer?
A. -4.000.000 SEK with probability 80% or B. -3.000.000 SEK with certainty
> (82%) (18%)

Situation 9:
9.1 Which of following would you prefer?
A. 4.000.000 SEK with probability 20% or B. 3.000.000 SEK with probability 25%
> (91%) (9%)
9.2 Which of following would you prefer?
A. -4.000.000 SEK with probability 20% or B. -3.000.000 SEK with probability 25%
< (27%) (73%)
When comparing situations 8.1 and 8.2 we can see that most of the managers (73%) preferred 3,000,000 SEK with certainty in preference to 4,000,000 SEK with probability 80%. But when looking at the loss domain, in situation 8.2, we can see that most of them (82%) were willing to accept a risk of 80% to lose -4,000,000 SEK in preference to a certain loss of -3,000,000 – although 8.2A has a lower expected value. As mentioned above the comparison between situation 6.1 and 6.2 does not display such an obvious reflection since 55% of them were willing to accept a certain loss of -300,000 SEK (6.2B) in preference to a risk of 80% to lose -400,000 SEK (6.2A). However, when comparing situations 6.2 and 8.2 one conceivable explanation could be that the managers chose a certain loss when the loss is not so high, but when the loss increases they turned to a more risk prone behaviour. When analysing situations 8.2 and 9.2, we can see that by reducing the prospects from -4,000,000, 80% to -4,000,000, 20%, and from -3,000,000, 100% to -3,000,000, 25%, their methods of choosing between the prospects shifted compared to that presented in a win situation, see situation 8.1 and 9.1. So, what we can see is that when there is no longer a certain win prospect then they did not choose the prospect with the lowest variance, instead they chose the prospect with the highest expected value, see situations 8.1 and 9.1. This is, however, not the case in a loss domain. When there was no longer any certain loss, they chose the prospect with the highest expected value instead, compare for instance situations 8.2 and 9.2.

In situation 10 we face two situations that express the reflection effect in a slightly different manner. In situation 10.1 we can see that 64% of the managers chose Alt. A even though the probability of winning was as low as 0,001% and the expected value was the same as in Alt. B (500 SEK). In situation 10.2, with negative outcomes, we observed the opposite. Now most of them preferred a certain loss of -500 SEK in preference to a 0,001% risk of losing -500,000 SEK. So what does this imply? It could imply that the managers disregarded the low probabilities if the possible outcome was large – but only in the positive prospect. In the negative prospect, in situation 10.2, we can instead establish the fact that most of the managers chose the certain loss in preference to -500,000 SEK with probability 0,001%.
Situation 10:

10.1 Which of following would you prefer?
A. 500.000 SEK with probability 0.001% or B. 500 SEK with certainty

64% 36%

10.2 Which of following would you prefer?
A. -500.000 SEK with probability 0.001% or B. -500 SEK with certainty

18% 82%

In situation 10.1 we note that the managers preferred what was in effect a lottery ticket to the expected value of that ticket. On the other hand in situation 10.2 they preferred a small loss, which can be viewed as a payment of an insurance premium, to a small probability of a large loss. These situations that are characterised as high consequence-low probability events have been confusing economists for a long time, because the same person may buy both insurance and lottery tickets.71 “The former being a display of risk aversion and the latter, of risk seeking” (Shapira, 1995, p.11).

3.5.3 The isolation effect

When people try to simplify the choice between alternatives, they tend to disregard components that the alternatives share, and focus on the components that distinguish them (Tversky, 1972). This phenomenon is referred to as the isolation effect. “This approach to choice problems may produce inconsistent preferences, because a pair of prospects can be decomposed into common and distinctive components in more than one way, and different decompositions sometimes lead to different preferences.”(Kahneman and Tversky, 1979, p.192). When analysing situations 11 and 12 we can see that most of the managers (64%) chose Alt. B in the first situation, i.e. they preferred 50.000 SEK with certainty in preference to 100.000 SEK with probability 50%. In situation 12 most of them then chose Alt. A, i.e. they preferred -100.000 SEK with probability 50% in preference to -50.000 SEK with certainty. These preferences confirm the results we received in situations 6-9, which display risk seeking for negative prospects and risk aversion for positive prospects. Note, however, that situations 11 and 12 are identical in their final states, i.e. the expected value in all four situations is 150.000 SEK. So, the apparent neglect of a bonus that was common to both options in the situations below, indicates that the carriers of values or utility are the changes in wealth, “rather

71 An interesting notation in this realm is that Shapira and Venezia (1992), when studying the purchase of state lottery tickets, found that the demand for the lottery tickets where related to the size of the first price but not to the expected value.
than final asset positions that include current wealth” (ibid, p.195, see also Section 2.3.2).

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 probability 50% and B. 50,000 SEK with certainty
(36%) (64%)

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 probability 50% and B. -50,000 SEK with certainty
(73%) (27%)

The results in situations 11 and 12 also exhibit the framing problems, i.e. that people may choose in opposite way and end up with contrary results when data are presented in different, but mathematically equivalent, ways which is also the case in the example below. These problems are however totally ignored by the normative theories (Bell et al., 1988). But, it is very important to handle the framing problems cautiously when supporting people in making decisions (see also Section 2.2.4.4).

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72 Among others has McNeil et al. (1982), Slovic et al. (1983) and Tversky and Kahneman (1981) 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. So, why are many people inconsistent in this respect? One thesis is that irrelevant contextual effects influence people. Tversky and Kahneman (1981) give an example (also earlier presented in Section 2.2.4.4) by offering a choice between two programs (see below) which aims to fight an Asian disease that is expected to kill 600 people.

Program 1
A. Exactly 200 will be saved
B. A 1/3 probability that 600 will be saved, and a 2/3 probability that none will be saved.

72% out of 152 persons preferred program A. Then 155 persons where offered the same choice in a different formulation:
Program 2
A. Exactly 400 will die
B. A 1/3 probability that nobody will die, and a 2/3 probability that 600 will die.

This time 22% preferred program A. The idea is to show that irrelevant contextual effects may influence a decision-maker.
3.6 Discussion

The managers referred to risk as something that was related to specific situations and to specific contexts, and they identified different types of risk such as fire risk, financial risk, technical risk, commercial risk, and investment risk. However, when they were asked to describe risky decisions they have recently made or risky situations they have recently been involved with, more than half of them referred to different type of investment activities. Risk areas within this sphere that they pointed out were investing in new machines and in new techniques, acquisition of new companies, development of new products and entering new markets. When asking the managers how they try to manage risk in different situations the majority of them said that they try to collect more information, check different aspects of the problem and actively work on the problem to reduce the risk. Furthermore, all of them thought that risk could be managed if one has the correct information and good knowledge about the problem.

Many of the managers, however, said that they did not have the necessary information or the skills to estimate different types of risks and that they therefore make their decisions based on intuition and their gut feeling.

The majority of the managers agreed that risk taking is necessary for the organisation and that risk and return are related. In fact, 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.” But, on the other hand, several of them stressed that they are not gamblers and that it is important to reduce the risky elements as much as possible. Four of them also emphasised that one should avoid taking risks if the consequences could turn out to be “catastrophic”. Nevertheless, only two of them explicitly said that they sometimes try to calculate the risk in order to do some sort of sensitive analysis. 50% of the managers defined risk as something that turns out badly and several of them designated uncertainty as a factor in risk and said that uncertainty and risk is almost the same thing. One manager said, “Risk is an uncertain outcome, some sort of uncertainty in the future.” And according to four of the managers the uncertainty could in many cases be reduced if the actual case could be analysed in an orderly fashion. Uncertainty is thus perceived as one significant variable that causes a great degree of risk. It is also noticeable that none of them use any kind of computer-based decision-tools or programs. Two of them, however, do use
Excel for some investment calculations and one of them said that he use to do some risk estimations regarding financial risks by using Excel.

So, it is fair to say that the managers are not familiar with using computer-based decision tools when handling risk and making 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 labelled 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 “good ones”, and that the risk-averse were regarded as the “bad 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.” Another of them said, “A risk-prone person is someone who really wants to make progress and that’s the kind of persons companies are looking for.” So, what about the managers in this study – are they risk-prone or risk-averse? 50% of them labelled themselves as risk takers. Only two of them say that they are risk-averse and the other four lie somewhere in between. When analysing 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, 7.1, and 8.1. In the negative domains, on the other hand, most of the managers tend to exhibit risk-prone behaviour, see e.g. situations 7-9, where the reflection effect appears.

When asking the managers how they perceive the structure of the organisation most of them agreed that it is a mixture of a bureaucratic and an organic organisation with a mixture of a centralised and a decentralised decision-making.
50% of the managers had, however, one opinion in common, namely that they thought that decentralised decision-making was only the case up to a certain level and that most of the important decisions were made higher up in the hierarchy. Several of the managers talked about the fact that they perceive the forest industry to be very hierarchical, and many of them also expressed their fear of doing something wrong, i.e. making poor decisions. It also came to light that the managers higher up in the organisation thought that the decision-making was more decentralised than the managers at the middle management level.

The managers were, furthermore, asked to choose between two alternatives about the culture in the organisation, as to whether the level of trust in subordinates was low or high. Most of them did choose the alternative that expressed that the organisation is organic and that the decision-making in the organisation was decentralised. But, once again many of them said that the decentralised 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.” Several of the managers also talked about it being necessary to “adapt to the style” of the organisation, i.e. to learn what is right and what is wrong to do. One of them said, “We are free to a large extent to perform our job as we want - as long as it fits into the norms.” Two of the top level managers also discussed these issues and established the fact that they wanted to employ people who were willing and able to “adapt to the style of the firm and who were able to fit into the prevailing culture.”

When the managers chose from the prospects in situations 1 – 3 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. But, 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 73% of the managers prefer 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%. And, finally, in situations 11 and 12 we can observe the *isolation effect*. The isolation effect is displayed when the majority of the managers chose between the alternatives, and obviously did not take into account the components of the offered prospect that the alternatives share, 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 the 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.
4. Computerised risk modelling

4.1 What problem areas have been identified?

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. Most of the managers, see chapter 3, also pointed out the lack of information as a source of risk and uncertainty. Four of the managers also stressed the importance of avoiding taking risks that could turn out to be “catastrophic” or risks that they could not afford for some reason. In the light of that it would probably be beneficial to do a formal analysis of several of the decision problems that the managers deal with. Also, when doing such a formal analysis of decision situations, computer-based decision tools can be useful, e.g. in order to do sensitive analysis, risk estimations and to visualise the outcomes of different prospects. Computer-based decision analysis tools could furthermore be valuable support for the managers since many of them explicitly expressed their fear of doing something wrong, e.g. making poor decisions. Keeney and Raiffa (1976) state that using computer-based decision aids can be one method to legitimise and justify decisions that are based on vague information and intuition. Today, however, only a few of the managers use computers when making decisions and none of them actually use any type of decision analysis tools. A majority of the managers also stressed the fact that there are a lot of unwritten rules and built into the culture that guides people in their way of making decisions. Janis (1972) states that one symptom of groupthink is the direct pressure on dissenters to conform. Deviation from the group norms are not accepted – the more cohesive the group, the greater the demand for conformity (see also the discussion in

73 Is it possible to use subjective values in formal analysis? Keeney and Raiffa (1972) believe that many complex problems demand the consideration of subjective values and they say that, “It is almost a categorical truism that decision problems in the public domain are very complex. They almost universally involve multiple conflicting objectives, nebulous types of non-repeatable uncertainties, costs and benefits accruing to various individuals, business, groups, and other organizations–some of these being non-identifiable at the time of the decision–and effects that linger over time and reverberate throughout the whole societal superstructure. It would be nice if we could feed this whole mess into a giant computer program the superintellect to generate an “objectively correct” response. It just can’t be done!” and they furthermore say that “a purely “objective” analysis might fall so far short of providing guidelines for decision-making that the output of the analysis may not pass the threshold of relevancy.” (ibid., p.64).

74 See also Janis and Mann (1977). They have identified two types of social pressure that affect the decision-making by individuals. The first one is what they called “anticipatory regret”, which is our tendency to worry about how disappointed we, and others, might feel after we have made an incorrect decision, and secondly, threats, or constraints imposed by others. Bell (1982) discusses a similar phenomenon that he calls “regret aversion”.

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Section 2.5.4, concerned basic underlying assumptions (Schein, 1992)). So, using computer-based decision aids could moreover be one way to circumvent the traditional, well-established, ways of thinking and making decisions. Clemen (1996) discusses decision-making in terms of that decisions are “hard”, i.e. hard to make. They can be hard for many different reasons such as complexity, uncertainty or because the situation contains conflicting objectives, etc. Clemen states that computer based decision-analysis tools might be helpful in order to make the decision-making less hard (ibid.). One problem is, however, as Keeny and Raiffa (1976) discovered that many decision-makers do not undertake a more formal analysis since they have already made up their minds. They also think that decision-makers view the formal analysis as a kind of window dressing. So, if the decision-maker already “knows” what to do, why should he then bother to do a formal analysis? The answer is, according to Keeney and Raiffa (ibid.), that there is a legitimate purpose for doing this.

- Firstly, the decision-maker might want the security of having a formal analysis that corroborates his unaided intuition.
- Secondly, the formal analysis might help him in the communication process.
- Thirdly, he might have to justify his decision to others or he might try to convince others of the carefulness of his proposed action.
- Finally, a formal analysis needs to be done even though your mind is already made up, in order to enable a reconciliation process.

However, before continuing to the modelling of risky prospects, some problems concerning the use of probability and utility values should be mentioned.

The elicitation and the interpretation of utilities are not easily done even in simplified situations such as those illustrated in the next part of this thesis, and the problem will not become easier to deal with when facing complex real life decision problems. There is, however, a multitude of suggestions as to how to

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75 Other studies have also demonstrated the tendency of members of cohesive groups towards excessive conformity, even when this conflicts with the individual’s rational or moral judgement, see for example Asch (1951) and Millgram (1974).
76 See also Dreyfus (1982) who argues that real decision-makers are not interested in the analytical approach of decision-making. For an interesting reply on this statement, see Brown (1984).
motivate the expected utility rule using an axiomatic approach.\textsuperscript{77} But, even if we accept the axioms suggested in these, to be of instrumental value for a decision-maker, the axiomatic approach makes strong requirements of the ability of a decision-maker concerning the actual measurement of the utilities that must be distilled when constructing the proofs. The problem is that the elicitation of utilities takes the decision-maker away from the real problem, i.e., from the real world, into a world of hypothetical lotteries (see Section 2.2.4.2). Others argue that it is difficult to measure the expected utilities and state, that if it only can be measured approximately it is better to use the value function (e.g., von Winterfeldt and Edwards, 1986).

Another line of criticism is that utility theory is insufficient for modelling risk attitudes adequately. Proponents of utility theory often use the following argument to show that the concept of utility captures different risk attitudes.\textsuperscript{78} “Suppose, for example, that all consequence values are monetary. Then associate two expectations with each alternative: its expected monetary value and its expected utility. To each expected utility, there corresponds a certainty monetary equivalent $x_{ce}$. The decision-maker is indifferent to having this monetary value for certain, as compared to the alternative action, i.e., $u(x_{ce}) = \sum p_i u(x_i)$, where $u(x_i)$ is the utility of receiving the monetary value $x_i$. The risk premium $p$ of an act can be defined as the demand that a decision-maker has for carrying out the action, instead of having the monetary equivalent $x_{ce}$ for certain, i.e., $p = \sum p_i x_i - x_{ce}$. Decision-makers can be divided into three classes with respect to the risk premium $p$: a decision-maker is risk averse if $p$ is positive; risk prone if $p$ is negative; and finally risk neutral if $p = 0$.\textsuperscript{79} From this description, it is easy to see how a utility function can be regarded as modeling a decision-maker’s attitude towards risk. Assume that a decision-maker needs a certain amount of money, and a small amount would not be very useful to him/her. The decision-maker would normally risk only a certain part of his/her wealth.

However it is not difficult to imagine extreme situations where this does not hold true, such as when he/she is desperately in need of money for a medical treatment of a disease that, if not cured, will result in death. Faced with a choice of buying a ticket or not with his/her last funds that will yield a chance of winning an amount sufficient for paying for the treatment, most rational people would gamble. The risk premium $p$ in such a situation is probably a negative number.” However, the use of a utility function to formalise the decision process with all possible risk attitudes is not possible

\textsuperscript{77} See for example Ramsey (1931), von Neumann and Morgenstern (1947), Savage (1972), Herstein and Milnor (1953), Suppes (1956), Luce and Krantz (1971) and Jeffrey (1983).

\textsuperscript{78} I use the presentation by Ekenberg \textit{et al.} (2001, pp.33-34).

\textsuperscript{79} See also figure 1 and the discussion in Section 2.2.1.
(ibid.) and Schoemaker (1982) states that most mathematical models of decision analysis are oversimplified and disregard important factors. Additional problems are that individuals tend to avoid, if they are given the choice, the use of precise probability estimates, and it also seems that the value of outcomes defines risk for managers, rather than the weighted average of probabilities and utilities (Kunreuter, *et al.*, 1978 and Shapira, 1995). The question also arises as to whether or not people are able to provide the inputs which utility theory requires (see e.g. Fischhoff, *et al.*, 1983). Shapira (1995) gives us an example and he says that people cannot distinguish between probabilities ranging roughly from 0.3 to 0.7. And, furthermore, Ekenberg *et al.* (2001, p.34) state that “even if a decision-maker is able to discriminate between different probabilities, very often adequate information is missing. Consequently, there seems to be significant reasons to discriminate between measurable and immeasurable uncertainty.”

We have now seen that there are several reasons as to why the managers should complement the traditional ways of making decisions by doing a formal analysis. But, how could such formal analysis be carried out? What can be done in order to structure the problems? What decision-analysis tools are available and what type of situations are the different methods useful for?

In the next part of this thesis some examples will be presented of how a formal analysis by using computer-based decision aid can be carried out, and some problems related to such analysis methods will also be discussed.
4.2 Modelling risky prospects

The use of *Decision trees* is one type of technique that can be helpful in order to develop a clear view of a problem, and to make it easier to determine different possible scenarios that may occur if a particular course of action is chosen. Another technique available is *influence diagrams*. These are good for displaying the basic structure of a decision situation, while a decision tree can be used to display more of the details.

Figure 1.4 General decision tree

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80 For a summary of published decision tree applications see; Ulvila (1987), Cohan et al. (1984), Bell (1984), Hosseini (1986), Madden et al. (1983), Winter (1985) and Hertz and Thomas (1984). See also Raiffa (1968) for an early presentation of the use of decision trees.

81 An influence diagram is a graphical display of the elements of a decision problem and their relationship. In the diagram rectangles represents decisions, ovals represents chance events, and rectangles with rounded corners represents a constant value (consequences) (Bodily, 1991). The tree shapes are referred to as nodes: decision nodes, chance nodes, and consequence or calculation nodes. Nodes are put together in a graph, connected by arrows or arcs (Clemen, 1996). For a more extensive presentation of symbols used in an influence diagram see Bodily (1985, fig. 3.2) where he extends influence diagrams to cover preferences. Influence diagrams are usually easily understood as they give non-detailed information about the problem (Bodily, 1985, 1991 and Clemen, 1996), and because they can be easily revised and altered when the decision-maker and the decision-analyst iterates with each other. One of the most important applications of influence diagrams, according to Watson and Buede (1987), is the communication between a technical decision-analyst and a substantive decision-maker. If the intention is to create a decision tree out of an influence diagram, it could never have cycles or loops; no matter where the starting point is. This is one of the two conditions that must be met in order to be able to represent an influence diagram as a decision tree. One common mistake, when working with influence diagrams, is that people interpret them as flowcharts. Even though they look a little like flowcharts, they are different in several ways. Since an influence diagram is a snapshot of a decision situation, all different decision elements that play a part in the immediate decision must be taken into account (Clemen, 1996). "Note that the influence diagram has certain flexibilities not available in the decision tree. In the decision tree you must either put Fixed Costs in front of or behind Variable Costs (thus suggesting that it may influence or be influenced by Variable Costs), but the influence diagram can show that no influence relationship exists between them" (Bodily, 1985, p.29). For earlier development of influence diagrams in several forms see Forrester (1968), Owen (1978), Miller (in Miller et al., 1976), Howard and Matheson (1981) and Shachter (1986).
In a decision tree the branches emanating from a *square* correspond to the decision situation where the decision-maker must choose action or direction, and branches from a *circle* represents possible outcomes from a chance event. The third element, the consequence, is specified at the ends of the branches. If a chance node is placed to the right of a decision node, then the decision must be made in anticipation of the chance event. On the contrary, a chance event placed to the left of a decision node means that the decision is made dependent on the outcome of the chance event. One problem is, however, that a chronological sequence of alternatives and unfolding events does not apply to all type of problems. “*Some problems are static, involving cause-and-effect relationships at a single point in time*” (Bodily, 1985, p.14). Consider, for example, a problem concerning different ways to avoid air pollution. The decision variables in such a case might be the capital investment and energy needs of various kinds of pollution control equipment and who will pay for them. The intermediate variables could then be demographics at the site, the level of production at the site and external air conditions. Finally, the outcome variables might be the impact on various tax rates, health effects, and political consequences (ibid.).

The decision trees are, however, useful when displaying details of a problem. One should, nevertheless, be aware of the fact that very large and complex trees, designed to take into account every possible scenario that can occur, may be counterproductive. Some argue that influence diagrams are superior when presenting results to decision-makers, since understanding of graphical illustrations is crucial. And Clemen, (1996), emphasises that influence diagrams are more easily understood by people without a mathematical background. But, on the other hand Bodily (1985) states that some people find that the easiest first step in modelling is to structure the problem using decision trees.

The two approaches have different advantages, one might be better than the other, depending on the problem situation. For example, if the aim is to communicate the overall structure of a model to other people, an influence diagram may be appropriate to use. But if the aim is to make careful considerations and sensitive analysis on specific probability and value inputs then the decision tree approach may be the proper one to use.

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82 See also Raiffa (1988).
4.3 Evaluation of risky prospects

There are vast amounts of computer-based decision tree tools, dealing with various types of risk and multi-criteria analysis. Unfortunately, the majority of these must be provided with precise information and are not really suitable for the analyses of this section, since a representation allowing imprecise statements is needed. Several representations of the latter kind have been suggested. These are generally based on capacities (of order 2), evidence theory and belief functions, various kinds of logic, upper and lower probabilities or sets of probability measures. A common feature of these approaches is that they do not include the additivity axiom of probability theory and consequently do not require a decision-maker to model and evaluate a decision situation using precise probability and utility estimates.

However, a big disadvantage with most imprecise models is that they, to a large extent, are not implemented. Neither do they generally include utility statements and evaluation procedures. An exception to this is the theory of Danielson and Ekenberg (1998), which is implemented in the computer-based decision tool JML-DELTA. The main advantage of that tool is its capability to handle imprecise information provided in intervals as well as relations.

By using this tool, the aim with the evaluations below is to analyse some of the results from the study where the managers have been choosing from the risky prospects (see Section 4.5). This will be done in order to point out situations in which the managers act inconsistently and to propose methods, which make the decision situations easier to analyse. Without going into details concerning the elicitation of utility values, the use of utilities will be introduced. Since we, in real life decision situations, often suffer from the lack of precise objective data, interval estimations concerning probability and utility estimations could be one solution in order to make better decisions under risk and uncertainty. According to Shapira (1995), most people seem to have problems in distinguishing between probabilities ranging roughly from 0.3 to 0.7. It is therefore desirable to also introduce the use of risk constraints (Ekenberg, 2000 and Ekenberg et al., 2001), so the decision-maker will be able to identify unwanted events and thus prevent their occurrence. Managers may, for example, appreciate the option to state threshold values and use them in the evaluation.

84 A good survey of theories of imprecise probabilities is provided in, e.g., Walley, (1991).
85 This is a tool for evaluations that may include a number of different decision criterias. JML-DELTA has been tested in several real-life applications, and has currently been used in a case study involving catastrophic risks in the upper Tiza region in Hungary, see Ekenberg et al. (2002). For a good introduction to the algorithms contained in the JML-DELTA tool see Danielsson (1997).
Before starting the evaluations a few words must be said about how the decision tree tool is used and how to interpret the results displayed in the graphs. A decision frame must capture the structure of the tree internally in the tool once transformed into a one-level form. A one-level tree consists primarily of sets of consequences. Then, there are statements regarding probability and value collected in structures called constraint sets and cores. In graph 5.4, for instance, the evaluation of Alt.1 and Alt.3 in Decision tree 5.1 is shown as a comparison between the two alternatives. The y-axis is the expected value (EV) difference for the pairs. The result is presented as a cone in the figure and consists of three graphs. For comparing Alt.1 and Alt.3, the upper graph shows the maximal difference between EV(A₁) and EV(A₃); the lower graph shows the maximal difference between EV(A₃) and EV(A₁) (and is deducible from the former one). The middle graph shows the average value between these two. The shape of these graphs is generated by calculating these values for various cuts, shown on the x-axis as percentages. The idea behind the cuts is to provide the possibility to consider values near the boundaries of the constraint intervals as being less reliable than the original statements, due to the former being deliberately imprecise. If dominance is evaluated on a sequence of ever-smaller sub-intervals, a good appreciation of the strength’s dependency on boundary values can be obtained. This is denoted as cutting the intervals, and the amount of cutting is indicated as a percentage ranging from 0% to 100%. For a 100% cut, the bases are transformed into single points, and the evaluation becomes the calculation of the ordinary difference in expected values. It is possible to regard the procedure 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.

86 I will use the explanation in Ekenberg et al. (2002).
In example 1, the managers were asked to choose between two alternatives. When analysing the prospect by using the JML-DELTA tool we can see, from the line above the contraction axis in graph 1.1,\(^{87}\) that Alt.1 is slightly better than Alt.2, according to the expected value rule. Nevertheless, 73% of the managers chose Alt.2. As we have seen in this example, and previously in this thesis, managers do not choose in accordance with the normative expected value rules (see Section 2.2.4). Why? The phenomenon that appears in example 1 is called the certainty effect and it shows us that people overweight outcomes that are certain to those that are merely probable (see also Section 2.3.2, and Kahneman and Tversky, 1979). So, even though the expected value is higher in Alt.1 most of the managers took the risk aspect into consideration and therefore chose Alt.2, i.e. they were not prepared to take the 20% risk of ending up with nothing.

Example 1
Which of following would you prefer?
Alt.1 4.000.000 SEK with probability 80% or Alt.2. 3.000.000 SEK with certainty (27%) (73%)

Decision tree 1.1

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\(^{87}\) If the line above the contraction axis had been below the contraction axis then alt.2 been the better alternative.
In example 2 the monetary values are replaced by arbitrary assessed utilities, in order to take the decision-makers attitude to risk into account. Bernoulli (1954) was the first person to identify the differences between the objective economical outcome and the value of consequences (see Section 2.2.4.1). The allotted utilities in example 2 are 0.5 for C1, 0 for C2, and finally 1 for C3. These utility assessments are, according to the results in example 1, feasibly realistic as to how the managers have valued the prospects when they chose between them. One can assume that they valued the certain outcome to be approximately twice as valuable as the uncertain one. These subjectively assessed utility values are now applied in decision tree 2.1. By treating these utilities in the same way as the monetary values we are now able to identify the course of action that leads to the highest expected utility, instead of the highest expected monetary value.
Example 2

Decision tree 2.1

Thus, we can clearly see in graph 2.1 that Alt.2 is the preferable alternative, which also reflects the results in example 1, whereas 73% of the managers chose Alt.2. So, what does graph 2.1 actually tell us? It tells us that they had been choosing the less risky alternative, i.e. that they were risk-averse and wished to avoid the uncertain prospect, and that they do not choose in accordance with the expected monetary value rules. So, when relying on utility values instead of monetary values, we also include the manager’s attitude to risk, and end up with contrary results in comparison to the results in graph 1.1.
Example 3 displays an additional scenario to example 2. The difference in this example is that Alt.1 has been provided with a utility value instead of the utility values that the chance nodes C1 and C3 would have been provided with, as in example 2. This is probably a more correct way of handling the problem since the decision-maker does not choose between three alternatives, C1-C3, but merely the two alternatives, Alt.1 and Alt.2. The utility value for Alt.1 is given as an interval, i.e. that the subjectively estimated utility is in the interval of 0.3-0.5. And even though we do not specify any precise value of the expected utilities, we can see that Alt.2 still is the better alternative. Graph 3.1 also shows us that there is a range in the utility outcome because we use interval estimations in this case.

Example 3
Decision tree 3.1

\[\text{Graph 3.1}\]

\[\text{Since this is not easily done even in these relatively simply decision situations, see also the discussion in Section 4.1 and Section 5.}\]
Let us now look at example 4, where we deal with the same type of prospect as in example 1, but in this case with negative outcomes. The managers were asked to choose between the following alternatives:

Example 4

Which of following would you prefer?

Alt.1. -4.000.000 SEK with probability 80% or Alt.2. -3.000.000 SEK with certainty (82%) (18%)

The analysis in graph 4.1 shows us that Alt.2 is slightly better than Alt.1, i.e., Alt.2 has the lowest expected loss (-3.000.000 VS. -3.200.000). However, we can see that a majority (82%) of the managers nevertheless preferred Alt.1. In decision tree 4.2 and graph 4.2 we find the same example analysed by using utility measures instead of monetary values. Since they did not want certain loss (-3,000,000) they valued Alt.1 higher. When providing the decision tree with utilities in order to analyse the prospect, with regard to the managers’ attitude to risk, we rank the 0-outcome as the best possible one. So, C2 in Alt.1 is provided by utility 1.
The second best alternative was, according to the choices the managers have made, C1 in Alt.1. C1 is thus subjectively provided by utility 0.6. The last preferred alternative was Alt.2, and it will therefore obtain utility 0.2.

Decision tree 4.1

Graph 4.1

Hence, we can establish the fact that they rank C1 three times higher than Alt.2, i.e., they are willing to take the risk of loosing more than the certain loss should have been. We can therefore assume that the managers, more or

\[89\] Or alt.1 as an entirety, as the problem illustrated in example 3.
less implicitly, have assessed utilities that correspond to their intuitive attitude to risk, i.e. they are more risk prone in loss domains. In graph 4.2 we can now see that Alt.1 is a better alternative according to the use of utility values, which also reflects the way they did choose.

Decision tree 4.2

Graph 4.2

We have in the above examples (examples 1-4) seen that it is possible to evaluate risky prospects by using decision trees. Decision trees are also, as demonstrated above, helpful when analysing risky prospects not only by using the expected value rules, but also when analysing the problems by using the
expected utility rules. This is important for several reasons. The managers’ attitude to risk is one such reason as we have seen. Other motives for using the expected utility rules are, more explicitly, the possibility to work with decision situations involving multiple objectives and also to involve other values than strictly monetary. Examples of such values are environmental values, social values, health values, political values, etc.

So, how can these techniques be used in real-life decision situations? Let us, by way of conclusion, look at a simplified fictitious decision situation. The decision problem will be evaluated by using the expected utility principles, i.e. that the probabilities will be subjectively estimated. Shapira (1995) says that such estimates can only be subjective and since most risky choices refer to future states of the world, subjective estimation of probabilities is a fundamental part of risk taking processes (see Section 2.2.1). These examples represent an investment situation concerning a machine purchase.

4.3.1 Computer based prescriptive decision support – an investment example

These fictitious investment problem deals with decision problems concerning investing in a new paper machine or not. We have three options in the first phase of the problem; (1) buy machine-1, (2) buy machine-2, or (3) keep the old machine. In table 9 we can see how much each alternative should cost to purchase.

Table 9

The estimated cost for each alternative is:

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Cost (SEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt.1. Machine-1</td>
<td>6.000.000</td>
</tr>
<tr>
<td>Alt.2. Machine-2</td>
<td>3.600.000</td>
</tr>
<tr>
<td>Alt.3. Keep the old machine</td>
<td>500.000</td>
</tr>
</tbody>
</table>

The cost for each alternative is then used in order to provide each branch, after decision situation D1, in decision tree 5.1 with a value (a negative value since it is a cost). The next step, in order to calculate the expected monetary value for each alternative, is to estimate the expected income from the products that will be sold and each machine is able to produce. This will, in this case, be done by calculating three different possible sale scenarios, A, B and C for each investment alternative. Each scenario will be estimated with a probability value in an interval. If we chose Alt.1, for instance, then the estimated
probability to sell for a sum somewhere between 5,500,000 – 6,500,000 is in the interval of 10 – 15%, and so on. Below in table 10 we can see the possible sale scenarios for each alternative.

Table 10

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Scenarios</th>
<th>Probabilities</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt. 1</td>
<td>A</td>
<td>0.08 - 0.15</td>
<td>5,500,000 - 6,500,000 SEK</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.83 - 0.90</td>
<td>9,000,000 - 15,000,000 SEK</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.01 - 0.02</td>
<td>-2,600,000 - -1,600,000 SEK</td>
</tr>
<tr>
<td>Alt. 2</td>
<td>A</td>
<td>0.15 - 0.20</td>
<td>3,000,000 - 4,000,000 SEK</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.75 - 0.80</td>
<td>4,500,000 - 5,500,000 SEK</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.00 - 0.05</td>
<td>-3,000,000 - -1,000,000 SEK</td>
</tr>
<tr>
<td>Alt. 3</td>
<td>A</td>
<td>0.65 - 0.70</td>
<td>6,000,000 - 6,500,000 SEK</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.10 - 0.15</td>
<td>4,000,000 - 4,200,000 SEK</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.15 - 0.20</td>
<td>-100,000 - 400,000 SEK</td>
</tr>
</tbody>
</table>

In decision tree 5.1 we can now see that each branch after the chance events E1 – E3 is provided with input data concerning monetary values (investment costs and estimated incomes). The branches are also provided with probability estimations concerning how possible it is that the different sale scenarios will occur (after that one of the three alternatives has been chosen).
The results from the evaluation in decision tree 5.1 are displayed in graphs 5.1 – 5.3 and we can see the expected monetary values for each alternative.

- Alt.1 is analysed in graph 5.1 and we can see that this alternative has an average expected monetary value of **5,079,800 SEK**. On the basis of the interval estimations we have made in table 10 we also get information about the lowest expected value and the highest expected value. Thus, we can see that the lowest expected value in Alt.1 is 2,243,000 SEK, and that the highest expected value is 8,069,000 SEK.

- When analysing Alt.2 in graph 5.2 we can see that the average expected monetary value is **876,790 SEK**, the lowest expected value is 225,000 SEK, and that the highest expected value is 1,550,000 SEK.

- In graph 5.3 we can see that Alt.3 has an average expected monetary value of **4,250,000 SEK**, that the lowest expected value is 3,870,000 SEK, and that the highest expected value is 4,635,000 SEK.
Graph 5.1

Graph 5.2
What conclusions can we draw from the above analysis? If we follow the expected value rule we can easily see that Alt.1 is the most preferable since it has the highest expected value. However, we also notice that the span between the lowest and the highest expected value is much larger in Alt.1 than in Alt.3. What does this imply? What is the important difference between these two alternatives? Let us study graph 5.4 and compare the expected value distributions of Alt.1 and Alt.3.
The graph confirms that if we follow the expected value rule then Alt.3 should be considered as the best alternative, since it has an expected value that is 829.800 SEK higher than in Alt.3. We can furthermore observe that Emax(Alt.1) - Emin(Alt.3) is 4.199.000 SEK, and that Emin(Alt.1) - Emax(Alt.3) is 2.392.000 SEK. And that the span in the expected value in Alt.1 is 5.826.000 SEK, and only 765.000 SEK in Alt.3, see also table 11.

Table 11

<table>
<thead>
<tr>
<th></th>
<th>Lowest expected value</th>
<th>Expected value</th>
<th>Highest expected value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt.1</td>
<td>2.243.000</td>
<td>5.079.800</td>
<td>8.069.000</td>
</tr>
<tr>
<td>Alt.2</td>
<td>225.000</td>
<td>876.790</td>
<td>1.550.000</td>
</tr>
<tr>
<td>Alt.3</td>
<td>3.870.000</td>
<td>4.250.000</td>
<td>4.635.000</td>
</tr>
</tbody>
</table>

This signifies that Alt.1 is a riskier alternative than Alt.3, and that we have a more concise expected value distribution in Alt.3. If C2 for instance, with probability 83-90%, in Alt.1 occurs, the value of that event will be 3.000.000 - 9.000.000 SEK. But, if C3, with probability 1-2%, Alt.1 occurs, then the value will be somewhere between -7.600.000 and -8.600.000 SEK. The worst possible scenario in Alt.3 is if event C9 occurs. The value of C9 is -100.000 - 500.000 and the probability for this event is 15-20%. So, since the difference
between the expected values in Alt.1 and Alt.3 is not large, the decision-maker must consider other aspects of the problem in order to choose between them. The decision-maker must for instance take into consideration whether he/she can afford, or is willing, to take the 1-2% risk of loosing approximately 8.000.000 SEK when the expected value is only slightly higher in Alt.1 than in Alt.3.

One way of handling this type of problem is to introduce risk constraints. This can be useful since several of the managers explicitly stressed the importance of avoiding taking risks that could turn out to be “catastrophic” or risks that they can not afford for some reason. This is, furthermore, important in order to analyse which decisions, or which parts of a particular decision situation, must be more thoroughly analysed.

4.3.2 Risk constraints

Let us introduce risk constraints into the investment example above. One feasible scenario could be, irrespective of which alternative is chosen, that the management wants the return to exceed 1.500.000 SEK, and that they can manage a deficit that no more than -500.000. In table 12 we find two threshold values implemented. The first stated value is a Min Value, which is 1.500.000 SEK, i.e. that the return must not be below that value. The second threshold value implemented is Max Probability, which indicates that the first value, 1.500.000 SEK in return, must occur with a probability of 0.85 or higher. When analysing the security levels in table 12 we can see that Alt.1 will yield 1.500.000 SEK with a probability that is higher than 0.85 (85%) if the uncertainty in the estimated probabilities in decision tree 5.1 can be reduced by 50%. If not, and we keep the estimated probabilities, then there is 17% risk that that return will be lower than 1.500.000 SEK. We can also see that under present conditions we face a risk, which is between 18.33 – 20% in Alt.3 of ending up with less than 1.500.000 SEK. So, one can roughly say that the Alt.1 and Alt.3 are more or less equal when analysing them with parameters Min Value 1.500.000 and Max Probability 0.15.
The next step in such an analysis could be to take a closer look into the loss domain. How much can we afford to lose and what risks are we prepared to take? Let us say that a deficit of -4,000,000 SEK would jeopardise the whole company and we want to know how large a risk we take if we choose Alt.1 for instance. When analysing table 13 we can see that we take a 2% risk of facing a deficit that is -4,000,000 SEK. Are we prepared to take the risk, which can be considered as “catastrophic”? We can also point out that the maximum deficit when choosing Alt.3 is 400,000 SEK with probability 20%.

Table 13
So, in order to sum up and prescriptively help the decision-makers to make up their mind, the results from the analysis above can be presented as follows.\(^9\)

<table>
<thead>
<tr>
<th>Alt.1</th>
<th>Alt.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected value 5.079.800 SEK</td>
<td>Expected value 4.250.000 SEK</td>
</tr>
<tr>
<td>1.500.000 SEK with probability 85%</td>
<td>1.500.000 SEK with probability 80-81.6%</td>
</tr>
<tr>
<td>-4.000.000 SEK with probability 2%</td>
<td></td>
</tr>
</tbody>
</table>

We can see that the two alternatives in the prospect above are relatively similar, except for the fact that Alt.1 contains a 2% risk of ending up with a -4.000.000 SEK deficit. So, how does the argument go at this stage? According to Allais (1953) and the behaviour of the managers in this study (see Section 3.5) most people would probably disregard the expected values, i.e. they would not follow the expected utility rules and would choose Alt.1. When analysing how the managers made their choices from the risky prospects in Section 3.5 we can for example see that situation 1 reminds us of the above current situation. We can furthermore see that a majority of the managers chose Alt. B in situation 1, even though the expected value was practically the same. The “big” difference between the alternatives in situation 1 was that in Alt. A there was a 1% risk of ending up with nothing. Alt.1 above contains a worse risk, namely a 2% risk of ending up with a -4.000.000 SEK deficit and this specific part of the analysis reminds us of situation 10.2 in Section 3.5. We can see in situation 10.2 that a majority of the managers did not want to take the risk of loosing -500.000 SEK even though the risk was very small (0.001%). However, when analysing the choices that the managers have made among the offered prospects in Section 3.5 we can see that a majority of them show risk-averse behaviour in positive domains, see e.g. the results in situation 1.1, 2.1, 3.1, 4.1, 5.1, 6.1, 7.1, and 8.1. In the negative domains, on the other hand, they tend to exhibit risk-prone behaviour, see e.g. situations 7-9, where the reflection effect appears. So, when analysing Alt.1 and Alt.3 in the investment example above in the light of the results from the study in Section 3.5 there is reason to believe that most people would chose Alt.3 and avoid taking the risk to jeopardise the whole company.

\(^9\) This provides further evidence for the need of structured decision support and adequate tools for analysis that are not normative in the classical sense. The resulting choice between Alt.1 and Alt.3 is an instance of a reduction of the kind discussed in Section 2.3.2, i.e., the editing rule or the concept of framing from (Kahneman and Tversky, 1979 and Tversky and Kahneman, 1981). As extensively discussed in Section 2.4.1, the way of framing a problem is of high significance and to a large extent influences the behaviour of decision-makers.
5. Concluding Remarks and Further Work

The overall aim of this thesis has been to study in what type of decision situations (involving risk and uncertainty) managers encounter problems and pitfalls, and to start formalising methods for handling such situations. The main theme of the thesis has been that computer-based prescriptive decision support can be of great value when modelling and analysing risky decisions, in particular when only vague information is available.

With a few exceptions, little has been done in this boundary between how real decisions, based on imprecise information, are made and the formalisation of decision-making rules and processes. 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. However, normative theories have general problems with the issue of validation, and descriptive theories do not really purport to provide instrumental decision aid. For such reasons, more holistic prescriptive decision theories have more recently come into focus. Basically, these aim to assist decision-makers in solving real decision problems individually and to consider various kinds of components. This is a different approach to those that e.g., normative theories hold, when suggesting rules for whole classes of problems. However, a functional prescriptive theory is a difficult task to accomplish.

Making such an attempt, this thesis has suggested an approach to real life decision aid, based on a compilation of normative, descriptive and prescriptive theories within the area of risk taking and decision-making. In particular, some of the problematical features of evaluation through utility theory have been discussed. Managerial decision-making and risk attitudes have been analysed and partly formalised, also taking into account how to relax the demand for precise data in situations where only imprecise data are available. As a component of this analysis, an empirical investigation of managerial decision-making from different risky prospects has been included. This study examined various aspects regarding how managers define risk, how they handle risk, how they make risky decisions and how the organisational context affects the decision-making processes. The results were thoroughly analysed in the thesis against the background of the proposed model, and it was concluded that computer-based decision support could be of great value when modelling and analysing prospects containing risk and uncertainty.

Several issues have been raised in this thesis and some of them are also a matter for further research. In particular, it has been argued that an instrumental decision theory should permit a wider spectrum of risk attitudes
than merely utility theory. It should also give a decision-maker the means to express risk attitudes in a variety of ways, as well as provide procedures for handling both qualitative and quantitative aspects.

The overall goal for further research is therefore to formulate a computationally meaningful decision theory for handling this issue. Pursuing similar goals, some researchers have previously tried to modify the behaviour of, e.g., the principle of maximising the expected utility by introducing regret or disappointment into the evaluation to analyse cases where numerically equal results are considered differently, cf., e.g., Loomes and Sudgen (1982). Several researchers, including Quiggin (1982), have suggested a requirement for functions to modify the probabilities and values. However, Malmnäs (1996) has shown that for these and other proposals, their performance, at best, roughly equals that of the expected value and, sometimes, is inferior to this (e.g., inconsistent with first order stochastic dominance).

As has been argued above, the approach based on the analysis in Section 4 above, seems to be more promising. There is no reason to completely reject the use of the principle of maximising the expected utility, but a reasonable method should provide possibilities for analysing decision situations in a more sensitive way. Ekenberg (2000) has suggested a general framework for modelling classes of decision rules called risk constraints. However, this is a set of modelling techniques and provides no concrete decision rules. Against the results of this thesis, such a work seems nevertheless to be promising, but actual rules have to be produced along these lines. Some possible solutions have become more concrete from the above analysis, but larger classes of rules have to be formulated and calibrated against real life decision-making.

Furthermore, a major obstacle when analysing managerial decision problems are 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., Stanford, 1998, Cope et al., 2000, Druzdzel and van der Gaag, 1995 and Kirkwood, 1997), but so far, little has been concluded. This is particularly true when handling scenarios involving imprecise data.
Literature/References


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Appendix 1 - Survey questionnaire: Risk taking in managerial decision-making.

Dear respondent,

My name is Ari Riabacke and I am a PhD student in the Fibre Science and Communication Network Project at Mid Sweden University. The purpose of this study is to examine the role of risk taking in organisational decision-making. All answers will be handled anonymously.

1. How do you define risk?

2. Think of a decision you have recently made or were involved with in which there was an element of risk.
   (a) Describe the decision
   (b) What are the risky elements in the decision?

3. It is usually thought that risk is related to return or profit, namely, when taking larger risks there is, on average, an expectation of a larger return. What is your opinion regarding this argument?
   Comments:

4. In your opinion (choose one, put an X next to it):

   ____ (a) Return is always related to risk.
   ____ (b) Return is conditionally dependent on risk.
   ____ (c) Return is not necessarily related to risk.
   ____ (d) There is no relation between risk and return.

5. Some people identify risk with uncertainty. What, in your opinion, is the relationship between risk and uncertainty?

6. What do you think best describes the relation between risk and uncertainty? (Choose one, put an X next to it):

   ____ (a) Uncertainty leads to risks.
   ____ (b) Uncertainty and risk are always related.
   ____ (c) Uncertainty and risk are only sometimes related.
   ____ (d) There is no relation between risk and uncertainty.
7. Please rate the relation of risk and return on the following scale:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong Negative Relation</td>
<td>Negative Relation</td>
<td>No Relation</td>
<td>Positive Relation</td>
<td>Strong Positive Relation</td>
<td></td>
</tr>
</tbody>
</table>

Comments:

8. Another version of this relation suggests that “If you don’t take risks there will be no returns.” What is your opinion about this statement? (First, mark your response on the scale by circling a number and then explain.)

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<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not True</td>
<td>True</td>
<td>True Beyond a Certain Level</td>
<td>True for Large Returns Only</td>
<td>Always True</td>
<td></td>
</tr>
</tbody>
</table>

9. What do you do when you are faced with a problem that involves risk? In particular, do you do any of the following? (Please rank 1, where it would be the most descriptive, through 7 the least descriptive.)

<table>
<thead>
<tr>
<th>Rank</th>
<th>(a) Avoid taking risks</th>
<th>(b) Collect more information</th>
<th>(c) Check different aspects of the problem</th>
<th>(d) Actively work on the problem to reduce the risk</th>
<th>(e) Delay the decision</th>
<th>(f) Delegate the decision</th>
<th>(g) Other (specify)</th>
</tr>
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10. Are there any conditions or situations where organizations should:

(a) take risks?
(b) avoid taking risks?
11. Observing other managers who are your superiors, peers or subordinates, can you identify risk-prone (who like to take risk) versus risk-averse (who try to avoid take risk) managers?

How?
   a. Risk-Prone:
   b. Risk-Averse:

12. How do you make your risk estimations? (Explain.)

13. Do you use computer based decision aid when working risk estimations and decision problems?
   _____ (a) Yes, almost every time.
   _____ (b) Yes, sometimes .
   _____ (c) Never.

   If yes, what system or program do you use?

14. Think about previous risky decisions that you have taken – some that have succeed as well as those that were not successful. Reflecting on these, do you think risk can be managed? In what way?

15. How would you describe the environment you are working within? (Choose one, put an X next to it):
   _____ (a) Stable and unchanging.
   _____ (b) Unstable and changing.
   _____ (c) Other. (Specify.)

16. How do you perceive the structure of the organisation? (Choose one, put an X next to it):
   _____ (a) Bureaucratic with a highly centralised decision-making.
   _____ (b) Organic with a decentralised decision-making.
   _____ (c) Other. (Specify.)

17. How do you perceive the culture of the organisation? (Choose one, put an X next to it):
   _____ (a) Autocratic with a low level of trust in subordinates.
   _____ (b) Democratic with a high level of trust in subordinates.
   _____ (c) Other. (Specify.)

18. How do you perceive the decision-making culture of the organisation? Are there, or are there not, unconscious, taken-for-granted beliefs that guide the decision-makers in some way? Explain.

19. Do you usually take decisions involving risk on your own or are there several persons involved?
20. Do you look up on your self as a (Choose one, put an X next to it):

_____ (a) risk-averse person. (Do not like risk taking.)
_____ (b) risk-neutral person. (Are indifferent between taking risk or not.)
_____ (c) risk-prone person. (Do like risk taking.)
_____ (d) Other. (Explain.)
Appendix 2  - Offered prospects

Dear respondent,

I ask you to imagine that you really are facing the choices described in the problems below, and to indicate the decisions you would have made in such a case (with a circle round the alternative you choose). It is important to keep in mind that there is no “correct” answer to such problems. All answers will be handled anonymously.

Situation 1:
Which of following would you prefer?
A. 250,000 SEK with probability 33%  
   240,000 SEK with probability  66%  
   0 SEK with probability 1%  
   or  
B. 240,000 SEK with certainty

Which of following would you prefer?
C. 250,000 SEK with probability 33%  
   0 SEK with probability 67%  
   or  
D. 240,000 SEK with probability 34%  
   0 SEK with probability 66%

Situation 2:
Which of following would you prefer?
A. -600,000 SEK with probability 45%  
   or  
B. -300,000 SEK with probability 90%

Which of following would you prefer?
C. -600,000 SEK with probability 0.001%  
   or  
D. -300,000 SEK with probability 0.002%

Situation 3:
Which of following would you prefer?
A. 4,000,000 SEK with probability 80%  
   or  
B. 3,000,000 SEK with certainty

Which of following would you prefer?
C. 4,000,000 SEK with probability 20%  
   or  
D. 3,000,000 SEK with probability 25%

Situation 4:
Which of following would you prefer?
A. 600,000 SEK with probability 45%  
   or  
B. 300,000 SEK with probability 90%

Which of following would you prefer?
C. 600,000 SEK with probability 0.001%  
   or  
D. 300,000 SEK with probability 0.002%

Situation 5:
Which of following would you prefer?
A. 400,000 SEK with probability 80%  
   or  
B. 300,000 SEK with certainty

Which of following would you prefer?
400,000 SEK with probability 20%  
   or  
D. 300,000 SEK with probability 25%

Situation 6:
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 probability 50%  
   and  
B. 50,000 SEK
Situation 7:
Which of following would you prefer?
A. -6.000.000 SEK with probability 45% or B. -3.000.000 SEK with probability 90%
Which of following would you prefer?
C. -6.000.000 SEK with probability 0,001% or D. -3.000.000 SEK with probability 0,002%

Situation 8:
Which of following would you prefer?
A. 500.000 SEK with probability 0,001% or B. 500 SEK with certainty
Which of following would you prefer?
C. -500.000 SEK with probability 0,001% or D. -500 SEK with certainty

Situation 9:
Which of following would you prefer?
A. -400.000 SEK with probability 80% or B. -300.000 SEK with certainty
Which of following would you prefer?
C. -400.000 SEK with probability 20% or D. -300.000 SEK with probability 25%

Situation 10:
Which of following would you prefer?
A. -4.000.000 SEK with probability 80% or B. -3.000.000 SEK with certainty
Which of following would you prefer?
D. -4.000.000 SEK with probability 20% or D. -3.000.000 SEK with probability 25%

Situation 11:
Which of following would you prefer?
A. 6.000.000 SEK with probability 45% or B. 3.000.000 SEK with probability 90%
Which of following would you prefer?
C. 6.000.000 SEK with probability 0,001% or D. 3.000.000 SEK with probability 0,002%

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
C. -100.000 SEK with probability 50% and D. -50.000 SEK

Situation 13:
In addition to whatever is going to happen in a business situation, you have already received 1.000.000 SEK.
You are now asked to choose between
A. 1.000.000 SEK with probability 50% and B. 500.000 SEK

Situation 14:
In addition to whatever is going to happen in a business situation, you have already received 2.000.000 SEK.
You are now asked to choose between
C. -1.000.000 SEK with probability 50% and D. -500.000 SEK

Thank you for taking your time!