The risk preferences of the general public regarding multiple fatalities in large scale accidents

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Riskpreferenser hos allmänheten med avseende på dödsfall i storskaliga olyckor

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Abstract
The purpose of this thesis is to investigate whether the risk attitudes of experts in risk management, i.e. the group of experts participating in the study made by Abrahamsson and Johansson (2006), comply with the preferences of the general public. A major focus of the thesis is the development of the experimental setup, which is based on the trade off method developed by Wakker and Deneffe (1996). This includes investigation of biases associated with the method and of decision strategies used by the public while conducting the experiment. The results show that the public has a risk prone risk attitude, similar to the risk attitude of experts in risk management.

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Summary

This thesis is concerned with risk preferences regarding multiple fatalities in large scale accidents. This means how a person values one human life in a small accident e.g. involving three fatalities compared to one human life in a large accident or a disaster, e.g. involving 1500 fatalities. Is she or he willing to gamble with the risk of having larger disasters in order to gain possibilities of smaller accidents regarding number of fatalities?

Societal risk management decisions are usually handled by experts, often with little input from the public. The purpose of this thesis is to investigate the public preferences regarding multiple fatalities in large scale accidents and compare these results to the preferences of experts in risk management. The main research questions of the thesis are:

- What are the risk preferences of the general public regarding multiple fatalities in large scale accidents?
- Are there any differences in risk preferences regarding multiple fatalities in large scale accidents between the general public and experts in risk management?

The results show that the general public has a risk prone risk attitude (with a β value of 0,59). There is no statistically significant difference between this β value and the corresponding results of Abrahamsson and Johansson (2006), who investigates the preferences of experts in risk management. Consequently, the general public and experts in risk management have the same risk attitude regarding this attribute.

The experimental setup of the empirical study was developed from the study by Abrahamsson and Johansson (2006) which is based on the trade off method by Wakker and Deneffe (1996). The empirical study was executed at Lund City Library on 38 subjects representing the general public and at Lund University on 41 students. In the study subjects were confronted with several morally demanding risk preference decision situations. From these decision situations the subjects' risk attitudes were obtained. This decision process forced subjects to make decisions which many of them never had reflected before. Therefore this process, the strategies used by the subjects in this process and how this affected the subjects became an area of great interest for the thesis.

On an early stage the experimental setup was tested and adapted to the population in question, which was accomplished by a series of tests on 22 test subjects. The testing and adaptation of the experimental setup had two major purposes; firstly to increase the reliability and the validity of the setup and secondly to gain knowledge of what problems a subject exposed to the experiment could experience. During the testing it was observed that subjects conducting the experiment were likely to change their decision strategies and sometimes also their preferences. To investigate these issues the following subordinate research questions were formulated:

- What kinds of strategies for decision making are used?
- Do the population change their strategies while gaining experience in decision making from conducting the test, and if so, in what way?
- Do the risk attitudes of the population change with different sizes of accidents?

This table illustrates the results of the first subordinate research question:

Strategy	Percentage using this strategy	Risk attitude associated with this strategy
Choosing the alternative with the possibility of having the least number of fatalities	~ 50 %	Risk prone
Choosing the alternative with the lowest total number of fatalities	~ 20 %	Risk neutral
Avoid the alternative with the largest number of fatalities	~ 15 %	Risk avert

The second subordinate research question showed that no statistically significant change can be observed regarding the median β value of the whole population as a function of increasing experience or education, although about 30% of the subjects radically changed their risk attitude during the experiment. About 40% of the subjects also stated that they changed their strategy of judging the alternatives during the experiments.

The answer to the third subordinate research question is that there is no statistically significant difference in risk attitude between accidents in the range of 0 to 100 fatalities compared to accidents in the range of 0 to 1000 fatalities.

This thesis has been concerned with the preferences of the general public compared to experts in risk management. The results show that the two groups have similar risk attitude. As a last question in the experiment subjects were asked if they consider the general public or experts in risk management should make decisions in risk management issues in society. The result from this question showed that more than 70% of the population representing the general public wanted experts in risk management to make the decisions.

Sammanfattning (in Swedish)

Detta examensarbete handlar om riskpreferenser hos allmänheten med avseende på dödsfall i storskaliga olyckor. Med detta menas hur en person värderar ett människoliv i en liten olycka, t.ex. med tre döda jämfört med ett människoliv i en stor olycka eller katastrof, t.ex. med 1500 döda. Är hon eller han villig att spela med risken att få en större katastrof för att vinna möjligheten att få en chans på en mindre olycka avseende antal döda?

Riskhanteringsbeslut i samhället hanteras vanligtvis av experter, ofta med liten påverkan från allmänheten. Syftet med detta examensarbete är att undersöka allmänhetens preferenser med avseende på dödsfall i storskaliga olyckor och jämföra dessa resultat med motsvarande preferenser hos experter i riskhantering. Examensarbetets huvudfrågeställningar är:

- Vilka är allmänhetens riskpreferenser med avseende på dödsfall i storskaliga olyckor?
- Finns det några skillnader mellan riskpreferenser hos allmänheten och experter med avseende på dödsfall i storskaliga olyckor?

Resultaten visar att allmänheten har en riskgillande riskattityd (med ett β-värde på 0,59). Det finns ingen statistiskt säkerställd skillnad mellan detta β-värde och motsvarande resultat hos Abrahamsson och Johansson (2006), vilka undersökte preferenser hos experter i riskhantering. Följaktligen så har allmänheten och experter i riskhantering samma riskattityd avseende detta attribut.

Den empiriska undersökningens utformning utvecklades från Abrahamsson och Johansson (2006) som i sin tur baserades på trade off-metoden av Wakker och Deneffe (1996). Den empiriska studien utfördes vid Lunds stadsbibliotek på 38 personer som representerade allmänheten och vid Lunds Universitet på 41 studenter. I studien blev deltagarna konfronterade med flera moraliskt krävande riskpreferensbeslutssituationer. Utifrån dessa beslutssituationer kunde deltagarnas riskattityder utläsas. Denna beslutsprocess tvingade deltagarna att fatta beslut som många utav dem aldrig tidigare hade reflekterat över. Därför var denna process, de av deltagarna använda beslutsstrategierna och hur detta påverkade deltagarna ett område av stort intresse för examensarbetet.

I ett tidigt skede testades och anpassades den empiriska undersökningens utformning till den avsedda populationen. Detta genomfördes med hjälp av 22 testdeltagare. Testningen och anpassningen hade två huvudsyften; för det första att öka reliabilitet och validitet och för det andra att vinna kunskap om vilka problem deltagarna kunde uppleva. Under testfasen observerades att deltagare ofta ändrade sina beslutsstrategier och ibland även sina preferenser. För att undersöka dessa områden skapades följande underordnade frågeställningar:

- Vilka beslutsstrategier används?
- Ändrar deltagare sina beslutsstrategier efter hand som de får erfarenhet av undersökningen, och i så fall, på vilket sätt?
- Förändras riskattityderna hos deltagare med olika storlek på olyckor?

Denna tabell innehåller resultaten på den första underordnade frågeställningen:

Beslutsstrategi	Andel som använde denna strategi	Risk attityd förknippad med denna strategi
Att välja det alternative som är förknippat med en chans att uppnå det lägsta antalet döda	~ 50 %	Riskgillande
Att välja det alternativ som har den lägsta summan av antal döda	~ 20 %	Riskneutral
Att undvika det alternativ som har det högsta antalet döda	~ 15 %	Riskavert

Den andra underordnade frågeställningen visade att ingen statistiskt säkerställd förändring kan påvisas med avseende på median β-värdet för hela populationen som funktion av ökande erfarenhet eller utbildning, trots att cirka 30 % av deltagarna radikalt ändrade sin riskattityd under undersökningen. Ungefär 40 % av deltagarna uppgav också att de hade ändrat sin beslutsstrategi under undersökningens gång.

Svaret på den tredje underordnade frågeställningen är att det inte finns någon statistiskt säkerställd skillnad i riskattityd mellan olyckor i området 0 till 100 döda jämfört med olyckor i området 0 till 1000 döda.

Detta examensarbete har fokuserat på allmänhetens preferenser jämfört med experter i riskhantering. Resultaten visar att det de två grupperna har liknande riskattityder. Som sista fråga i undersökningen fick deltagarna svara på om de ansåg att allmänheten eller experter i riskhantering skulle fatta beslut i riskhanteringsfrågor i samhället. Resultatet från denna fråga visade att mer än 70 % av de deltagare som representerade allmänheten ansåg att experter i riskhantering bör fatta dessa beslut.

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1. Introduction

In our daily lives we are exposing ourselves and our surroundings to numerous risks, in a tremendously wide range of ways. It can be economical risks, e.g. a risk of loosing your job, environmental risks, e.g. a risk of exposing the environment to a discharge from a chemical plant or risks to your health and safety, e.g. a risk of being injured or killed in a car accident.

Naturally, we are always trying to avoid that people or things that we value are exposed to risks. However it is impossible to eliminate all risks in our society. This implies that we, deliberately or not, always have to make priorities with risk reducing resources.

These priorities can be made on different levels in our society. Here follows three examples of choice situations where priorities with risk reducing resources are revealed. On an individual level the priorities are revealed in many common choice situations, for example the choice between two cars, identical in all ways except safety equipment and price. On a company level the choice situation could be between installing a water sprinkler system in the production facility and investing in a new production unit. Finally, on a societal level the choice could be between lowering the taxes and building median safety fence on busy roads. These examples are intentionally made simple for easy understanding, but in fact almost every choice of any kind affects risk exposure of people or other values in society.

Obviously, these priorities are made by many different decision makers and are based on many different opinions. However, there are circumstances when a priority decision affects risks not only for the decision maker but for many other people, assets or interests in a way that cannot be tolerated by different stakeholders. The bigger the risk and the more wide spread the consequences, the more important that the decision is well founded. Important decisions of this kind are often involving some kind of experts in risk management, e.g. to make risk analysis or evaluating the severity of a potential accident. The opinion of a decision maker and the result of a risk evaluation are based on the risk perception of the decision maker or the person conducting the risk evaluation. Risks are perceived differently depending on the observer. This is true for all people including people with no experience or educational knowledge in risk management as well as experts in risk management.

Important decisions regarding risk management should be made in line with the interest of all stakeholders. Today this creates a potential problem in society since all stakeholders are not involved in all decision making processes that affects their risk exposure.

There are two important steps that need to be taken. Firstly, the issue of risk management decision making should be brought up on the agenda of the public debate. This is in order to make sure that the public are aware that important decisions are made without their involvement and that they find this satisfactory. Thereby these decisions are made more legitimate. Secondly, although the public is not involved in the decision making process it is important that the public opinion is reflected by decision makers and experts in risk management during the decision making process.

This master's thesis aims at investigating the public's preferences regarding multiple fatalities in large scale accidents. The results from this study can be used to shed light on the issue whether the risk preferences of the public corresponds to those of experts.

1.1. Definitions

In the wide field of risk management numerous terms and expressions are used. Unfortunately, several different definitions can be found for these terms and expressions. Table 1.1 contains a summary of the terms and expressions used in this thesis and how they are defined by the authors.

Table 1.1: Summary of definitions

Term	Definition
Accident	An accident is here defined as an unexpected and harmful event which causes injury and/or damage.
Large scale accident	In this thesis the preferences of the public regarding multiple fatalities are investigated. The subjects are confronted with events involving a number of fatalities ranging from 0 to 2400, where events involving low numbers of fatalities could be defined as accidents, while events involving higher numbers of fatalities could be defined as disasters. To avoid confusion, the word large scale accident will be used to describe all events in the range of interest.
Disaster	A disaster is here defined as an accident with large proportions, i.e. an event which causes serious injuries and/or damage.
Risk	In this thesis risk is defined in accordance with the ISO/ICE definition, i.e. as a combination of the probability of an event and its consequence (ISO/ICE, 2002).
Utility	The utility is a way of describing preferences. If a bundle x is preferred to a bundle y this means bundle x is associated with a higher utility than y (Varian, 2006).
Disutility	In this thesis disutility is defined as the opposite of utility described above.
Risk preferences	A subject's risk preferences describe how that person judges different risks in relation to one another and in relation to certain consequences. Risk preferences are specific for a certain choice decision.
Utility function	A subject's utility of a specific attribute can be illustrated with a utility function, where the utility ranges from 0 to 1.
Beta value (β)	In reality the utility function can be very complex. A recognised simplification of this complex function is to assign an exponential function with the exponent β to describe a subject's utility of a specific attribute.
Risk attitude	The shape of a subject's utility function displays that subject's risk attitude. A utility function which is marginally increasing for a positive attribute displays what is called a risk-prone risk attitude. If, on the other hand, the utility function is marginally decreasing for the same attribute it is said to display a risk-avert risk attitude. If the utility function is linear the subject is said to have a risk neutral risk attitude. A subject's risk attitude is based on that subject's risk preferences in one or several choice decision situations.

Experts in risk management	Experts in risk management are here defined as people with educational or professional experience of risk management.
Tolerable risk	Tolerable risk is here defined in accordance with Jacobsson and Lamnevik (2001) as a risk that can be valued as ethically reasonable in relation to its associated benefits.
Risk criteria	Requirements that state what level of risk are tolerable. This can be achieved in many different ways.
Deterministic risk criteria	Risk criteria which take into consideration only the consequence of a specific risk.
Probabilistic risk assessment criteria	Risk criteria which take into consideration both the likelihood and the consequence of a specific risk.
Subjective risk criteria	Risk criteria based on the risk preferences of one or more subjects.
Societal risk criteria	Risk criteria with the purpose of restricting risks that expose important societal values. The major one of these values is the health and safety of the public.
Individual risk criteria	Risk criteria with the purpose of restricting the risk for each individual.
Cost benefit analysis	Risk criteria based on a comparison of the utility of a risk reducing measure with the cost of this measure.

1.2. Background

This master's thesis is related to the FRIVA (Framework Programme for Risk and Vulnerability Analysis, Internet 1) project. FRIVA is an integrated framework research programme run by LUCRAM (Lund University Centre for Risk Analysis and Management, Internet 2) and financed by SEMA (The Swedish Emergency Management Agency, Internet 3). The main mission for LUCRAM is to serve as a dynamic, forward thinking resource for risk management research at Lund University (Internet 2).

FRIVA is divided into 10 subprojects. The second FRIVA subproject focuses on risk and vulnerability assessment methods. Within this subproject Abrahamsson and Johansson (2006) have conducted research on risk preferences on a test population regarding multiple fatalities by means of the so called Trade Off method (Wakker & Deneffe, 1996). The test population consisted of 87 persons with professional or educational knowledge of risk and crisis management issues. The results from the study showed that a majority of the test population displayed a risk-seeking behaviour.

1.3. Purpose

Existing societal risk criteria have been developed by experts in risk management. The purpose of this thesis is to investigate whether the risk attitudes of experts in risk management, i.e. the group of experts participating in the study made by Abrahamsson and Johansson (2006), comply with the preferences of the general public. In a wider perspective the purpose also

includes investigating the strategies and reflections of the public when considering preferences regarding multiple fatalities in large scale accidents.

1.4. Objectives

The main objective of this thesis is to compare the risk preferences of the general public and experts in risk management regarding multiple fatalities in large scale accidents and ultimately state whether there are any differences between these groups.

In order to achieve the main objective, the following subordinate objectives have been formulated:

- To find a method for measuring the public's risk preferences of multiple fatalities in large scale accidents, i.e. to develop the experimental setup used by Abrahamsson & Johansson (2006) and adapt it to suit a population with little or no knowledge of risk and crisis management.

- To identify problems associated with the chosen method, e.g. to identify what problems of understanding the experimental arrangement the subjects experience.

- To solve or to minimize the identified problems

- To collect data to form the basis of a utility function that describes the public's preferences of the attribute multiple fatalities in large scale accidents.

- To draw conclusions from the results regarding the differences in risk preference between the public and experts in risk management.

1.5. Research questions

The main questions in this thesis are:

- What are the risk preferences of the general public regarding multiple fatalities in large scale accidents?
- Are there any differences in risk preferences regarding multiple fatalities in large scale accidents between the general public and experts in risk management?

There are also subordinate questions developed to study the problems of the method:

- What kinds of strategies for decision making are used?
- Do the population change their strategies while gaining experience in decision making from conducting the test, and if so, in what way?
- Do the risk attitudes of the population change with different sizes of accidents?

1.6. Scope

This thesis only covers the attribute multiple fatalities in large scale accidents in the range of 0 to 1000 fatalities. The empirical study is bounded to two groups. The first group represents the general public. The second group is a reference group and consisted of fire safety engineering students at Lund University. The groups consisted of 38 and 41 subjects, respectively.

1.7. Target group for the thesis

The target group for this thesis is people with an interest in societal risk management. To understand all parts of the thesis some educational or professional knowledge in the area of interest is required.

1.8. Scientific sequence of work

The outline of the thesis follows the sequence of the actual work. The writing of the report has been a continuous process during the entire project.

Initially, a time plan was created including the main parts of the work. This plan was updated on several occasions. At this point the major issue was to define the purpose and objectives of the thesis.

The choice of method was closely linked to the definition of the task, since the results needed to be comparable to the work by Abrahamsson and Johansson. Yet, in order to confirm that the method was as adequate and accurate as possible, a survey of different methods was carried out. The survey resulted in important and thorough knowledge of possible biases associated with the family of utility elicitation methods. The knowledge of these biases was taken into consideration when choosing the method.

The general public were assumed to have less experience of reflecting upon abstract decision situations than the population studied by Abrahamsson and Johansson (experts in risk management). This called for an adaptation of the method to the intended population, i.e. the general public, which was accomplished by a series of tests on 22 test subjects. Each test was followed by analysing and evaluation, which resulted in improvements of the method and further testing. This process was repeated according to the so called PDCA-cycle (Plan-Do-Check-Act), Akselsson (2005). The main focus of this process was to maximize the reliability and the validity of the method.

Some problems regarding reliability and validity could not be solved completely. The impact of these issues was further investigated, which lead to the formulation of some control questions in a questionnaire following the empirical preference study. In addition to this, questions regarding demographic data were asked.

In order to investigate the subordinate research questions, three questions were added to the questionnaire. Finally, the purpose of the last question was to shed light on the public's opinion regarding who should decide upon decision making in risk management issues. This was somewhat out of the scope of the thesis. However, the authors considered this being a relevant question to the field of study.

When a satisfactory version of the method was achieved the empirical study was carried out. The empirical study was executed at Lund City Library on 38 subjects representing the general public and at Lund University on 41 students representing a reference group (see Table 1.2). There were mainly two reasons why the group of students did not qualify as representative for the public; they had predetermined thoughts and anticipations on their expected capability of dealing with the questions on the topic and they were a homogenous group regarding demographic data, which clearly separated them from the general public.

Table 1.2: Summary of participants in the study

	Adaptation and testing	Empirical study	
		General public	Students
Number of subjects	22	38	41

The results from the empirical study were analysed and compared to the intended data according to the objectives and purpose. Finally, conclusions were drawn and suggestions on further study and improvements were formulated.

2. The risk management process

This thesis is aiming at investigating preferences regarding multiple fatalities in large scale accidents. These preferences can be used as a basis for expressing societal risk criteria in a probabilistic way. However, this is just a small part of the vast landscape of risk management. The purpose of this chapter is to present an overview of the risk management process with focus on risk criteria in general and probabilistic societal risk criteria in particular.

Risk management is a systematic process which involves analysing, evaluating and controlling risks. There are several different standards for describing the risk management process, e.g. COSO (2004), ICF (2000) and ÖCB (1999). The approach that will be complied with in this thesis is the IEC standard (IEC, 1995). According to this standard, the risk management process can be divided into three main steps, which are shown in Figure 2.1 below.

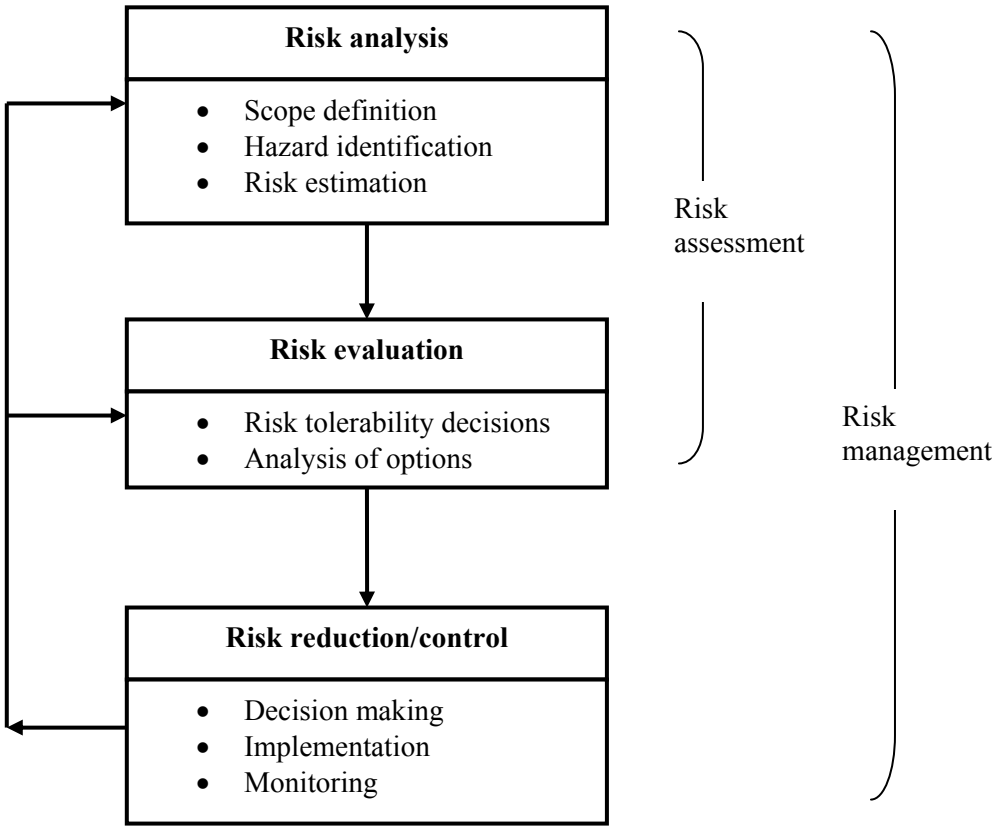

Figure 2.1: The risk management process (IEC 1995). Illustration made by the authors

2.1. Risk analysis

There is an incredible amount of different risks; the area of risk analysis is therefore much diversified. The structure, method and extent of the risk analysis step are depending on the specific situation and the desired accuracy. Because of this, a first step must be to define these parameters.

Identifying the hazards and making an inventory of them is a central step of the analysis. In order to keep the extent on a reasonable level it is often necessary to make some kind of priority, excluding those hazards which are considered acceptable from the analysis.

The next step is to perform a more thorough examination of the chosen hazards. This can be done in many ways. These ways are often classified as qualitative or quantitative analysis methods. The quantitative risk analysis methods (QRAs) are more advanced than qualitative ones in the matter of accuracy (Mattsson, 2000).

2.2. Risk evaluation

Over the years QRAs have become more frequently used as a foundation for decision making (Abrahamsson, 2002). Still, well performed risk analyses are not enough to provide sufficient basis for decisions on how to manage risks; there is also a need for risk criteria stating what risks are tolerable and what risks are not. The risk evaluation step is about deciding what these criteria are. This step also includes a process of investigating the consequences of different risk management options. For instance, at a chemical plant the purpose of formulating risk criteria can be to minimize production interruptions to a cost efficient level, while a transport company can formulate their criteria to minimize the impact on the environment in the case of an accident.

Even if a risk is considered tolerable by society it might be cost efficient to take further control of it. An example could be the storage area of a production company. Since there are few people working in the area, all of them having good knowledge of the working environment, the risk of casualties in case of fire is tolerable. However, the stored goods are valuable, and the economic loss in case of fire can therefore be large. In this case further control of the fire risk is desirable, e.g. installation of an automatic water sprinkler system.

2.3. Risk control/reduction

This step involves decisions on how to handle risks, e.g. reducing, accepting, insuring, separating or dividing them. The implementation and evaluation of the measures are also parts of this step. If the evaluation shows that the magnitudes of the risks are still unsatisfactory, the whole or part of the process is to be repeated until the result is satisfactory.

It is also important to notice that risks are dynamic, which means that even if no actions are taken the risks might change over time. This calls for monitoring, i.e. continuous review of all risks in order to keep them from becoming intolerable or keeping the enterprise from putting more resources into controlling them than considered necessary. A part of this is keeping track of current legislation and societal demands, i.e. the tolerable level of risk.

2.4. Societal risk management decision making

According to COSO (see above) the purpose of every enterprise and activity is to create values for its stakeholders. Stakeholders are here very widely defined as every subject who can benefit from the enterprise in some way. This implies that all activities in society as well as every enterprise should involve decision making based on the interests and preferences of the stakeholders (COSO, 2004). Analogical to this the stakeholder of society is the general public which ultimately implies that the general public should be involved in societal decision making. This is in line with the opinion of Klinke and Renn (2002) and Slovic (1999).

In this thesis societal risk management decision making is referred to decision making concerned with distribution of risk reducing resources in society and introduction of regulations controlling different sources of risk exposure to people and values to society.

No matter what advanced tools and accurate risk assessments are used for assessing risks, an element of subjective risk assessment is always present. The sources of risks are physical in their nature, and therefore often possible to assess by scientific means. However the risks themselves have a nature of being more social and psychological constructions, and they are

therefore better suited for assessments made by subjective preferences (Slovic, 1999; Renn, 1998).

2.4.1. Societal risk management decision making today

In societal risk management decision making experts play a central role. For example fire protection design in a large public building is reviewed by experts working in local authorities (the fire brigade); another example is the approval of the construction of a large hazardous chemical process plant which is reviewed by experts working in regional authorities (Länsstyrelsen). Both of these levels rely on laws and regulations which are introduced by the Swedish government (Riksdagen, Internet 4). The first example relies on the Swedish building regulations (Boverkets Byggregler, Internet 5) and the second on several different ones e.g. the Seveso II directive (SFS 1999:381, Internet 6) and Environmental Code (SFS 1998:808, Internet 7). These examples of legal requirements give indirect acceptable levels of risk in society. However, there is no overall societal risk criterion that can be used to determine what risks are tolerable (Davidsson, 2003).

These examples illustrate the role of experts and hence as a consequence a lack of direct public influence. It is therefore interesting to investigate the preferences of the public in societal risk management.

2.4.2. Problems associated with public preferences as foundation for risk management decisions

There are several problems (biases) associated with public preferences as foundation for risk management decisions, which often lead to non-rational risk management decisions. Some of the aspects leading to these problems are presented below (Riskkollegiet, 1993; Kammen & Hassenzahl, 1999; Kahneman & Tversky, 1979; Klinke & Renn 2002, Slovic 1999):

- Dread; risks associated with consequences which are experienced as particularly dreadful e.g. consequences involving fear, pain, anxiety and uncertain outcomes.
- Catastrophic potential; risks associated with consequences of large, catastrophic potential tend to be perceived as proportionally more threatening than risks associated with smaller consequences, even though the likelihood of these events are extremely small.
- Familiarity; risks perceived as more familiar and common in people's every day life are often considered less threatening than more unknown and unusual risks, e.g. the risk of being involved in a car accident is much more accepted than the risks associated with eating genetically modified food.
- Control; if two risks have the same likelihood and the same consequences, the risk which is perceived as more deliberately chosen is often considered less threatening.
- Prospect; the concept of prospect has been a major contribution to the research area of risk perception. Basically, this concept means that people have a tendency to valuing their present, well-known and controlled, situation very high. This leads to an unwillingness to take risks to reach further benefits and improvements in the overall situation (more money, healthier life etc.), but on the other hand we are often willing to take great risks to avoid deteriorating our situation.

There are at least two important reflections to be made from this section. First, the biases should be reduced in order to simplify the evaluation of the public opinion. This could be done by raising these questions to public debate and creating consciousness about these problems. Second, scientists must be aware of these problems while gathering information about the public opinion.

2.4.3. Involving the general public in the societal risk management decision process

There are several possible ways of involving the general public in the societal risk management decision process. One concrete way is direct influence, i.e. referendum regarding questions that are considered very important, or opinion polls to investigate the public's opinion. Another way of involving the general public is making experts more available to listen to the public opinion or introducing a more frequent and extensive dialogue with groups of the public. Ultimately experts might serve as representatives of the general public.

This is one important reason to investigate whether the preferences of the public regarding societal risk management decisions comply with the corresponding preferences of experts in risk management. This thesis is concerned with a narrow field of this issue namely comparing the preferences of the general public with the preferences of experts regarding multiple fatalities in large scale accidents.

3. Decision theory

The purpose of this chapter is to explain the basics of decision theory. Knowledge of the fundamentals on decision theory is required to be able to perform the empirical study that forms the basis of this thesis. In addition, the method used for the empirical study can generate several biases which must be identified, and therefore decision theory needs to be explained. The arrangement of the empirical study will be further described in Chapter 4.

The results from the empirical study will be compared to the results from Abrahamsson and Johansson (2006). However, to assure that no other method is better suited for this study, a brief summary of some available methods will be carried out in the end of the chapter.

3.1. Different categories of decision theory

Decision theory can be divided into three categories depending on the purpose of the decision analysis; normative, descriptive and prescriptive theory. The purpose of the normative theory is to explain how people ideally should make decisions, while the descriptive theory is aimed at explaining how people actually make decisions. The third category of decision theory is the prescriptive theory, which is developed to help decision makers to make as good decisions as possible.

The output from the empirical study will be descriptive, i.e. it will describe the public's preferences of multiple fatalities in large scale accidents. However, the results will have a prescriptive purpose, i.e. to help decision makers to make as good decisions as possible regarding risks in society based on the public's opinion.

3.2. Expected utility

The theory behind decision making was originally developed in the area of monetary gambles. It was observed that, although the expected value for a specific gamble was positive, people were not always willing to participate in the gamble. In 1738 Bernoulli came to the conclusion that it is not the expected value, but rather the expected utility that governs people's decision making (Mattsson, 2000).

In 1947 von Neumann and Morgenstern developed the idea of expected utility as a rule for decision making (Keller, 1992). Gradually, the theory has come to include any uncertain decision situation, not only monetary gambles. The expected utility (EU) theory states that a decision maker who can choose between several uncertain alternatives chooses the alternative that maximises his or her expected utility. Expected utility theory can mainly be used for normative and prescriptive purposes (Mattsson, 2000).

Von Neumann and Morgenstern showed that different alternatives in a decision situation can be ranked by their expected utility if a number of axioms are fulfilled. These axioms are further discussed in Howard (1992) and Keller (1992). A subject's utility of a specific attribute can be illustrated with a utility function. The utility function for a specific attribute is generated by assigning the worst outcome a utility of 0 and the best outcome a utility of 1. If a subject has a utility of an attribute, e.g. money, that is marginally decreasing, this person is said to be risk averse and displays a concave utility function. On the contrary, a person who has a utility of a specific attribute that is marginally increasing is called risk prone and displays a convex utility function. If a subject has linear relation between the amount of the attribute and the corresponding utility this person displays a utility function represented by a straight line. This is called risk neutrality. Different risk attitudes, i.e. risk aversion, risk proneness and risk neutrality, and corresponding utility functions are illustrated in Figure 3.1.

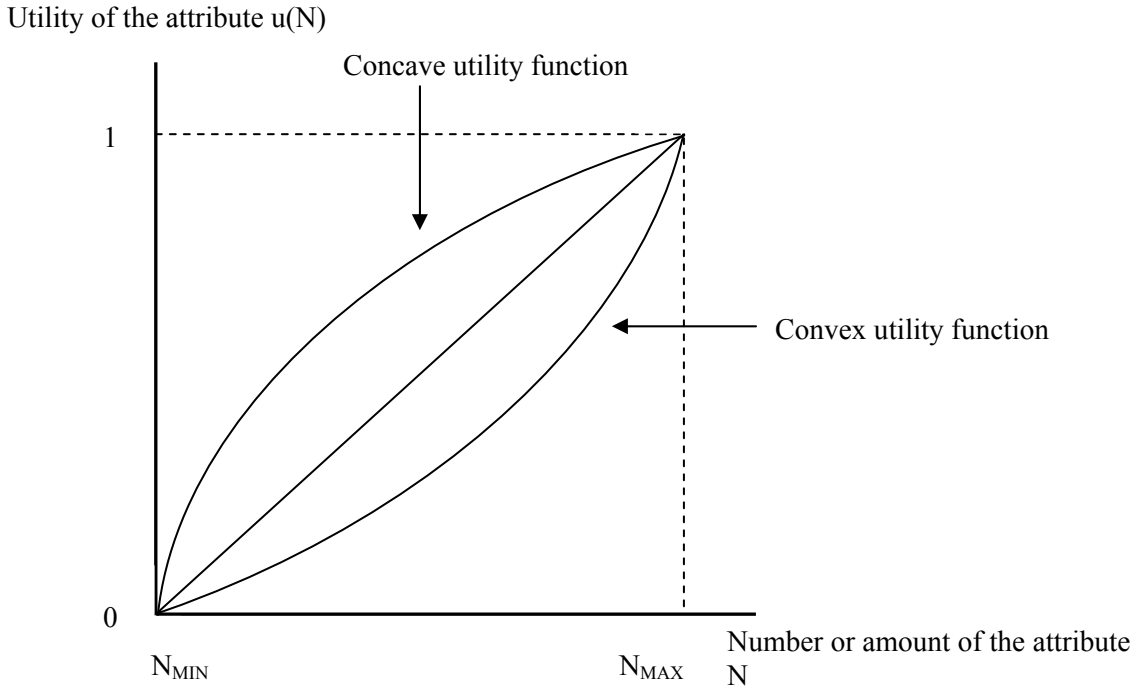

Figure 3.1: Illustration of utility functions

The utility functions illustrated in Figure 3.1 are created by assigning the horizontal axis the amount or number of the attribute of interest, N, and the vertical axis the utility of this attribute, u(N), ranging from 0 to 1. The minimum and maximum anchor points are fixed at (N, u(N)) = (N_{MIN}, 0) and (N_{MAX}, 1), respectively. These notations are the same as in Figure 3.1.

A recognized way of constructing utility functions is to use an exponential function $u(N) = N^{\beta}$, where $\beta = 1$ represents risk neutrality while $\beta < 1$ and $\beta > 1$ represent risk proneness and risk averseness, respectively. This relationship is shown in Table 3.1.

Table 3.1: Relationship between risk attitude, shape of utility function and β value

Risk attitude	**Shape of utility function**	**β value**
Risk aversion	Concave	$\beta > 1$
Risk neutrality	Straight line	$\beta = 1$
Risk proneness	Convex	$\beta < 1$

3.3. Methods for eliciting utility functions

There are several different methods for eliciting utility functions, all of which are associated with some disadvantages or biases. The starting point of this study was to use the same method as Abrahamsson and Johansson (2006), since the results from this study will be compared to the results from their study. However, to assure that no other method is more suited for this study, a brief summary of some available methods will be carried out below.

3.3.1. The direct scaling method

A first method, which is slightly different to the ones described in subsequent sections, is the so called direct scaling method. In this method, the subject is asked to directly assign the best outcome a value of 100, the worst outcome a value of 0 and the outcome that lies halfway between the worst and the best outcome a value of 50, and so on.

Obviously, the direct scaling method is very simple and easy to use. However, the method lacks theoretical justification (Wakker & Deneffe, 1996).

3.3.2. Standard-gamble methods

Table 3.2 contains a summary of different methods for eliciting utility functions, divided into so called standard-gamble methods and paired-gamble methods. A brief overview of some of these methods, which is largely based on the work by Farquhar (1984), is presented in subsequent sections.

Table 3.2: Methods for eliciting utility functions, based on the work by Farquhar (1984). The underlined character is specified by the subject.

	Standard-Gamble Methods
Preference comparison	$[x, \alpha, y] \underline{\leftrightarrow} w$
Probability equivalence	$[x, \underline{\alpha}, y] \sim w$, where w is between x and y
Value equivalence	$[\underline{x}, \alpha, y] \sim w$
Certainty equivalence	$[x, \alpha, y] \sim \underline{w}$
	Paired-Gamble Methods
Preference comparison	$[X, \alpha, y] \underline{\leftrightarrow} [x, \beta, Y]$
Value equivalence	$[\underline{X}, \alpha, y] \sim [x, \beta, Y]$
Trade off	$[\underline{X}, \alpha, y] \sim [x, \beta, Y]$

The standard-gamble methods are composed by a gamble and a certain outcome. The gamble is denoted [x, α, y], i.e. there are two possible outcomes x and y with a probability of α for outcome x, and consequently a probability of 1- α for outcome y. The certain outcome is denoted w. The utility function can be elicited by letting the subject specify either x, α, w or ↔ in the situation

$[x, \alpha, y] \leftrightarrow w$

where ↔ represents the preference relations > (is more preferred than), ~ (is indifferent to), or < (is less preferred than).

This situation can be illustrated by a choice between participating in a monetary gamble and receiving a sure sum of money. The gamble has two possible outcomes; $100 or $1000. The probability of winning $100 equals to 0,9 and the probability of winning $1000 equals to 0,1. In accordance with the notations used above, i.e. [x, α, y], this gamble can be denoted [100, 0.9, 1000]. The sure outcome can be denoted w and equals to $190. This choice method can be varied by letting a subject specify either one of the possible outcomes of the gamble, x, the probability, α, the sure gain, w, or the preference relation, ↔.

3.3.2.1 The preference comparison method

In the preference comparison method the subject is asked to specify ↔ in the following situation;

$[x, \alpha, y] \leftrightarrow w$

where ↔ is one of the relations > (is more preferred than), ~ (is indifferent to), or < (is less preferred than).

The main disadvantage of the preference comparison method is its limited applicability. One common area of using the method is to investigate the consistency of an assessed utility function (Farquhar, 1984).

3.3.2.2 The certainty equivalence method

In the certainty equivalence (CE) method the subject is asked to compare a gamble with a certain outcome. The gamble is denoted [x, α, y] and the certain outcome is denoted w. The subject is asked to specify a value of the certain outcome which makes him or her indifferent between the certain outcome and the gamble.

The certainty equivalence method is one of the most widely used methods to eliciting utility functions. However, it has been demonstrated that people generally are more attracted of sure gains than risky prospects for positive outcomes. This bias is called the certainty effect and represents a major disadvantage of the certainty equivalence method. The opposite bias has been proved for negative outcomes, i.e. people tend to prefer the risky alternative instead of a sure loss (Tversky & Kahneman, 1992).

3.3.2.3 The probability equivalence method

In the probability equivalence (PE) method the subject is asked to specify a probability α which makes him or her indifferent between the gamble [x, α, y] and the certain outcome w.

As with the equivalence method, the probability equivalence method is biased by the certainty effect. In addition, people generally experience problems making probability judgements, especially for probabilities close to zero or one (Farquhar, 1984).

3.3.2.4 The value equivalence method

In consistency with previous described methods, the value equivalence method is carried out by comparing a gamble denoted [x, α, y] with a certain outcome w. In this case, the subject is asked to specify a value of x, which makes him or her indifferent between the gamble and the certain outcome. In this method the probability α usually equals ½. The major disadvantage of the value equivalence method is that it biased by the certainty effect (Farquhar, 1984).

3.3.3. Paired-gamble methods

The methods described in previous sections all include a gamble that is compared to a certain outcome. These methods are biased by the certainty effect. A slightly different approach for eliciting utility functions is to compare two gambles. These methods are called paired-gamble methods and are generalisations of the standard-gambles. Since a large number of generalisations are possible, only a few of these methods are presented here.

3.3.3.1 The preference comparison method

An example of a paired-gamble method is the preference comparison method. In this method the subject is asked to compare two gambles, each of them having two possible outcomes. The gambles are denoted [X, α, y] and [x, β, Y], X>x and Y>y, where X and y are the possible outcomes of the first gamble while x and Y are the possible outcomes of the second gamble. α and β represent the probabilities for outcome X and x respectively. Consequently, the probabilities for outcomes y and Y are 1- α and 1- β, respectively. The subject is asked to specify ↔ in the situation

[X, α, y] ↔ [x, β, Y]

where ↔ corresponds to the relations > (is more preferred than), ~ (is indifferent to), or < (is less preferred than).

The preference comparison method is not biased by the certainty effect. However, according to Farquhar (1984) the only reported applications are consistency checks and multi-attribute independence tests.

3.3.3.2 The value equivalence method

This method is composed by two gambles denoted [X, α, y] and [x, β, Y]. All values except X are being fixed, and the subject is asked for the value of X that makes him or her indifferent between the two gambles.

This method is not biased by the certainty effect. The downside is that it requires more effort to elicit the utility function (Farquhar, 1984).

3.3.3.3 The trade off method

A generalisation of the value equivalence method is the so called trade off method (hereafter called the TO method) developed by Wakker and Deneffe (1996). In this method the same probabilities are used in both gambles, i.e. $\alpha = \beta$. Here the gambles are denoted [X, α, y] and [x, α, Y]. The subject is asked to specify the value of X that makes him or her indifferent between the two gambles.

The trade off method reduces the certainty effect by letting the subject choose between two gambles and it is not sensitive to probability distortions since probabilities are kept constant and equal to 0,5 throughout the entire procedure. The major disadvantage of the trade off method is that more questions have to be asked to elicit a utility function compared to the probability equivalence and certainty equivalence methods. This is because the trade off method is chained, i.e. the subject's answer from one situation is used as input in the following situation. The trade off method can also be perceived as a more complicated method (Fennema & van Assen, 1999).

3.3.4. Choice of method for eliciting utility functions

The starting point of this study was to use the same method as Abrahamsson and Johansson (2006). To assure that no other method is more advantageous, the summary of different methods presented above was carried out.

As far as possible, a desired characteristic of the method that will be used in the empirical study is to reduce potential biases from psychological effects, e.g. the certainty effect and the effect of low probabilities. Therefore, the standard-gamble methods presented in previous sections are considered deficient.

Consequently, the paired-gamble methods better correspond to the characteristics of a desired method, although these methods require more effort to elicit the utility functions. Therefore, the method that is considered superior for this study is the trade off method. Compared to the paired-gamble value equivalence method the trade off method has the same advantages but is simpler since the same probabilities are used in both gambles.

However, the most important characteristic of the method that will be used in this study is that the results are comparable to the results from the study by Abrahamsson and Johansson (2006). To obtain comparable results the method used here must be akin to their method. All methods are associated with some biases, and by using the same methods as Abrahamsson and Johansson (2006), the same biases will be generated. Thereby the differences between the two studies can be refined, which supports the choice of the trade off method.

4. Method

This chapter will provide a more thorough presentation of the trade off method. Moreover, an adaptation of the experimental setup to the existing circumstances will be carried out. In the end of the chapter, the final design of the experimental arrangement will be presented.

4.1. Characteristics of the trade off method

In this section a more detailed description of the trade off method and its characteristics will be presented. To begin with, a summary of the notations given in Chapter 3 is repeated.

In the trade off method the subject is asked to compare two gambles, denoted $[X_0, \alpha, y]$ and $[x_0, \alpha, Y]$. For a positive attribute, e.g. money, the relation of the outcomes are $X_0 > x_0$ and $Y > y$. All outcomes except X_0 are being fixed, and the subject is asked to specify the value of the outcome X_0 that makes him or her indifferent between the two gambles. From this first indifference situation no conclusions are drawn. Instead, the same reference outcomes Y and y are used in a new comparison between two gambles denoted $[X_1, \alpha, y]$ and $[x_1, \alpha, Y]$. In this new situation the subject is asked for the value of the outcome X_1 that makes him or her indifferent between the two gambles, keeping all other outcomes fixed. The two indifference situations are:

$$[X_0, \alpha, y] \sim [x_0, \alpha, Y] \quad (1)$$

$$[X_1, \alpha, y] \sim [x_1, \alpha, Y] \quad (2)$$

The first indifference, (1), is substituted with a utility function u and corresponds to the equality

$$\alpha \cdot u(X_0) + (1-\alpha) \cdot u(y) = \alpha \cdot u(x_0) + (1-\alpha) \cdot u(Y)$$

Rearranging the equality gives

$$\alpha \cdot (u(X_0) - u(x_0)) = (1- \alpha) \cdot (u(Y) - u(y))$$

The second indifference, (2), is also substituted with a utility function u

$$\alpha \cdot u(X_1) + (1-\alpha) \cdot u(y) = \alpha \cdot u(x_1) + (1-\alpha) \cdot u(Y)$$

Rearranging the second equality gives

$$\alpha \cdot (u(X_1) - u(x_1)) = (1-\alpha) \cdot (u(Y) - u(y))$$

Combining the two equalities and cancelling out the common right hand sides gives

$$\alpha \cdot (u(X_0) - u(x_0)) = \alpha \cdot (u(X_1) - u(x_1))$$

Cancelling out the probability α gives

$$u(X_0) - u(x_0) = u(X_1) - u(x_1)$$

The value of the outcome x_1 that is generated in the second indifference situation above is based on the subject's answer from the first indifference situation, i.e. $X_0 = x_1$. In the same way the outcomes in the next choice situation will be based on the subject's answer in the previous situation, i.e. the method is chained. The value of α makes no difference as long as it is positive and that the same value is used in all gambles (Wakker & Deneffe, 1996).

The difference in utility between the indifference points (1) and (2) above will be equal. Ultimately, since the method is chained, this means that the difference in utility between all indifference points will be equal (Fennema & van Assen, 1999). By assigning a utility of 0 to the worst outcome and a utility of 1 to the best outcome a utility function for the range of the best to the worst outcomes can be constructed (Wakker & Deneffe, 1996).

When the trade off method is used with intervals moving farther away from zero, the procedure is called the outward TO procedure. Conversely, when the intervals move towards zero it is called the inward TO procedure (Fennema & van Assen, 1999). Differences between the outward and the inward TO procedure are further described by Fennema and van Assen (1999) and will not be explained here.

The trade off method has been used by Davidsson and Lindhe (2005) to investigate how people value disasters with severe consequences on the environment. In their study, the size of the affected area was used as attribute. The trade off method has also been used by Abrahamsson and Johansson (2006) on persons with professional or educational knowledge of risk management to investigate preferences regarding multiple fatality accidents. Below follows a brief summary of their work.

4.1.1. The empirical study by Abrahamsson and Johansson

In 2006 Abrahamsson and Johansson conducted a study aiming at investigating the preference of 87 persons in Sweden with professional or educational knowledge of risk and crisis management.

The experimental arrangement consisted of a written document of four pages, see, appendix 1, (in Swedish), with background and instructions for the study. This was followed by a set of computer based trade off choice situations. The situations consisted of two alternatives, each of them having two possible outcomes.

Using the same terminology as above, the choice situation can be described by the following set of variables

$[X_i, \alpha, y] \leftrightarrow [x_i, \alpha, Y]$

Where;

Y is a fixed number throughout the whole experiment equal to 2000 fatalities
y is a fixed number throughout the whole experiment equal to 1500 fatalities
X_i is a variable number of fatalities starting at 500
x_i is a variable number of fatalities starting at 0
α is a probability of 0,5 throughout the whole experiment, therefore this term will be excluded in the following notations resulting in the short form notation $[X, y] \leftrightarrow [x, Y]$

The subjects were asked to choose which of the two alternatives they preferred, or if they considered the alternatives to be equivalent. The choices were made by pressing the buttons “Alternativ 1” (Alternative 1), “Alternativ 2” (Alternative 2) or “Likvärdiga” (Equivalent) on a computer. The initial choice situation that was presented to the subjects is illustrated in Figure 4.1 (in Swedish).

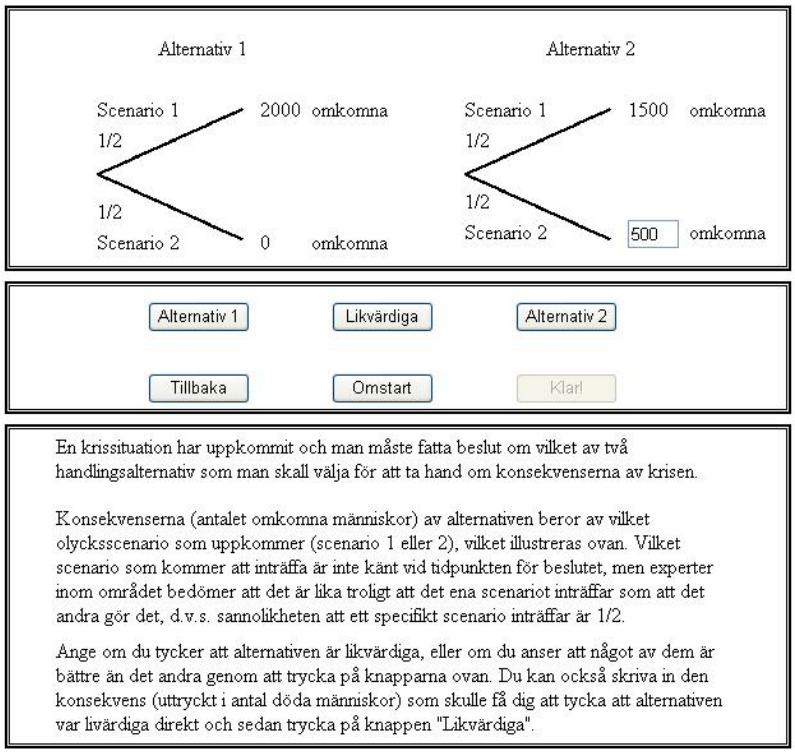

Figure 4.1: Trade off situation in the study by Abrahamsson and Johansson

As the subjects pressed the Alternative 1 or Alternative 2 buttons, the number of fatalities in the outcome called Scenario 2 of Alternative 2 (the variable X_0 above) illustrated in Figure 4.1 was changed. If the Alternative 2 button was pressed, this number (500 fatalities in Figure 4.1) was increased to a higher number, which made Alternative 1 more attractive. If, on the other hand, the Alternative 1 button was pressed, this number was decreased to a lower number, which made Alternative 2 more attractive.

By pressing the Alternative 1 or Alternative 2 buttons, the interval containing the subject's indifference point was constantly narrowed. This process followed an algorithm described further in the next section. If the subjects knew the number of fatalities in the outcome called Scenario 2 of Alternative 2 (500 fatalities in Figure 4.1), which made her/him indifferent between the two alternatives, it was possible to enter this value directly into the box. Eventually, either by using the buttons or by filling in the number manually, the subject reached a situation where he or she considered the two alternatives equivalent. Then the subject was asked to press the Equivalent button ("Likvärdiga" in Figure 4.1). When the subject pressed "Likvärdiga" the values of x_0 and X_0 were stored in a data base as a so called indifference point. Subsequently a new choice situation appeared denoted $[X_1, y] \leftrightarrow [x_1, Y]$ where x_1 was equal to the recently stored value of X_0 (500 fatalities in Figure 4.2 below) and the value of X_1 was equal to a value ($y>X_1>X_0$) generated by the computer programme (1000 fatalities in Figure 4.2 below).

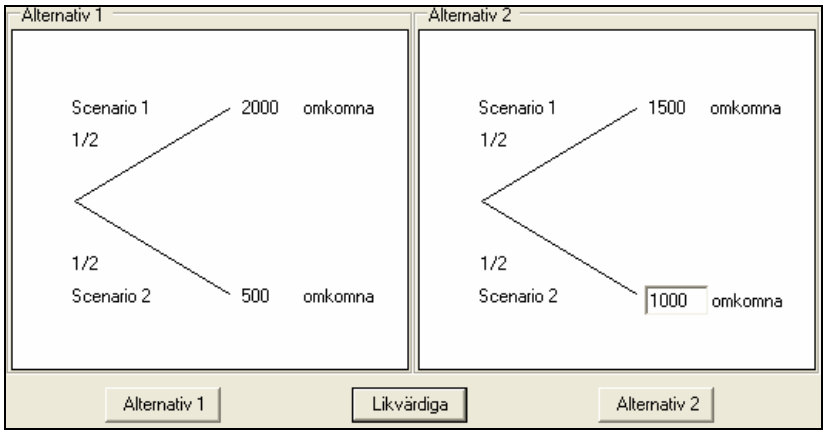

Figure 4.2: New trade off situation generated by the computer programme

This procedure was repeated until the number of fatalities in Scenario 2 of Alternative 2 (called X_i above) reached a value which hereby will be called limit, the outward procedure was terminated. Thereafter a new trade-off situation was presented, with the same numbers as the last outward procedure situation, but with the order of the numbers inversed (see Figure 4.3 below). This phase is called the inward TO procedure, in which the interval moved towards zero. Since the interval of interest in the Abrahamsson and Johansson study was 0 to 1000 fatalities, consequently the limit value was 1000 fatalities.

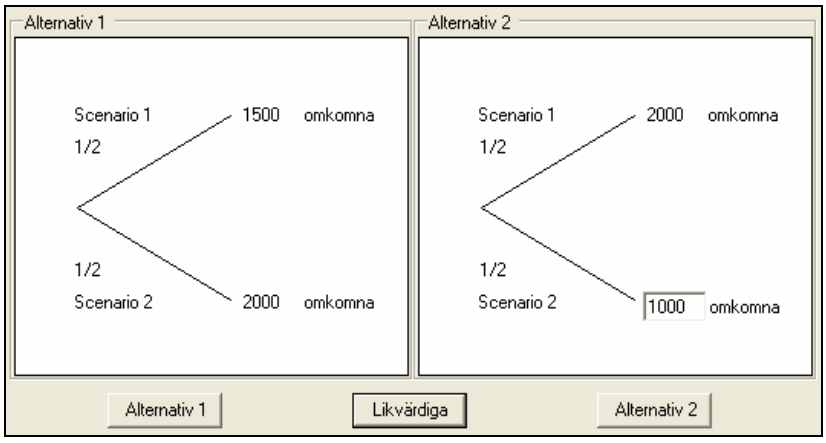

Figure 4.3: Inward TO procedure

Finally, the subjects were asked to fill in a short questionnaire with personal data, see Appendix 1 (in Swedish).

4.1.2. Interval containing the subjects' indifference points

In previous section it was mentioned that the interval containing the subjects' indifference point was narrowed as the subjects pressed the Alternative 1 or Alternative 2 buttons. This was a way of helping the subject to find the value of X_i in the trade off situation $[\underline{X_i}, y] \leftrightarrow [x_i, Y]$ which made her/him indifferent between the two alternatives. As the interval got smaller the subjects eventually found a value of X_i that made them indifferent between the two alternatives, then they were asked to press the Equivalent button.

To illustrate the procedure of narrowing the interval containing a subject's indifference point, let us assume that the subject chooses Alternative 2 in the situation [2000 0] ↔ [1500 $\underline{500}$]. This is interpreted by the computer program as the value of the underlined number of fatalities that makes the subject indifferent between the two alternatives is above 500. The next trade off situation that appears is [2000 0] ↔ [1500 $\underline{1000}$]. If the subject chooses Alternative 1, this is interpreted as the indifference point of the subject is below 1000 but above 500 fatalities. In the

same way the interval is continuously narrowed as the subject presses the Alternative 1 or Alternative 2 buttons until he or she considers that the two alternatives are equivalent. Then the subject is asked to press the Equivalent button and a new trade off situation appears. An example of the interval containing the subject's indifference point is illustrated in Figure 4.4

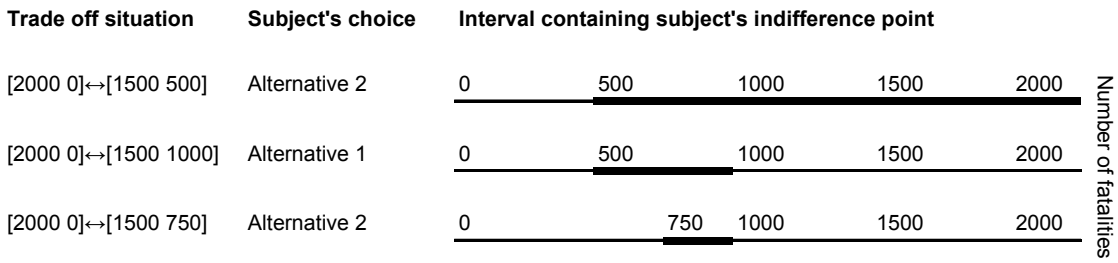

Figure 4.4: Example of interval containing a subject's indifference point

When the subject has terminated the experiment, a number of indifference points are obtained. Since these points (according to the theoretical background in the beginning of this chapter) are equally spaced in utility, they can be plotted and fitted to a parametric function of the kind $u(N)=N^{-\beta}$, for instance by using the least-square method.

4.2. Adaptation of the experimental setup

The computer based experimental setup of the trade off method developed by Abrahamsson and Johansson was used as a basis of this study. To be able to compare the results to their study, the same reference values were chosen, i.e. y and Y equal to 1500 and 2000 fatalities. However, their method was used to investigate the preferences of persons with professional or educational knowledge of risk and crisis management, while the empirical study carried out in this thesis aimed at investigating the preferences of the general public. This necessitated some simplifications and adaptations of the experimental setup to enable usage on the intended population.

To reduce as many of the potential biases as possible, testing of the method was carried out continuously, and the identified problems were dealt with as they came up. A total of 22 subjects were involved in the testing and adaptation of the method. Distribution of age and gender is illustrated in Figures 4.5 and 4.6.

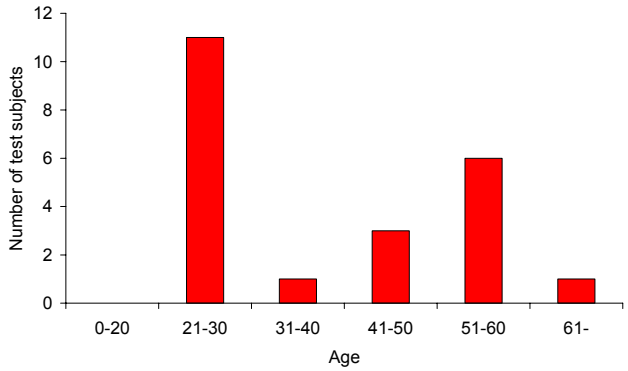

Figure 4.5: Distribution of age

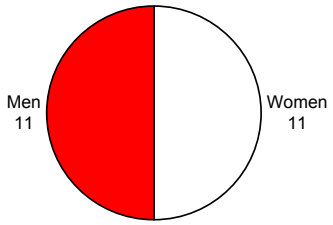

Figure 4.6: Gender distribution

Problems associated with the trade off method in general have been discussed previously in Chapter 3, i.e. that the method is more time consuming than other methods for eliciting utility functions and can be perceived as being more complicated. A number of problems specifically related to the empirical study were identified during the adaptation process and are described in

subsequent sections. These problems have been divided into problems concerning reliability and validity.

4.2.1. Reliability

The reliability of a chosen method reflects how accurate the results are. Ejvegård (2003) gives the following example. A tape measure made of rubber that can be easily stretched, will give different results depending on how tense it is stretched. This means that the result has a low reliability. Another more general example could be a test on two identical subjects which gives two completely different results.

In this section an inventory of problems concerning reliability are presented. Each problem is followed by a description of how the authors have dealt with this particular problem.

4.2.1.1 Change of strategy during the experiment

To be able to carry out the experiment, the subjects need to reflect upon the trade off situations. More or less effort can be put into this process. The term for describing a subject's approach, which includes the way that he or she reflects and analyses the problem, will be called the subject's strategy.

Already during the testing of the method it was made clear that subjects not only could, but were rather likely to change their strategies during the experiment. This gives rise to a problem of reliability, since a change of strategy during the experiment could result in answers that contradict each other. In that case, what answers should be considered the right ones?

As an attempt to explain the subjects' change of strategies that was observed during the testing of the method, the following statement was formulated;

Subjects gradually improve their ability to analyse the experimental choice situations as they are forced to confront them.

To analyse this problem, and to try to verify the proposed statement, two versions of the experiment were created, see Table 4.1.

Table 4.1: Illustration of the two versions of the experiment

Part 1	Introduction and instructions for the experiment	
	Version A	Version B
Part 2	Reference values 1500 and 2000	"Trial part"
Part 3		Reference values 1500 and 2000
Part 4	Questionnaire	

Both versions included one part with the reference values 1500 and 2000. However, in version B this part was preceded by a "trial part", while in version A this part was the first part that the subjects were confronted with. The purpose of the "trial part" was to let the subjects have time to practice and to become familiar with the experiment. By comparing the parts with reference values of 1500 and 2000 from version A and B, possible effects from getting familiar with the method in the "trial part" could be identified.

As mentioned previously, the purpose of the "trial part" was to familiarise the subjects with the experiment. To further facilitate the subjects' ability to understand the experiment, it was

decided to use smaller numbers of fatalities in this part. The choice of appropriate numbers of fatalities for the "trial part" was decided through a continuous testing procedure of different potential numbers. Different numbers of fatalities were tested on the test subjects. A version with the initial trade off situation [15 5] ↔ [20 0] with a limit value of 10 fatalities was tested to find out the effect from using considerably smaller numbers than [1500 500] ↔ [2000 0]. However, with these small numbers of fatalities problems arose from not obtaining the minimum of two indifference points, which is required to be able to create a utility function. From the testing of the method it was concluded that a practical relation between the reference values and limit, i.e. Y, y and limit, was 4:3:2 (e.g. Y = 2000, y = 1500 and limit = 1000 fatalities).

Consequently, an appropriate size of the numbers of fatalities for the "trial part" should be smaller than [1500 500] ↔ [2000 0] and thereby easier for the subjects to grasp, but at the same time higher than [15 5] ↔ [20 0] and thereby generate at least two indifference points. The number of fatalities fulfilling these characteristics were found out to be [150 50] ↔ [200 0] with the limit value of 100 fatalities. This was the final arrangement of Version B, part 1.

In order to keep the size of the experiment down, the trial part only consisted of the outward procedure. To further analyse this problem, several questions in the questionnaire in part 4 were created to shed light upon the issue. All questions and the reasons for including them are presented in Table 4.4 in the end of this chapter, where the questions are translated to English. Part 4 can be found in Appendix 3.

A change of strategy was particularly common for subjects characterised by risk-taking in the beginning of the experiment. These subjects initially took the chance of choosing alternatives including zero fatalities, while making tradeoffs where all possible outcomes were taken into consideration later on in the experiment. This problem is further discussed in the section *4.2.1.3 Risk-prone subjects*.

4.2.1.2 Stress and frustration

A problem that was noticed during the testing of the method was that subjects easily felt stressed. This resulted in that subjects rushed through the questions without reflecting on their answers. This also gave rise to an increasing risk of unreliable results. The reasons why the subjects felt stressed were studied and found to be:

- Noisy and disturbing surroundings
- A background and instruction text that was considered too extensive and therefore hard to read through
- The subjects did not know how long the experiment would take
- The subjects felt that they did not receive information on how much of the test that was left
- The subjects did not understand why they could not make a certain preferred choice

In order to counteract these effects the following measures where taken:

- The experiment was conducted in a quiet environment. The environment is further described in the chapter 5 *The empirical study.*
- In order to give the subjects an indication of how much of the experiment that was left it was divided into four parts. In this way the subjects roughly knew which quarter of the experiment they were up to. In addition a pop-up window appeared after every terminated part of the computer based experiment. When the first part, i.e. the outward procedure, of the computer based trade off method was terminated, a pop-up window appeared. The message was telling the subjects that they had reached half-way through the present part and that the second part would remind of the first one, but with the alternatives in inversed order. See Figure 4.7 (in Swedish).

Figure 4.7: Pop-up window telling the subjects that they had reached half-way through the present part

When both parts, i.e. both the outward and the inward procedures, were terminated another pop-up window appeared, see Figure 4.8 (in Swedish).

Figure 4.8: Pop-up window telling the subjects that they had finished both parts, i.e. both the outward and the inward procedures

- The instructions were rewritten and shortened. This was made possible by some simplifications of the experiment, with less buttons (see the section Comprehensibility below).
- The subjects were informed prior to their participation of the experiment that the time for the experiment was estimated to some 30 minutes.
- A pop-up window was created that explained why the subjects could not make the preferred choice. This was because the subjects had made previous choices which excluded the preferred answer. This is further explained in the section Comprehensibility.

4.2.1.3 Risk-prone subjects

Several subjects considered 2000 and 1500 being such large numbers of fatalities that the difference between these numbers did not matter in the trade off situations. This opinion was an indication that the subjects put more emphasis on the two smaller numbers of fatalities, and consequently had a tendency toward choosing the alternative with the lower of the two lower numbers. For instance, in the choice situation illustrated in Figure 4.9, some subjects excluded 1500 and 2000 fatalities since they are such large numbers of fatalities and only focused on the lower numbers, i.e. 150 and 200. The lower of these numbers is 150, and therefore these subjects often chose “Alternativ 1” (Alternative 1).

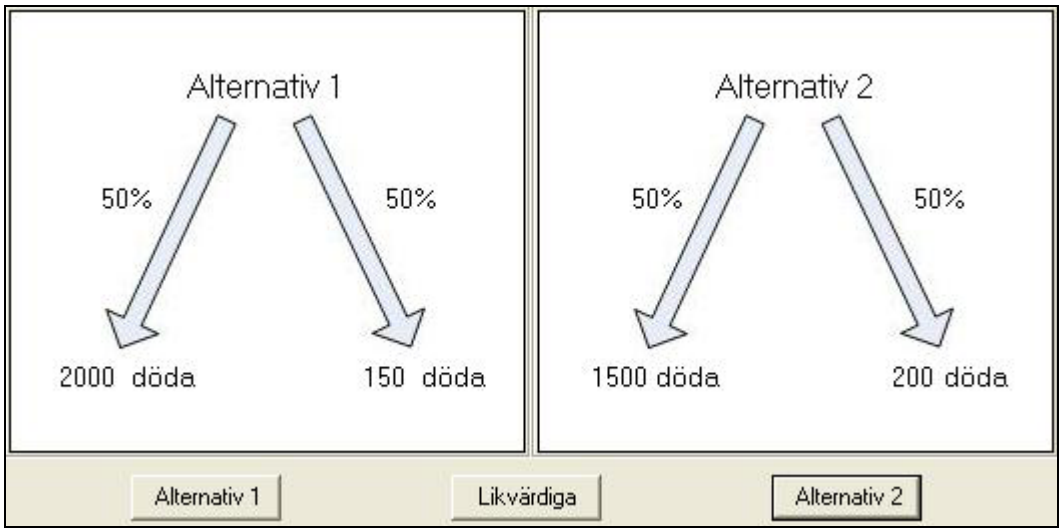

Figure 4.9: Example of trade off situation

This behaviour indicates that the subjects are risk prone, since they judge the difference in utility between small numbers of fatalities as larger than the difference in utility between larger numbers of fatalities.

Tversky and Kahneman (1992) have suggested an explanation to this behaviour, which they call the principle of diminishing sensitivity. They state that the impact of a change diminishes with the distance from the reference point, i.e. the difference between 1000 and 1050 is not experienced as large as the difference between 100 and 150 although the absolute difference is 50 in both cases. The authors assume that most subjects have a reference point of zero fatalities when starting the experiment.

A closely related behaviour was observed in trade off situations containing alternatives with a possible outcome of zero fatalities. During the testing of the method it was noticed that several subjects consistently preferred the alternative with a possibility of zero fatalities, although the difference between the lower numbers was considerably smaller than the difference between the higher numbers, i.e. the reference values. An example of this situation is illustrated in Figure 4.10, where the described subjects would prefer Alternative 1 although the difference between the lower numbers (0 and 32) is much smaller than the difference between the higher numbers (1500 and 2000).

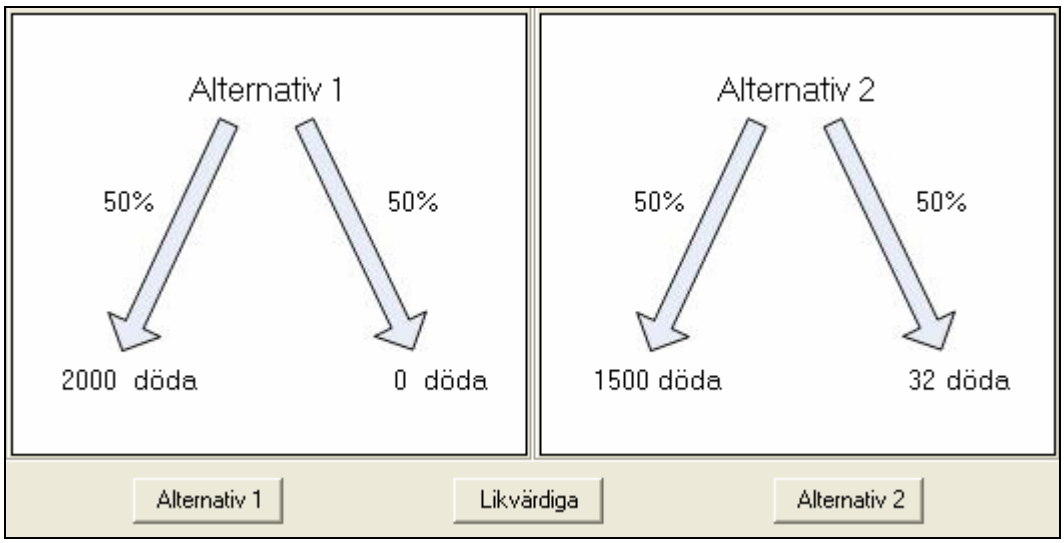

Figure 4.10: Example of trade off situation

Some of the subjects with these preferences consistently chose Alternative 1 until the lower numbers of both Alternative 1 and Alternative 2 included zero fatalities. However, when the subjects reached this situation, i.e. [2000 0] ↔ [1500 0], the subjects wanted to choose Alternative 2, which was a prohibited choice since the subjects' indifference point was interpreted by the computer program to lie below 1 fatality but above 0 fatalities.
An example of choices made by this kind of subjects is shown in Table 4.2. Table 4.2 also shows how the interval is being narrowed as the subjects press the Alternative button.

Table 4.2: Example of choices made by a risk prone subject

No	Trade off situation [Alternative 1] ↔ [Alternative 2]	Subjects' preferred choice
1	[2000 0] ↔ [1500 500]	[Alternative 1]
2	[2000 0] ↔ [1500 250]	[Alternative 1]
3	[2000 0] ↔ [1500 125]	[Alternative 1]
4	[2000 0] ↔ [1500 63]	[Alternative 1]
5	[2000 0] ↔ [1500 32]	[Alternative 1]
6	[2000 0] ↔ [1500 16]	[Alternative 1]
7	[2000 0] ↔ [1500 8]	[Alternative 1]
8	[2000 0] ↔ [1500 4]	[Alternative 1]
9	[2000 0] ↔ [1500 2]	[Alternative 1]
10	[2000 0] ↔ [1500 1]	[Alternative 1]
11	[2000 0] ↔ [1500 0]	[Alternative 2]*

* This choice was not permitted in the original version of the computer program

To be able to include these subjects' preferences, a modification of the computer program was made. When the subjects reached the trade off situation numbered 10 in Table 4.2, i.e. [2000 0] ↔ [1500 1], and the subjects chose Alternative 1, the next situation that appeared was [2000 1] ↔ [1500 501]. This forced the subjects to make trade offs in situations not including an alternative with zero fatalities.

4.2.1.4 The dependence on the size of accidents

During the testing of the method it was indicated that the size of the reference values y and Y, i.e. 1500 and 2000, to some degree affected the subjects' answers, although the theory behind the trade off method stated that the results should be independent of these values. From observing this effect, the following statement was formulated;

Although the theory behind the trade off method states that the results are independent of the size of the reference values y and Y, these values are believed to affect the results

To analyse this problem and to verify or falsify the statement formulated above, version A was divided into two parts; one part with the reference values of 1500 and 2000 and one part with reference values differing considerably from these values, but with the same limit value, i.e. 1000 fatalities. Several reference values were tested to find the most appropriate values for this part.

First, attempts were made to change y, i.e. the reference value of 1500, to a lower number. However, by changing this value to a lower number, the results were at risk to become biased by the certainty effect as the difference between both outcomes of this alternative came close to each other when the subjects approached the limit value of 1000 fatalities in the outward procedure.

Attempts were also made to change Y, i.e. the reference value of 2000, to a value of 3000, resulting in the situation [3000 0] ↔ [1500 500]. This was believed to show whether a change of the reference values affected the results or not. However, with this large value of Y, the minimum requirement of two indifference points would not be generated for risk-neutral or risk-averse subjects.

Eventually, the final reference values of version A, part 3, were decided to be 1500 and 2400, see Table 4.3. These values were chosen to study any possible differences from the values 1500 and 2000 used in part 2. The difference between the two parts of version A was made smaller than originally desired. However, this was unavoidable due to the problems mentioned above.

The only requirement on the reference values specified by Wakker and Deneffe (1996) is that they should be chosen close enough to each other so that the revealed sequence is sufficiently narrow and gives utility to the desired level of accuracy. In practice, this means that part 2 of version A should yield the same results as part 3 of version A.

Table 4.3: Illustration of the two versions of the experiment with different reference values

Part 1	Introduction and instructions for the experiment	
	Version A	Version B
Part 2	Reference values 1500 and 2000	"Trial part" with reference values 150 and 200
Part 3	Reference values 1500 and 2400	Reference values 1500 and 2000
Part 4	Questionnaire	

In order to keep the size of the experiment down version A, part 3, only consisted of the outward TO procedure.

4.2.2. Validity

Validity indicates how well the method measures the intended parameter. An example could be to have the intention of measuring the weight of an object and obtain the results in meters. In this section problems related to validity of the results are discussed.

4.2.2.1 Comprehensibility

Compared to the experimental arrangement used by Abrahamsson and Johansson (2006) some simplifications had to be made to facilitate the use of the trade off method, since the population used in this study were assumed to have less experience of reflecting upon abstract decision situations than the population studied by Abrahamsson and Johansson. Those parts of the experiment that required simplifications were identified during the testing of the method from the test subjects' feedback.

A first step to facilitate the comprehensibility of the experiment was to write all information in a simple and legible way. The first part of the study, i.e. the introduction and instructions for the study was made as short and easy to understand as possible.

In the experimental arrangement used by Abrahamsson and Johansson (2006) the subjects were given a possibility of entering a value of Scenario 2 in Alternative 2 that made them indifferent between the two alternatives, see Figure 4.11. This possibility was excluded to simplify the implementation of the study.

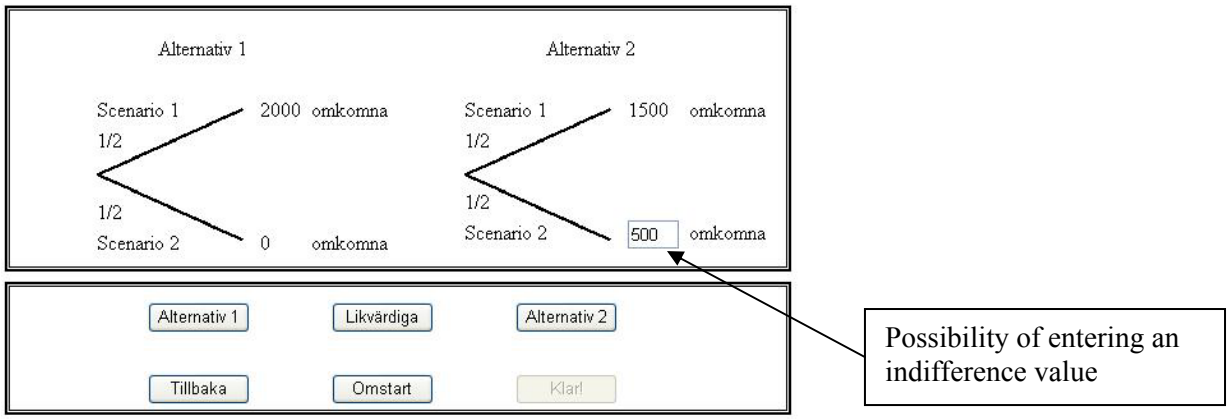

Figure 4.11: Possibility of entering an indifference value in the experimental arrangement used by Abrahamsson and Johansson

In the section *Utility elicitation and estimation of utility functions* it was explained that the interval containing the subjects' indifference points were constantly narrowed as they pressed the Alternative 1 or Alternative 2 buttons. When subjects tried to choose an alternative outside this interval a pop-up window appeared, see Figure 4.12 (in Swedish). The pop-up window asked the subjects to press the Back button until the trade off situation where they rejected the preferred choice was shown.

Figure 4.12: Pop-up window appearing when the subjects tried to choose an alternative outside the interval containing their indifference point

4.2.2.2 General applicability

The results from the experiment were aimed at being as general as possible, i.e. to be applicable to any societal risks. This means that aspects like dread associated with specific risks should be avoided. To be able to achieve this, the background of the trade off situations were described in a hypothetic way, e.g. the only information the subjects received about the causes of the trade off situation was that an accident had occurred. No facts about other circumstances were described.

To analyse this issue, the subjects were asked if they had any specific accidents in mind when carrying out the experiment. Negative answers on this question implied that the subjects had analysed the situation on a rather high level of abstraction, which increases the general applicability of the results. The formulation of the question can be found in the section *4.3 The final design of the experiment* and in Appendix 3.

4.2.2.3 Personal involvement

If the subjects would feel personally involved in the accident leading to the trade off situation they would not analyse the problem on a hypothetical level. In other words, this is closely linked to the general applicability of the results discussed in previous section. This effect can be identified by the question whether the subjects had any specific accidents in mind when carrying out the experiment.

4.2.2.4 Outward and inward TO procedure

Fennema and van Assen (1999) have showed that the outward and the inward trade off procedures give slightly different results. Therefore, both procedures were included in the part of the experiment with reference values of 1500 and 2000. In addition, both procedures were used by Abrahamsson and Johansson (2006), and to be able to compare the results to their work both procedures were also included in this study. Further information and possible explanations to the differences between the outward and inward procedures can be found in Fennema and van Assen (1999).

4.3. The final design of the experimental arrangement

The final design of the experimental arrangement consisted of four parts in two different versions. The first part, which included an introduction and instructions for the experiment, was almost identical in the two versions. This part is shown in Appendix 2.

The second and third parts included the computer based trade off situations. In these situations the subjects were informed that a crisis had occurred and that there were two possible ways of managing the situation, Alternative A and Alternative B. Within both alternatives there were two possible outcomes, each having a probability of 50 %. The initial situation of version A is illustrated in Figure 4.13.

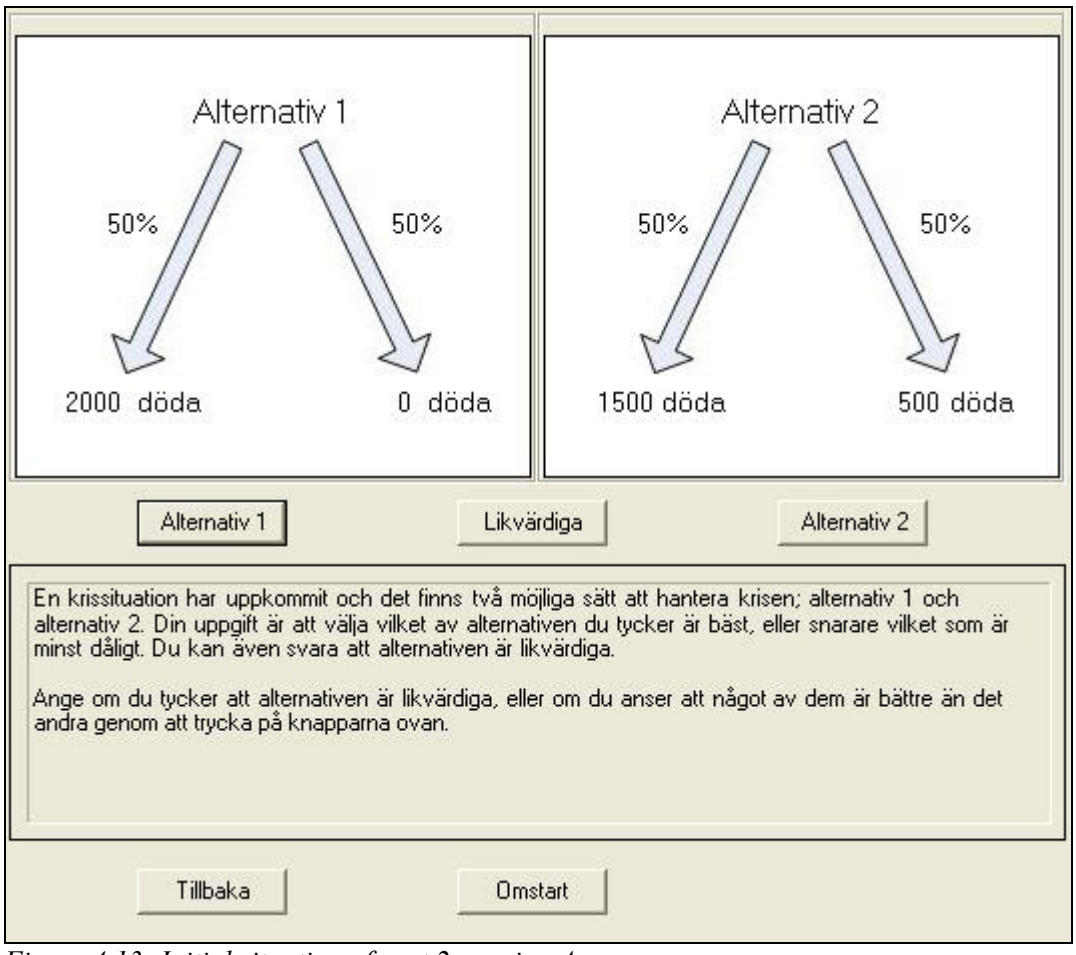

Figure 4.13: Initial situation of part 2, version A

The subjects were asked if they considered the two alternatives being equivalent. In this case they were asked to press the button 'Equivalent'. If the subjects preferred one of the alternatives over the other, they were asked to press the button for this alternative.

To go back to previous trade off situation, the subjects were able to press the button "Tillbaka" (Back) and to restart the experiment they were able to press "Omstart" (Restart).

Both versions of the experiment included trade off situations with the reference values y and Y of 1500 and 2000. This arrangement was carried out both with the outward and the inward procedures. The two versions differed in two ways; by number of fatalities and by the order in which the arrangement with the reference values 1500 and 2000 was carried out. The final reference values and test procedures of the two versions are illustrated in Table 4.4.

Table 4.4: Final reference values of versions A and B in parts 2 and 3 of the empirical study

Part 1	Introduction and instructions for the experiment	
	Version A	Version B
Part 2	Reference values 1500 and 2000 Outward + Inward	"Trial part" with reference values 150 and 200 Outward
Part 3	Reference values 1500 and 2400 Outward	Reference values 1500 and 2000 Outward + Inward
Part 4	Questionnaire	

Part 4 consisted of a questionnaire which is found in Appendix 3. The questions are also presented in Table 4.5 with reasons for including them.

Table 4.5: Questions included in the questionnaire and reasons for including them

No.	**Question**	**Reason for including the question**
1	Age	The reason for including these questions was not to find demographic differences, but rather to verify a satisfactory selection.
2	Sex	
3	Education	During the testing of the method it was indicated that people with university education found the problems easier to analyse than those with less education. People's ability to reflect and analyse theoretical problems was assumed to be correlated to their level of education. This was investigated by the third question.
4	Did you think of any specific accidents when you carried out the experiment? If yes, what accident/accidents?	The purpose of this question was to investigate the general applicability of the results. Negative answers indicated that the subjects were analysing the problems on a rather high level of abstraction, which increases the possibility to use the results in different areas. It also indicated that only the intended attribute, i.e. number of fatalities, was considered.
5	Take a short moment to reflect upon whether you used a specific strategy to carry out the experiment, and if so, try to describe this strategy	The purpose of this question was to investigate if the subjects improved their ability to analyse problems involving large numbers of fatalities as they were confronted with these kinds of problems. In addition, this question was interesting from a psychological aspect, i.e. how people reason when carrying out the experiment. The question was asked prior to the information on different strategies (see below) to avoid that subjects were influenced by this information.

6	Did you change your strategy during the experiment? If yes, try to describe how and when you changed your strategy	This is a way of investigating the problem of reliability that could arise if subjects changed their strategies during the experiment and gave answers that contradicted each other.
7	Are you satisfied with your answers in part 2 and 3, i.e. the experiment? If No, in what way would you like to have answered differently?	A basic condition for drawing any conclusions from the results is that the subjects are satisfied with their answers. Subjects who changed their strategies might have become more familiar with the experiment and eventually found a strategy which they preferred. In this case, they might not feel satisfied with their answers given in the beginning of the experiment, and this effect is hoped to be identified by this question.
Information on different strategies, see Appendix 3		This information contains descriptions of different possible strategies for carrying out the experiment, and can be regarded as an "education process". The reason for presenting these strategies is to make the subjects aware of other possible ways of analysing the problem that they might not have thought of.
8	Do you recognise your own strategy in any of the strategies presented above? If yes, which of the strategies?	This question is aiming at evaluation in what degree the subjects are affected by the presentation of other strategies than the ones they used themselves. The answers from this question will be compared to the answers from question 5, in which the subjects described their strategies in their own words.
9	Having reflected the strategies presented above, are you still satisfied with your answers? If No, in what way would you like to have answered differently?	When the subjects have received the information on different strategies they might question their own strategy and find their answers unsatisfactory. If the subjects find one of the presented strategies more appealing they have a possibility of describing this alternative preference.
10	Your answers from the experiment could be used to decide where risk reducing resources should be spent to reduce risks in society. The alternative could be to have experts to decide upon these issues. Of course it is possible to have a group consisting of both experts and the general public to decide, but if you had to choose one of the alternatives which one would you choose? (Experts in risk management or The general public?)	Although the subjects are satisfied with their answers, they might not be prepared to have their answers used as a basis for decision making on risks in society. This opinion is investigated by the last question.

5. The empirical study

In this chapter the implementation of the empirical study will be described. Two different groups participated in the study; one group of the general public at Lund city library, called group 1, and one group of fire safety engineering students at Lund University, called group 2.

5.1. Group 1

Group 1 consisted of people passing by the experimental arrangement that was set up in a passage way inside Lund city library, see Figure 5.1. A couple of posters with an inquiry for people willing to participate in an empirical study as a part of a Master's thesis were placed in the vicinity of the experimental arrangement. Only people who showed interest in those posters were asked to take part in the study, i.e. nobody was persuaded to participate. All participants were rewarded with a cinema ticket.

The study was carried out during four successive days in August 2006. The implementation of the study took part in the end of the university summer break, i.e. the number of students in Lund was unusually small.

In the beginning of the empirical study between two and four computers were used simultaneously. As the two supervisors found it stressful to watch over more than one computer at the time, the number of computers in operation at one time was reduced to two.

In order to avoid misunderstandings and to be able to answer questions as fast as possible the supervisors sat down next to the subjects during the second and third part of the experiment, i.e. the computer based trade off situations. Moreover, by sitting next to the subjects the supervisors wanted to make sure that enough indifference points were obtained to elicit utility functions (at least two indifference situations must be registered to be able to estimate a utility function). This might have affected the subjects (see section *7.2.5 Influence from the supervisors*).

Figure 5.1: The experimental arrangement at Lund City Library

5.2. Group 2

Group 2 consisted of fire safety engineering students at Lund University. The students were newly appointed to the fire safety engineering programme and the study was carried out on their second day at university in August 2006.

All students that were present at the day of the experiment were participating. The experiment was carried out in four computer rooms at Lund University and all participants doing a web-based version of the study at the same time.

The students were served tea or coffee and rolls after the experiment.

6. Results and analysis

In this chapter the results from the empirical study are presented. First, the utility functions obtained from the experiment are illustrated. These results are analysed and compared to the results from the study by Abrahamsson and Johansson (2006) and to the risk preferences underlying some countries' societal risk criteria. Thereafter, a presentation of the results from the questionnaire will be presented and analysed.

Table 6.1 is repeated from Chapter 4 to illustrate the arrangement of the two versions of the empirical study.

Table 6.1: The arrangement of the two versions of the empirical study

Part 1	Introduction and instructions for the experiment	
	Version A	Version B
Part 2	Reference values 1500 and 2000 Outward + Inward	"Trial part" with reference values 150 and 200 Outward
Part 3	Reference values 1500 and 2400 Outward	Reference values 1500 and 2000 Outward + Inward
Part 4	Questionnaire	

Two groups of subjects carried out the experiment. Group 1 consisted of 38 persons of the general public. This part of the study was carried out at Lund City Library. Group 2 consisted of 41 fire safety engineering students at Lund University. Distribution of age, gender and education for the subjects of the two groups are illustrated in Figures 6.1-6.4 and Table 6.2 (i.e. the answers to the first three questions of the questionnaire).

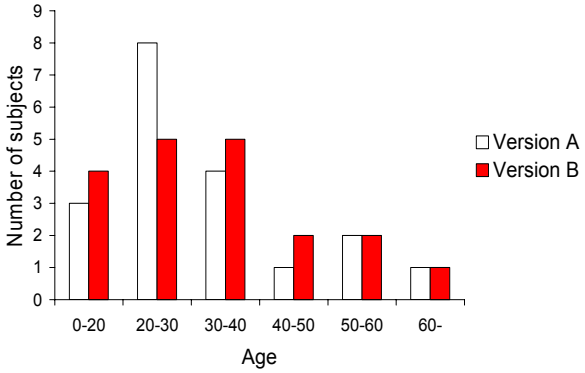

Figure 6.1: Age distribution group 1

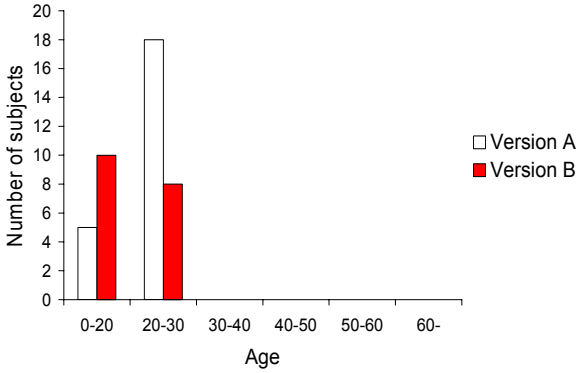

Figure 6.2: Age distribution group 2

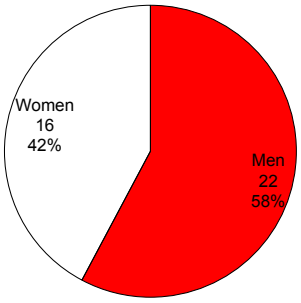

Figure 6.3 Gender distribution group 1

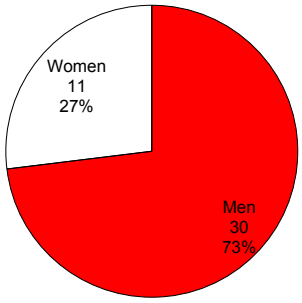

Figure 6.4 Gender distribution group 2

Table 6.2 Education

Education (This question was not asked to Group 2 since all of them were University students)

	Group 1		Group 2	
	Version A	Version B	Version A	Version B
Compulsory school	0	0	0	0
Senior high school or equivalent	2	3	0	0
University	16	15	23	18
Other	1	1	0	0

6.1. Utility functions based on the preferences of the public

The empirical study on group 2 was conducted on a web-based version of the trade off method. Unfortunately, the results from this study were not saved on the server. Consequently, all data forming the utility functions of group 2 were lost. Therefore, subsequent utility functions all come from group 1 and are illustrated in Figures 6.5-6.10. To be able to study the range of 0 to 1000 fatalities, the utility functions have been normalised in the following way:

$$u(N) = 1 - \frac{N^{\beta}}{1000^{\beta}}$$

For version B, part 2, the range of 0 to 100 fatalities was studied. The utility functions from this part were normalised by:

$$u(N) = 1 - \frac{N^{\beta}}{100^{\beta}}$$

The utility of 1 corresponds to 0 fatalities and the utility of 0 corresponds to 1000 fatalities (100 fatalities for version B, part 2).

The median values for β are illustrated by unbroken lines and approximations of the 5th and 95th percentiles are shown as dotted lines in Figures 6.5-6.10. Consequently, roughly 90 % of the subjects' utility functions can be found between the dotted lines. For all figures except for Figure 6.10 one of the 19 subjects generating each figure did not provide the minimum of two indifference points. Therefore all figures except Figure 6.10 are based on the utility functions from 18 instead of 19 of the subjects. The median values, mean values and standard deviations for β are summarised in Table 6.3. A summary of all Beta-values can be found in appendix 5.

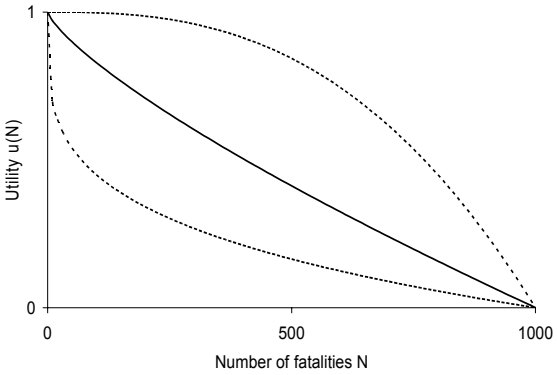

Figure 6.5: Version A reference values 1500 and 2000 Outward procedure

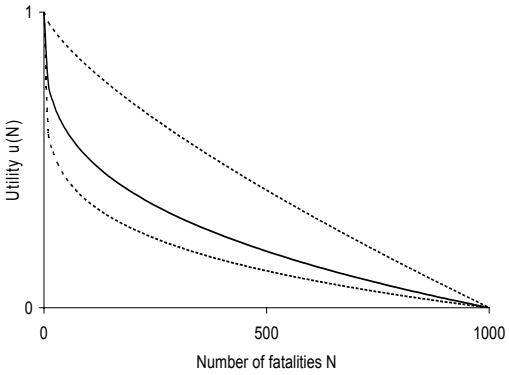

Figure 6.6: Version A reference values 1500 and 2000 Inward procedure

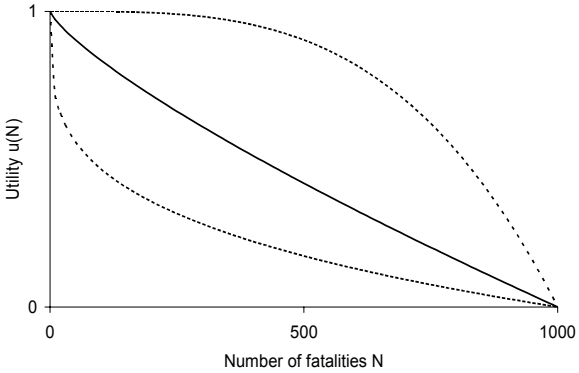

Figure 6.7: Version A reference values 1500 and 2400 Outward procedure

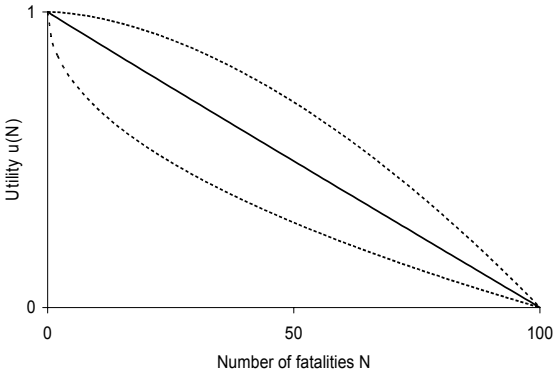

Figure 6.8: Version B Reference values 150 and 200 Outward procedure in the range 0 to 100 fatalities

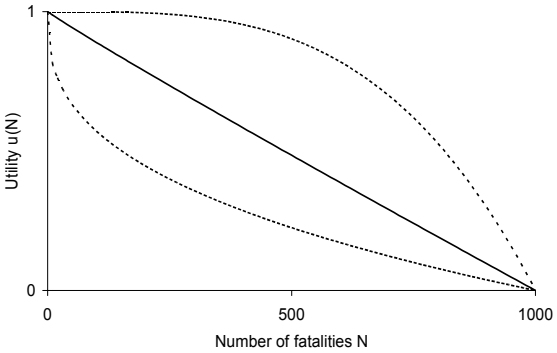

Figure 6.9: Version B reference values 1500 and 2000 Outward procedure

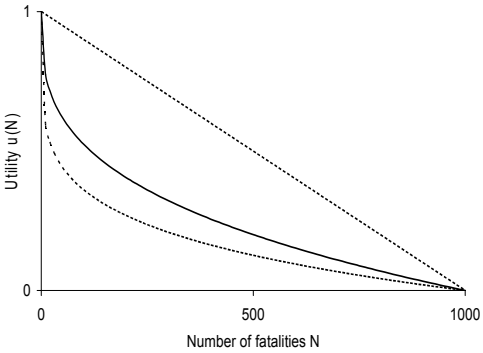

Figure 6.10: Version B reference values 1500 and 2000 Inward procedure

Table 6.3: Median values, mean values and standard deviations for β

	Median values for β			
	Version A		Version B	
Reference values	1500 and 2000	1500 and 2400	150 and 200	1500 and 2000
Outward procedure	0,77	0,85	1	0,96
Inward procedure	0,31	---	---	0,32
	Mean values for β			
Outward procedure	1,06	0,74*	0,97*	0,96*
Inward procedure	0,36*	---	---	0,35*
	Standard deviations for β			
Outward procedure	0,84	0,34*	0,35*	0,42*
Inward procedure	0,19*	---	---	0,16*

* Outliers excluded. Outliers are defined as β values > Q_3+ 1,5·(Q_3-Q_1) where Q_1 corresponds to the 25 % quartile and Q_3 corresponds to the 75 % quartile.

In Figure 6.11 the β values from the four parts with reference values 1500 and 2000 are illustrated as box plots.

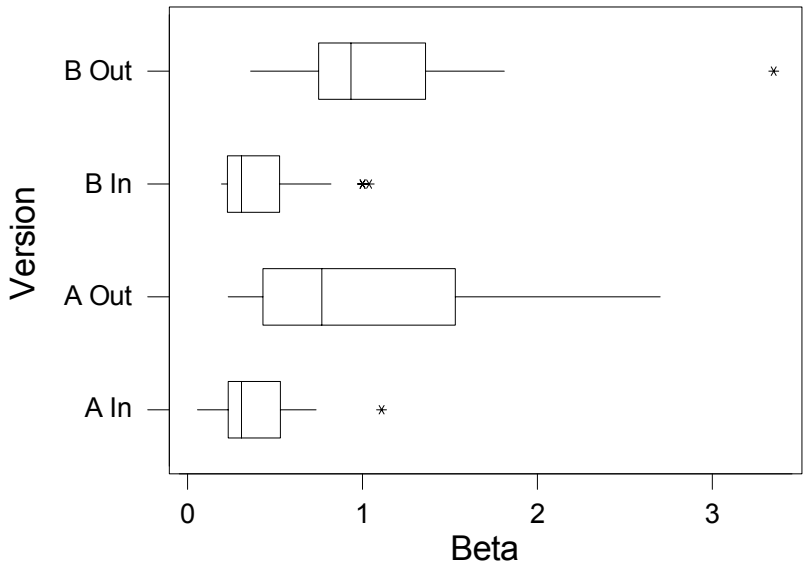

Figure 6.11: Box plot of β values of this study. One extreme outlier is excluded from version B Out (β value 11,91)

Table 6.4 shows the number of subjects whose utility function was classified as convex, concave or linear. In version A one of the subjects did not provide results that generated a utility function, therefore the total number of subject are 18 instead of 19. Also for the outward procedure of version B one subject did not generate a utility function, which gives a total number of subjects of 18 compared to 19 for the inward procedure.

Table 6.4: Number of subjects whose utility function was classified as convex, concave or linear

Number of subjects whose utility function was classified as convex, concave or linear, respectively (Reference values 1500 and 2000 fatalities)

	Version A		Version B	
	Outward	Inward	Outward	Inward
Convex (risk-seeking)	11	17	11	17
Concave (risk-averse)	7	1	6	1
Linear (risk-neutral)	0	0	1	1

The results show that a majority of the subjects reveal a convex utility function, which corresponds to a risk-seeking risk attitude.

6.2. Comparison to the study by Abrahamsson and Johansson

In Table 6.5 the median values for β are compared to the values for β from the study by Abrahamsson and Johansson (2006). Figure 6.12 show a comparison with the results from Abrahamsson and Johansson illustrated as box plots.

Table 6.5: Comparison of median values for β

Comparison of median values for β (Reference values 1500 and 2000 fatalities)

This study

	Version A		Version B	
	Outward	Inward	Outward	Inward
	0,77	0,31	0,96	0,32

The study by Abrahamsson and Johansson

	Group A		Group B	
	Outward	Inward	Outward	Inward
	0,74	0,32	0,76	0,41

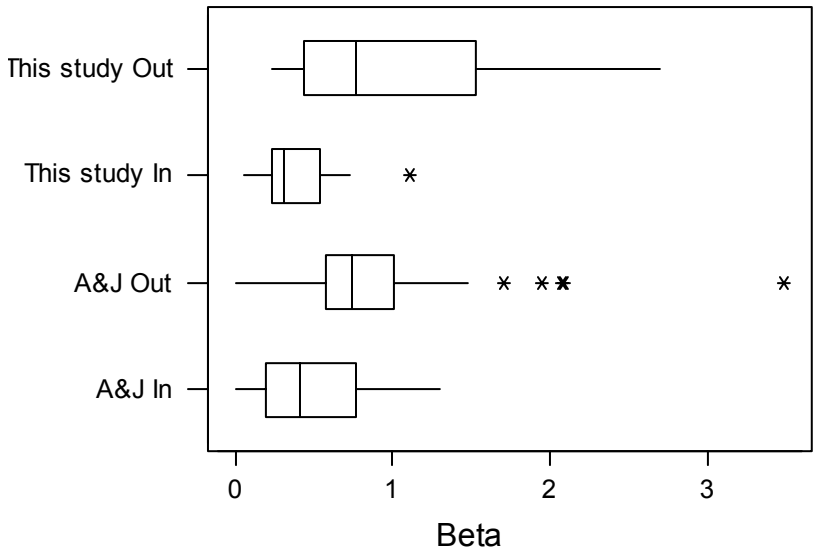

Figure 6.12: Box plot of β values of this study compared to the results of Abrahamsson and Johansson

Table 6.5 shows that the β -values for the outward procedures from this study are higher than the values from the study by Abrahamsson and Johansson, while the β -values for the inward procedures are lower.

Since version B of this study starts with a "trial part", which was not the case in the study of Abrahamsson and Johansson, the results from this version was not included in the comparison.

The differences between version A in this study and the Abrahamsson and Johansson study were not statistically significant at the 90 %the level of significance. The difference corresponded to a 67 % level of significance.

In Table 6.6 below a comparison of the percentage of subjects whose utility function was classified as convex, concave or linear is illustrated.

Table 6.6: Comparison of percentage of subjects whose utility function was classified as convex, concave or linear

Comparison of percentage of subjects whose utility function was classified as convex, concave or linear, respectively (Reference values 1500 and 2000 fatalities)

This study

	Version A		Version B	
	Outward	Inward	Outward	Inward
Convex (risk-seeking)	61 %	94 %	61 %	90 %
Concave (risk-averse)	39 %	6 %	33 %	5 %
Linear (risk-neutral)	0 %	0 %	6 %	5 %

The study by Abrahamsson and Johansson

	Group A		Group B	
	Outward	Inward	Outward	Inward
Convex (risk-seeking)	68 %	76 %	68 %	86 %
Concave (risk-averse)	13 %	24 %	18 %	2 %
Linear (risk-neutral)	19 %	0 %	14 %	12 %

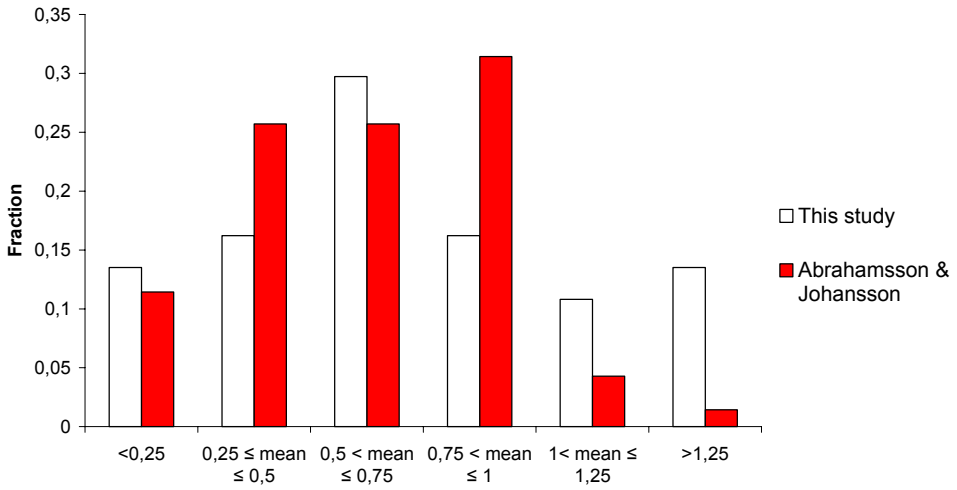

Figure 6.13 Normalised comparison of β values. All results included

6.3. Strategies used by the subjects

The questionnaire was filled in by both groups, i.e. both by group 1 consisting of the general public and by group 2 consisting of fire safety engineering students. Therefore the answers from

both groups will be presented and analysed in subsequent sections, although β values only are available from group 1.

Question 5 aimed at investigating what strategies the subjects were using when they carried out the experiment. The question read:

Take a short moment to reflect upon whether you used a specific strategy to carry out the experiment, and if so, try to describe this strategy

Table 6.7: Answers to question 5

Question 5

Described strategy	Group 1		Group 2	
	Version A	Version B	Version A	Version B
Avoiding the alternative with the largest number of fatalities	4	1	2	3
Preferring the alternative including the lowest number of fatalities	9	11	11	6
Preferring the alternative with the lowest total number of fatalities	2	4	6	4
Intuition	0	0	2	3
Do not know/no answer	1	0	0	0

Since question 5 was an open answer question, the answers were categorised by the authors. The results from this categorisation are shown in Table 6.7 above. The reason for including an open question was to give the subjects a chance of describing their strategies in their own words. After the information on different strategies supplied after question 7 in the questionnaire, the subjects were asked to choose which of these strategies that resembled their own strategy. Question 8 read:

Do you recognise your own strategy in any of the strategies presented above? If yes, which of the strategies?

The answers from question 8 are shown in Table 6.8 below

Table 6.8: Answers to question 8

Question 8

Described strategy	Group 1		Group 2	
	Version A	Version B	Version A	Version B
Avoiding the alternative with the largest number of fatalities	6	5	6	3
Preferring the alternative including the lowest number of fatalities	11	9	7	8
Preferring the alternative with the lowest total number of fatalities	9	4	10	10
Preferring the alternative with the number of	2	3	2	1

fatalities below a specific number				
Other strategies	0	2	1	2
Intuition	2	4	3	5

The most common strategy for both questions was alternative B, i.e. preferring the alternative including the lowest number of fatalities. Below follows a comparison between question 5 and question 8.

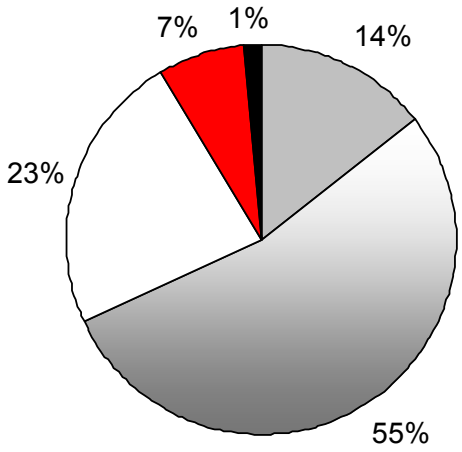

Figure 6.14: Answers to question 5, see legends below

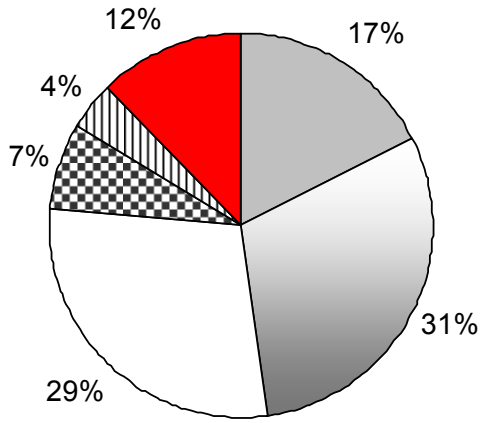

Figure 6.15: Answers to question 8, see legends below

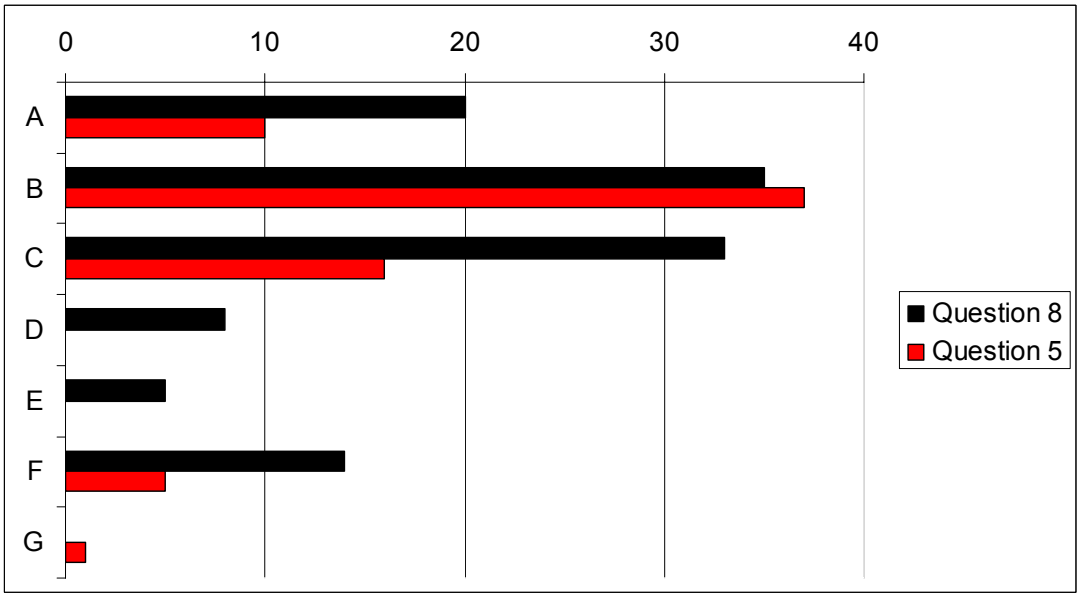

Figure 6.16: Comparison between the answers to question 5 and question 8

A. Avoiding the alternative with the largest number of fatalities
B. Preferring the alternative including the lowest number of fatalities
C. Preferring the alternative with the lowest total number of fatalities
D. Preferring the alternative with the number of fatalities below a specific number
E. Other strategies
F. Intuition
G. Do not know

An analysis was carried out comparing the subjects' β values with their stated strategies. Three of the strategies are considered to be associated with a specific risk attitude.

Strategy A, avoiding the alternative with the largest number of fatalities, is considered to correspond to a risk avert risk attitude.

Strategy B, preferring the alternative including the lowest number of fatalities, is considered to correspond to a risk prone risk attitude.

Strategy C, preferring the alternative with the lowest total number of fatalities, is considered to correspond to a risk neutral risk attitude.

The results of the analysis can be studied in table 6.9.

Table 6.9: comparison between the subjects' β values and their stated strategies

Question 5 (Answers categorised by the authors)

	Version A		Version B		Total	
Strategy	Number of subjects	Mean value of β	Number of subjects	Mean value of β	Number of subjects	Mean value of β
A	1	NaN	1	1,36	2	1,36
B	7	0,36	11	0,59	18	0,50
C	3	0,66	4	0,83	7	0,76

Question 8

	Version A		Version B		Total	
Strategy	Number of subjects	Mean value of β	Number of subjects	Mean value of β	Number of subjects	Mean value of β
A	6	1,14	5	1,44	11	1,28
B	11	0,39	9	0,61	20	0,49
C	9	0,53	4	0,80	13	0,62

Legend and comments

A	Avoiding the alternative with the largest number of fatalities This category corresponds to a risk avert strategy
B	Preferring the alternative including the lowest number of fatalities This category corresponds to a risk prone strategy
C	Preferring the alternative with the lowest total number of fatalities This category corresponds to a risk neutral strategy

6.4. Change of strategy during the experiment

In Chapter 4 the following statement was formulated as an attempt to explain the subjects' change of strategies observed during the testing of the method;

Subjects gradually improve their ability to analyse the experimental choice situations as they are forced to confront them.

To analyse this problem two versions of the experiment were created, both including one part with the reference values 1500 and 2000. However, in version B this part was preceded by a "trial part", while it was the first part that the subjects were confronted with in version A. The purpose of the "trial part" was to give the subjects time to practice and to become familiar with

the experiment, and by comparing the results from the common parts of version A and B, possible effects from getting familiar with the method could be identified. This comparison is shown for group 1 in Table 6.10 below.

Table 6.10: Comparison of β values between the versions with and without "trial part"

Comparison of median values for β of the two versions with and without a "trial part", both versions with reference values 1500 and 2000	Outward	Inward
Version A (without "trial part")	0,77	0,31
Version B (with "trial part")	0,96	0,32

The differences between the two versions illustrated in Table 6.10 were negligible for the inward procedure. For the outward procedure small differences were found. Statistically no difference was found on the 90 % level of significance. The difference that was observed corresponded to a statistical test on the 57 % level of significance.

However it can be observed that a total of 12 of the 38 subjects (approximately 30 %) from group 1 changed their risk attitude considerably during the experiment, which indicates a change of strategy for these subjects, see Tables 6.11.

Table 6.11: Number of subjects who changed risk attitude

Change of risk attitude	**Version A Number of subjects**	**Version B Number of subjects**
From risk averse to risk prone	3	4
From risk prone to risk averse	3	2
Total	6	6

In addition to the comparisons carried out above, question 6 in the questionnaire aimed at investigating the subjects' change of strategies.

6a. Did you change your strategy during the experiment?

The answers to this question are shown in Figure 6.17.

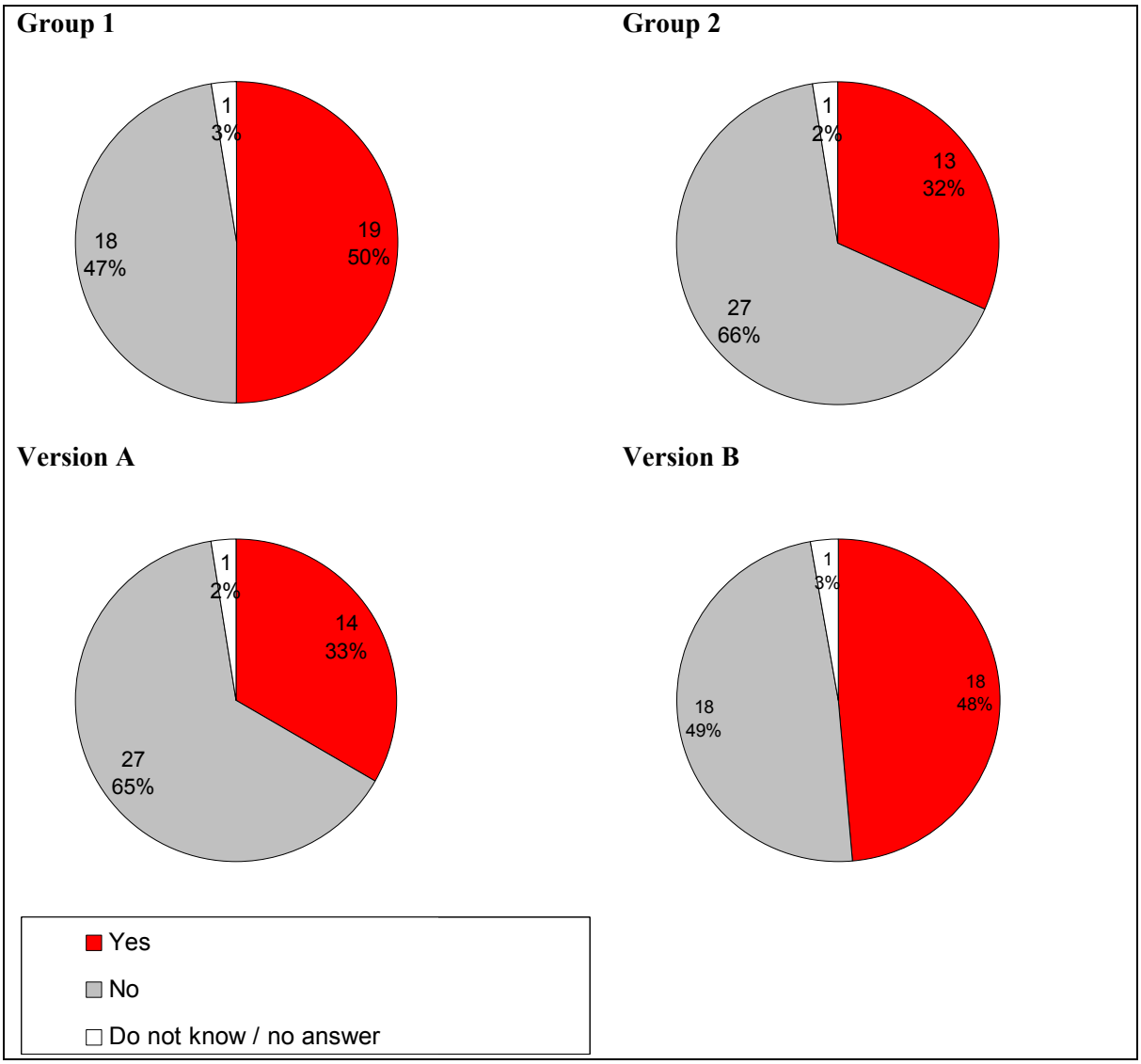

Figure 6.17: Answers to question 6a

The overall fraction of subjects giving positive answers was about 40 %.

An additional question, 6b, aimed at a more thorough examination of those subjects supplying a positive answer to question 6a.

6b. If yes, try to describe how and when you changed your strategy

This question was designed as an open answer question, which resulted in a much diversified amount of answers. Therefore no conclusions can be drawn from this question. A detailed classification of the change of strategy from question 6b can be found in Appendix 4.

6.5. The subjects' contentment of their answers

To be able to analyse whether information on different strategies affected the subjects' satisfaction with their supplied answers they were asked whether they were satisfied with their supplied answers both before and after the description of different strategies. Question 7 was placed before the information on different strategies and question 9 was placed after this information.

Question 7 was formulated;

Are you satisfied with your answers in part 2 and 3, i.e. the experiment?

And question 9 read:

Having reflected the strategies presented above, are you still satisfied with your answers?

Both question 7 and question 9 were formulated both as yes or no questions (question 7a and 9a, respectively) and as optional open answer questions (question 7b and 9b, respectively).

Question 7 **Question 9**

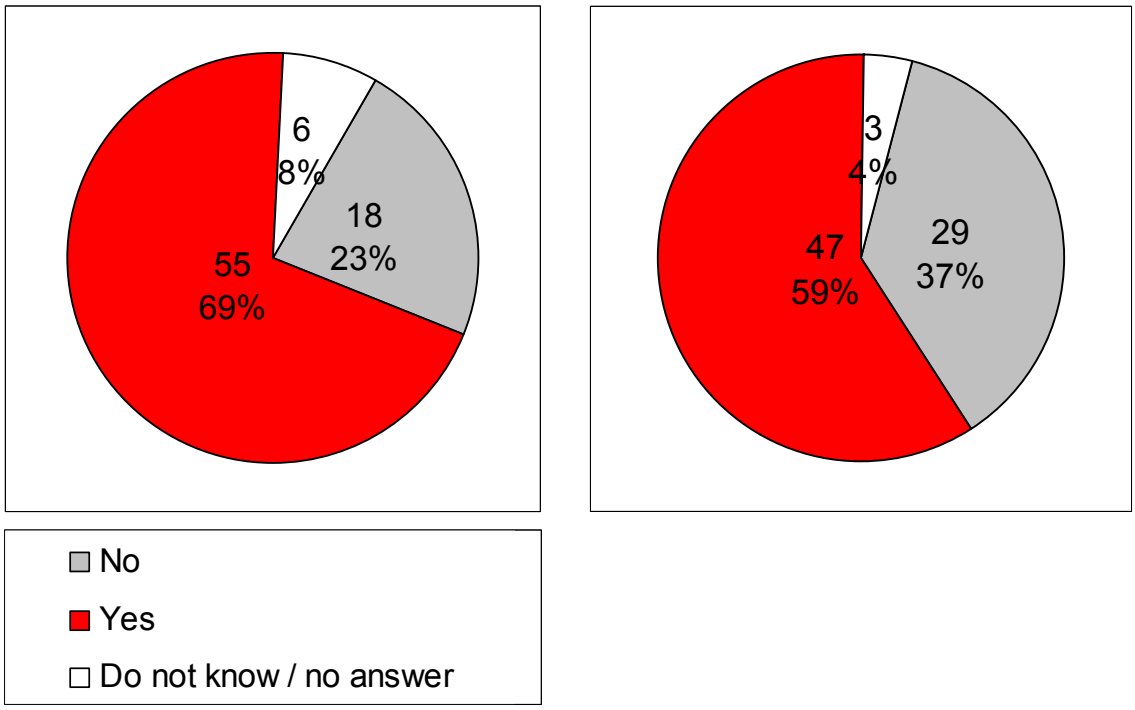

Figure 6.18: To the left answers to question 7a and to the right answers to question 9

Questions 7a and 9a showed that a majority of the subjects were content with their supplied answers (69 % and 59 %, respectively).

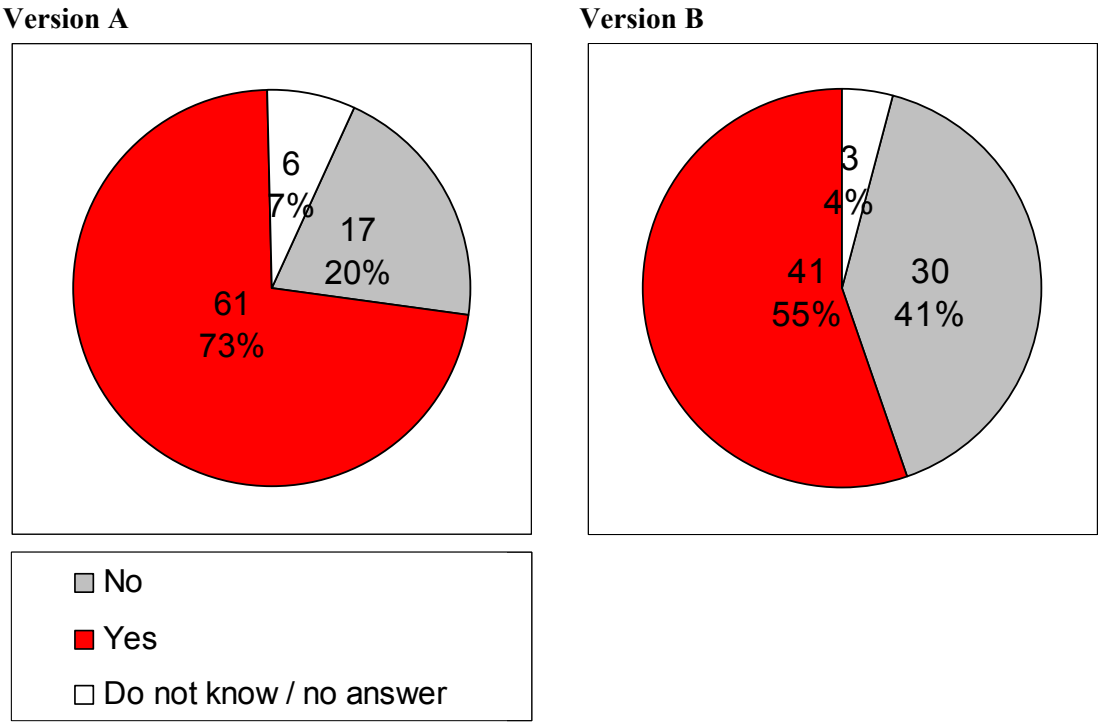

Figure 6.19: To the left answers to version A and to the right answers to version B

The answers from questions 7b and 9b showed that most of the subjects who felt unsatisfied with their answers would have liked to give the questions more reflection or felt uncomfortable with the topic. The answers to question 9b showed that about 30 % of the subjects were influenced by the information on different strategies. A slight decrease from question 7b to question 9b was observed regarding those who misinterpreted the questions or felt that they provided inconsistent answers. A detailed classification of the open answers can be found in Appendix 4.

6.6. The dependence on the size of accident

Version B was originally designed to investigate the effects of education or experience. Since the first part in this version has significantly lower values of y and Y (150 and 200) and since the subjects both in this part and in the part of version A with reference values 1500 and 2000 lacked previous experience, the first part of version B is well-suited for investigating the dependence on the size of accidents.

Table 6.12: Comparison between the first parts of version A and version B

Comparison of β of version A with reference values 1500 and 2000 outward procedure with version B with reference values 150 and 200 "trial part"	Median	Mean
Version A first part	0,77	1,06
Version B "trial part"	1	0,97*

* Outliers excluded. Outliers are defined as β values > Q_3+ 1,5·(Q_3-Q_1) where Q_1 corresponds to the 25 % quartile and Q_3 corresponds to the 75 % quartile.

Statistically no differences between the two versions were found on the 90 % level of significance. The difference that was observed corresponded to a statistical test on the 67 % level of significance.

6.7. The dependence on the reference values y and Y

During the testing of the method the following statement was formulated;

Although the theory behind the trade off method states that the results are independent of the size of the reference values y and Y, these values are believed to affect the results

To analyse this problem the reference values of version A, part 3, were decided to be 1500 and 2400, see Chapter 4 *Method*. These values were chosen to study any possible differences from the values 1500 and 2000 used in version B. According to the theory behind the trade off method part 2 and part 3 of version A should yield the same results. A comparison between these parts is shown in Table 6.13.

Table 6.13: Comparison between part 3 of version A and version B

Comparison between part 3 of version A and version B

	Median	Mean
Version B (reference values 1500 and 2000, outward procedure)	0,96	0,96*
Version A (reference values 1500 and 2400, outward procedure)	0,85	0,74*

* Outliers excluded. Outliers are defined as β values > $Q_3 + 1{,}5 \cdot (Q_3 - Q_1)$ where Q_1 corresponds to the 25 % quartile and Q_3 corresponds to the 75 % quartile.

A difference between the two versions was found on the 95 % level of significance.

6.8. General applicability and personal involvement

To be able to use the results on a general level the instructions for the experiment were formulated in general terms. To investigate whether the subjects were analysing the problems on a high level of abstraction, and thereby generating results possible to use in different areas, the following question was asked (question 4a);

Did you think of any specific accidents when you carried out the experiment?

Negative answers indicated that the problems had been analysed by the subjects on a rather high level of abstraction, which increases the possibility to use the results in different areas. It also indicated that only the intended attribute, i.e. number of fatalities, was considered. The answers from question 4 are illustrated in Figure 6.20.

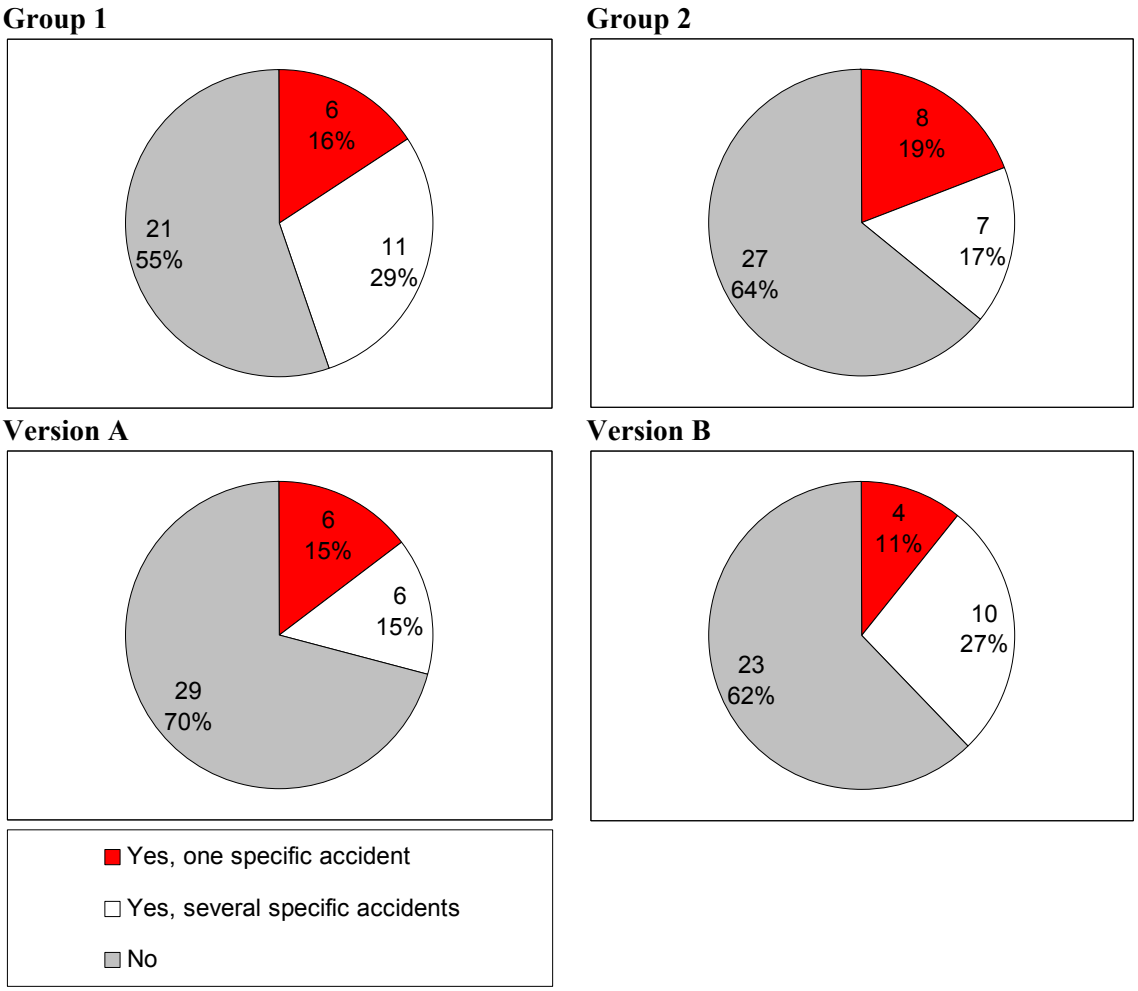

Figure 6.20: Answers to question 4a

Question 4a showed that a majority of the subjects did not think of any specific accidents when carrying out the experiment.

Question 4b read:

If yes, what accident/accidents?

The answers to question 4b showed that about 27 % of the subjects who had imagined one or several accidents had thought of deliberate harm, e.g. war or terror attacks while the rest had thought of accidental harm, e.g. car accidents or natural disasters. One third of the subjects had specific accidents that have occurred in mind, e.g. 9/11 or the Tsunami disaster, while the other two thirds thought of more general accidents, e.g. a fire or a natural disaster of any kind. A detailed classification of the specific accidents from question 4b can be found in Appendix 4.

6.9. Decision making regarding risks in society

During the work the authors have been concerned with the public preferences regarding multiple fatalities in large scale accidents. However another closely related question has also been on the authors' minds; who do the public think should decide in these matters? Since this question never was a part of the main objectives of the thesis a thorough investigation of this question has not been performed. Nevertheless the last question (Question 10) in the questionnaire was formulated in order to shed some light on this question;

Your answers from the experiment could be used to decide where risk reducing resources should be spent to reduce risks in society. The alternative could be to have experts to decide upon these issues. Of course it is possible to have a group consisting of both experts and the general public to decide, but if you had to choose one of the alternatives which one would you choose?

Table 6.14: Answers to question 10

Question 10

	Group 1		Group 2	
	Version A	Version B	Version A	Version B
Experts in risk management	14	16	18	17
The general public	4	3	2	1
Do not know/no answer	2	2	3	0

Obviously a large majority (79 %) of the subjects regarded experts in risk management best suited for making decisions on risks in society.

Many subjects chose to explain and justify their answers. The most common argument for experts in risk management to decide was simply that they have the necessary qualifications and experience. For a detailed description of the open answers the reader is referred to Appendix 4.

7. Discussion

In this chapter several matters will be discussed, partly concerning the results and partly concerning the study as a whole.

7.1. Results and analysis

The structure of this section is based on the structure of Chapter *6 Results and analysis*. The matters concerning reliability and validity are not included in this structure; instead they have their own sections later on in the chapter.

7.1.1. Utility functions based on the preferences of the public

The results showed that the risk attitude of the population generally is risk prone. This means that people tend to value the utility of the difference between low numbers of fatalities higher than the difference in utility between higher numbers of fatalities.

The difference between the results from the two versions A and B is very small. It is obvious that the outward procedure generated much larger variations than the inward procedure. β cannot take values below zero. The inward procedure generated β values significantly lower than the outward procedure. As can be observed almost every value from the inward procedure is below one. This implies that the variation from the values of the inward procedure cannot be large since most of the values are captured between zero and one.

7.1.2. Comparison to the study by Abrahamsson and Johansson

The population of the study made by Abrahamsson and Johansson was exclusively consisting of subject with professional or educational knowledge of risk management. One of the major objectives of this study was to investigate whether their population differs from the general public regarding risk attitude. From the results of this study no statistically significant difference can be showed.

The authors consider it to be important to note that the population of this study does not necessarily represent the general public in Sweden. Looking at the distribution of the three measured demographic parameters (age, gender and education) the population of this study does not represent the general public on at least one major point, namely education. Using Lund City Library as location for conducting the experiment had one major drawback, which was the selection of people attending the library. More than 80 % of the subjects were presently studying at the university or had a university degree (see Figure 7.1).

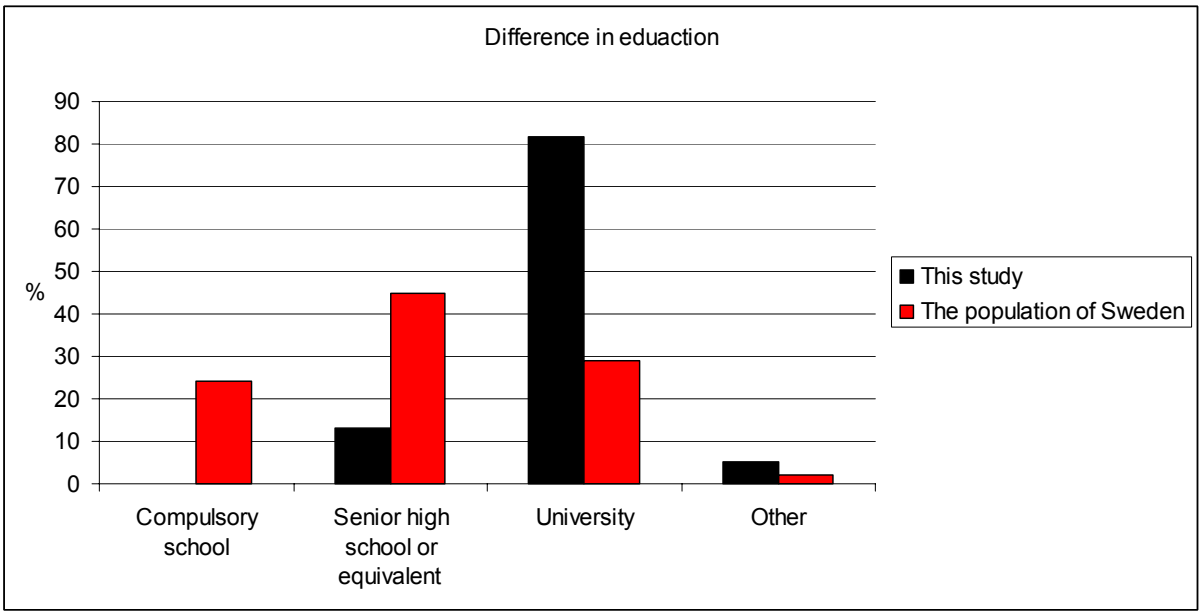

Figure 7.1: Difference in education between the population of Sweden (SCB 2006) and the subjects of this study.

Since academic background is assumed to be a parameter which might affect the outcome of the experiment, the results from this study can not be used to represent the risk attitude of the general public in Sweden. Further investigation is recommended in this matter, especially with focus on capturing the risk attitudes of people with less education than university studies.

The results from this study have a much larger variation than the study of Abrahamsson and Johansson. It is notable that the density of the answers of this study is not increasing around the median value, see Figure 6.13. This could be explained by the fact that the Inter-Quartile Ranges (IQRs) of the inward and the outward procedures do not overlap. This implies that there are actually two median values on the interval rather than one. The reason for the larger deviation between the inward and the outward procedures of this study compared to the study of Abrahamsson and Johansson will be discussed further in section *7.3.1. Biases associated with prospect and reference*.

7.1.3. Strategies used by the subjects

In this thesis the word strategy has been used to describe the subjects' way of reflecting and analysing the problems. Some of these strategies have been corresponding to a particular risk attitude. In order to analyse the results the strategies needed to be categorised. In the open answer question (question 5) the authors have done this categorisation while in question 8 the categorisation has been executed by the subjects themselves.

In the first case the problems lies within the judgment of the authors and the ability for subjects to describe their strategy. Self-evaluation and describing the abstract issues of strategies in risk preference experiments are evidently putting high demands on the subjects' capabilities in these matters. This sometimes makes the evaluations difficult to interpret.

In the second case the problem lies within the categories themselves. The subjects are forced to place themselves into fixed categories, which might not reflect the strategy of the subjects completely. Besides, the subjects might be influenced by the proposed strategies which make them sort themselves in categories they might not have considered in the first place.

As can be observed in Figures 6.14-6.16 the results from question 5 are more distinguishing than the results from question 8. This is probably because the subjects were allowed to choose

more than one category in question 8. All categories but the largest one, B, are increasing in number from question 5 to question 8.

The comparison of the subjects' β values with their stated strategies in section *6.3 Strategies used by the subjects* showed that most of the subjects' descriptions of their strategies were in line with the risk attitude underlying the corresponding β value. The largest deviations were found for the group who considered that they used strategy C. A risk neutral risk attitude should correspond to a β value of 1. However, the group who used strategy C had an average β value of 0,76. Although this value deviates from risk neutrality, it is still between the values from the groups using strategies A and B.

7.1.4. Change of strategy during the experiment

Judging by the reactions and the opinion of the subjects during the testing and the experiment, the authors thought that there would be a more significant difference between the risk attitude of the subjects in the beginning of the experiment (more risk prone) compared to the risk attitude in the end of the experiment (more risk neutral). This assumption was based on the fact that many subjects seemed to value the utility of zero fatalities very high in the beginning of the test, while they gradually seemed to change their way of thinking to a strategy involving all possible outcomes.

These assumptions proved wrong and it seems that the mean β value of a population is constant in time and increased experience.

From the study by Abrahamsson and Johansson it was shown that, although almost every subject in their study knew about the theory of expected utility, many chose other strategies than minimising the expected number of fatalities. The subjects of this study were not assumed to have knowledge in the theory of expected utility to the same extent as the subjects in the study by Abrahamsson and Johansson. Learning to handle uncertainties in a statistical way with expected numbers was thought to be a possible way for the subjects to change their strategies.

It is important to note that a change in decision strategy not necessarily needs to imply a change in preferences even though this is often the case. This probably explains why the fraction of the population who considered themselves to have changed their strategies is larger than the fraction that actually has shifted their risk preferences (see Figure 6.17).

The change of strategy and preferences indicates that the opinion of the general public has not reach a settled state in this issue. In order to investigate this issue and to involve preferences of the general public in the societal risk management decision process, a public debate that encourages the general public to reflect these matters should be initiated.

7.1.5. The subjects' contentment of their answers

An issue that initially was given much attention was whether the subjects were satisfied with their answers after having finished the experiment. If the subjects were discontent the result were considered less reliable than if the subjects were satisfied. This is because satisfaction is assumed to represent that fact that the subjects answer really represents his or her opinion.

The "trial part" was introduced to make the subjects familiar with the experiment. This would imply that the subjects in this category would feel more satisfied with their answers. However, the empirical results suggests otherwise; looking at both 7a and 9a the number of satisfied subjects was significantly higher among those who did not carry out the "trial part" (73 % satisfied compared to 55 %).

During the experiment the authors observed that many subjects felt uneasy with the outward part of the experiment. This was assumed to be induced by the fact that no matter what the

subjects did the expected number of fatalities increased. This effect was particularly considerable for the subjects executing version B, where the expected number of fatalities did not only increase within the first and second outward parts, but also between them. This could be the reason why subjects executing version B felt less satisfied than the ones executing version A.

As assumed the additional information on different strategies increased the number of unsatisfied subjects (from 23 % to 37 %). One likely explanation of this is that the introduction of new strategies made the subjects aware of new ways of thinking which were appreciated but not previously considered by the subjects.

7.1.6. The dependence on the size of accident

The method for eliciting the β value is to use a least square algorithm, which basically tries to find an average value of β for the entire interval of interest. If the subjects change their β over the interval the method will not detect this change in preference.

The results from this thesis show that there is no statistically significant difference between the β values of accidents in the range of 0 to 100 fatalities compared to accidents in the range of 0 to 1000 fatalities.

7.1.7. The dependence on the reference values y and Y

One of the major parameters for describing risk attitudes today is the β value. It is important to remember that an exponential function with the exponent β is nothing but a simplification of a subject's utility as a function of some attribute. In reality, a utility function can be very complex and abstract.

The results of this thesis show a statistically significant difference between the β values of two different experiments equal in every way but the values of y and Y. According to the theory behind the trade off method this should not be possible since the results should be independent of the value of y and Y.

Since the number of people conducting the study is rather low, it is possible that there are other small variations in the two different populations that explain the difference in β between the two experiments.

However looking at the deduction made by Wakker and Deneffe (1996)

$$[X_0, \alpha, y] \sim [x_0, \alpha, Y] \quad (1)$$

$$[X_1, \alpha, y] \sim [x_1, \alpha, Y] \quad (2)$$

Where the first indifference, (1), is substituted with a utility function u, which corresponds to the equality

$$\alpha \cdot u(X_0) + (1-\alpha) \cdot u(y) = \alpha \cdot u(x_0) + (1-\alpha) \cdot u(Y)$$

Rearranging the equality gives

$$\alpha \cdot (u(X_0) - u(x_0)) = (1- \alpha) \cdot (u(Y) - u(y))$$

The second indifference, (2), is also substituted with a utility function u

$$\alpha \cdot u(X_1) + (1-\alpha) \cdot u(y) = \alpha \cdot u(x_1) + (1-\alpha) \cdot u(Y)$$

Rearranging the second equality gives

$$\alpha \cdot (u(X_1) - u(x_1)) = (1-\alpha) \cdot (u(Y) - u(y))$$

Combining the two equalities and cancelling out the common right hand sides gives

$$\alpha \cdot (u(X_0) - u(x_0)) = \alpha \cdot (u(X_1) - u(x_1))$$

The last step is the step which the authors are concerned with. Cancelling out is alright as long as the functions are continuous over the interval of interest. As long as we assume that a person has a continuous utility function over the interval of interest we can say that the sizes of the reference values y and Y do not matter. The problem is obvious if a person's utility function is not continuous. According to the results mentioned in *7.1.6. The dependence on the size of accidents* this is not a problem for intervals of 0 to 100 fatalities. For practical reasons the kind of comparisons made in section 7.1.6. have not been conducted for the interval of interest. Therefore it can not be excluded that there are discontinuities in the utility function between the limit value 1000 and the largest reference value 2400 fatalities.

In order to assure that the utility functions are ok for the whole interval, it should be defined for all values in the experiment including the reference values y and Y.

7.1.8. General applicability and personal involvement

The results from the questionnaire indicate that most subjects completed the experiment without associating the alternatives with any particular kind of accident. This would indicate that the results mainly reflect the attribute in focus and that other attributes have a minor impact on the results.

There is an infinite number of attributes affecting a subject's opinion of the severity of an accident. In order to create a complete representation of how people value the severity of different sizes and kinds of accidents more studies need to be carried out. An example of this is the study by Davidsson and Lindhe (2005) which measures the disutility of the attribute *the size of the affected area* in disasters with some kind of environmental effect. A known bias that might evolve if a subject is referring to a particular accident is personal involvement, e.g. the subjects imagining themselves, their relatives or friends as possibly included in the number of fatalities associated with an outcome in the experiment.

A specific issue related to personal involvement is *equity*. Equity in this context means equal statistical chance to get a beneficial outcome or risk to get a harmful outcome. For a more thorough explanation of this word the reader is recommended to read Howard (1992). If the subjects who are conducting the experiment have a personal involvement they might value the life of the persons at risk differently. The subjects might as well distribute different probabilities to different people in the exposed groups which also bias the subject's answers.

However, no subject mentioned personal involvement of any kind in the questionnaire. This indicates that the biases mentioned above have small impact on the results of this study.

7.1.9. Decision making regarding risks in society

From the results of question 10 in the questionnaire[1] (see *6.8.1. Decision making regarding risks in society*) it seems obvious that the subjects carrying out this experiment believe that

[1] Question 10: Your answers from the experiment could be used to decide where risk reducing resources should be spent to reduce risks in society. The alternative could be to have experts to decide upon these issues.

experts in risk management should decide on societal risk criteria. Furthermore, there does not seem to be any differences among those who did not have any previous professional or educational contact with risk management and those who were in the beginning of an engineering program within this field. However, there are some objections to this conclusion.

Many of the subjects experienced the experiment as morally demanding. This encouraged many subjects to leave the problem to someone else. Moreover, more than 30% were not satisfied with their answers. This group might have disqualified themselves from deciding on societal risk criteria.

Even if the results are distorted by the experiment, this distortion itself is interesting. Does a test or experiment of this kind always affect the opinion of the subject in this matter? In order to find reliable material to base a further discussion on, a reference group who have not carried out the experiment should answer this question.

Independent of what such a reference group might think it is clear that subjects conducting this experiment and thereby are forced to reflect over these issues, believe experts in risk management should make these decisions. This might indicate that a more transparent decision process involving a larger fraction of the general public and thereby also forcing more people to reflect over these issues ends up in a public opinion believing experts in risk management should make the decisions. This would justify experts in risk management as decision makers.

7.2. Reliability and validity of the results

The testing, adjustment and adaptation of the method was made in order to improve the reliability and validity of the results. Yet, even after this process there were questions lingering about these issues. In order to investigate the reliability and validity of the method, several of the questions in the questionnaire were at least partly formulated with this objective (See chapter 4).

7.2.1. Stress and frustration

According to the results of the questionnaire about 18 % of those who were not satisfied with their answers would have liked to give the answers more reflection. However, this represents only 7 % of the total number of subjects. Moreover, only one subject in group 1 stated this was a reason for his/her discontentment. These results are well in line with the observed reactions of the subjects during the experiment. Consequently, the reliability problem of stress is not considered to be of great matter to the results.

Frustration seems to have been a bigger reliability problem, occurring for almost half of those subjects feeling discontent with their answers. The most frequent reason for frustration seems to be that the subjects are uncomfortable with the questions in the experiment. This is an issue closely related to the question itself and is therefore very hard to deal with. The major part of the other reasons for the frustration was connected to changes in strategies (see section *Change of strategy during the experiment*, above).

7.2.2. Risk-prone subjects

A major adaptation was made to the original method regarding this issue (see Chapter 4 *Method*). When making choices implying that the utility change from zero to one fatality was bigger than the utility change from 1500 to 2000 the computer program simply left out this point and provided the subject with a new set of alternatives without the possibility of zero fatalities.

Of course it is possible to have a group consisting of both experts and the general public to decide, but if you had to choose one of the alternatives which one would you choose? (Experts in risk management or the general public?)

A total of three subjects made choices of this kind, one in the outward procedure of version A (y and Y of 1500 2000), one in the "trial part" of version B and one in the outward part of version B (y and Y of 1500 2000). All these subjects made choices implying not only that the utility of changes between zero and one was bigger than the utility change between y and Y, but also higher numbers. The most extreme subject made choices indicating that the difference between 4 and 5 fatalities still was bigger than the utility difference between 1500 and 2000.

How the utility difference between the lowest numbers of fatalities should be found for these subjects is an unsolved problem. It is therefore important to note that the β value generated for these subjects is not valid below the number of fatalities for which the first equality was found.

7.2.3. Comprehensibility

This is a problem of validity that is difficult to investigate. The reason why there was no question examining this problem was simply that subjects were not assumed to state that they had not understood the trade off situations after conduction the whole experiment.

Since the supervisors of the experiment (the authors) actually sat next to the subjects during most of the experiments, an indication of the comprehensibility is given by the supervisors' impression of the subjects performing the experiments. The general impression is that those subjects who did not understand the trade off situations initially did ask the supervisors for guidance and were thereafter able to comprehend the task.

7.2.4. Outward and inward TO procedure

This was a problem known from the beginning of the project. Since this is a well-known and well-investigated problem, extensive efforts was not put into further investigation of this issue.

The results show that there are major differences between the generated β values between the inward and the outward procedure even in this study. Actually the difference between the inward and outward procedures in this study is bigger than the corresponding difference in the study by Abrahamsson and Johansson. One reason for this is further discussed in the section *7.3.1 Biases associated with prospect and reference* below.

7.2.5. Influence from the supervisors

As mentioned in Chapter 5 the supervisors were sitting next to the subjects during the experiment in order to avoid misunderstandings and to be able to answer questions. This might have affected the subjects. The reason for this might have been that the subjects wanted to make decisions in a way that they experienced that the supervisors considered being a better or more correct answer. It is not possible to say in what direction this might have influenced the subjects.

7.3. Problems that have evolved after the testing process

During the testing, adaptation and improvement of the experimental setup many problems were identified and managed. However, also during the empirical study problems have arisen. In this section these problems will be listed and discussed.

7.3.1. Biases associated with prospect and reference

Looking at both the median and the mean values, there are considerable differences between the inward and the outward procedures. This difference can be explained by the effect of diminishing sensitivity, i.e. the impact of a change diminishes with the distance from the reference point (Fennema & van Assen, 1999; Tversky & Kahneman, 1992).

Fennema and van Assen give an additional explanation; a positive change is always smaller relative to the value after the change than a negative change of the same absolute size relative to the value after the change. This means that in order to make the same fractional change subjects need to make smaller and smaller absolute steps in the inward procedure and bigger and bigger steps in the outward procedure. Since every step corresponds to an equal change in utility this means that the inward procedure would generate a β value associated with a more risk prone risk attitude than the outward process. In table 7.1 below follows an example in order to explain this effect.

Table 7.1: Illustrating example

Point of equality	Out	In (chosen with the absolute values as Out)	In (chosen with the same relative change compared to new value)
1	100	2700	2700
2	300	900	1620
3	900	300	972
4	2700	100	583*
5			350*
6			210*
7			126*
8			76*

*Rounded to the closest integer

In table 7.1 the column out is created to illustrate how values would be chosen by a subject consistently finding a new indifference point so that the difference between the old and the new value is 2/3 of the new value. The absolute difference corresponds to the inward values of the second column, which is illustrating how a consistent subject following the decision rules of rationality would chose. The third column, however, has the same starting point as the inward column but with the same relative change, i.e. the difference between the new value and the old value corresponds to 2/3 of the new value. Both the second and the third column are ended with a limit value of 100, meaning that the series is ended on 100 or at the closest number lower than this limit. Evidently the Inward process based on the same relative change as the outward column generates more indifference points.

There are several theories for explaining the difference between the outward and the inward procedure. The authors believe that most of these theories have one thing in common. That is the subject refers his or her latest choice to his or her next choice and to the difference in between.

Unfortunately, it seems as if the specific design of this study actually amplifies the subjects' focus on these numbers. This is because of the technique by which the subject is supposed to adjust the alternatives (the value of X) in order to find indifferences. In this study the subject only can change the alternatives by pressing buttons which generates a new set of alternatives by the computer. In this way the subjects will be exposed to many different alternatives before they find equal alternatives. Each of these alternatives that the subjects are exposed to could affect the subjects' prospect or reference points. This might enhance the effect of the biases explained above and ultimately the differences between the inward and outward procedures.

In order to avoid, or at least minimise, this problem future experimental setups are recommended to leave an empty space in which the subjects are supposed to fill in the numbers by hand which will make them indifferent between the alternatives.

7.3.2. Problems related to the implementation of β-values on societal risk criteria

Initially one of the objectives of the thesis was to create a criterion line in an FN-chart stating a societal risk criterion based on the preferences of the general public. However, this objective was not fulfilled. This was because of at least two additional problems that needed to be solved in order to enable the results of this study and other similar ones to directly state societal risk criteria.

In this study the utility of zero fatalities are decided to be one or close to one. When transforming the results into an F/N-chart the problem remains how to scale this utility to a

frequency. One way to solve this problem is to try and find an anchor point with some other method (e.g. the mortality in Sweden is about 10^{-3} which would indicate a "normal" state and therefore be assigned the utility of one).

Another problem is that criterion lines in FN-charts stating a societal risk criterion of today are cumulative on the N-axis. The utility function based on the preferences of the general public in this study is not cumulative. Mathematically it is possible to transform the results of this study to a utility function in a cumulative chart. It is important to notice that this affects the definitions of different risk attitudes. For instance a straight line in a logarithmic cumulative F/N-chart with a slope of -1 would be considered risk prone with the definitions of risk attitudes used in this thesis.

Another way to address these problems is to abandon the FN curve as measure for stating societal risk criteria. Evans & Verlander (1997) argues that the FN curve is inconsistent for stating this kind of overall criteria and suggests another criteria based on a minimising the expected disutility, called average harm. After deciding an anchor point according to point 1 above the results of this study could be transformed into a value of average harm which could be compared to corresponding values calculated from the criterion lines in FN-charts stating a societal risk criterion of today.

7.4. Suggestions on future studies

- A future version of the experiments with the TO method should avoid the use of Alternative buttons and give the subjects an open space to fill in the number that make them indifferent to the alternatives.
- Ask a population representative for the public of Sweden who has not been carrying out an experiment like the one in this study, who they think should state societal risk criteria.
- Find a way to make the population of the study more representative for the people of Sweden. This might be done by using email or regular mail and have the subjects conducting the experiments at home.
- Perform studies to investigate what attributes affect the experienced disutility of an accident the most. Perform more studies like this one but concerning other attributes, evidently attributes considered important for the experienced disutility.

8. Conclusions

This chapter follows the structure of chapter *1.5 Research questions*. Thereafter follows two conclusions drawn about the experimental design and method.

8.1. Main questions

• What are the risk preferences of the general public regarding multiple fatalities in large scale accidents?

From the revealed risk preferences according to this study the risk attitude of the population representing the general public is generally risk prone (with a median β value of 0,59).

• Are there any differences in risk preferences regarding multiple fatalities in large scale accidents between the general public and experts in risk management?

These risk attitudes do not show any statistically significant difference from the risk attitudes of experts in risk management according to the study of Abrahamsson and Johansson (2006).

8.2. Subordinate questions

• What kinds of strategies for decision making are used?

The most common strategy among the subjects was choosing the alternative with the possibility of having the least number of fatalities, with about 50% of the subjects describing their strategy with something that could be sorted into this category. This strategy can be described as a gambling strategy. This is since the possibility of having a low number of fatalities in these choice situations always is combined with a risk of having the largest number of fatalities. Therefore this strategy would be associated with a risk prone risk attitude.

The second largest strategy was choosing the alternative with the lowest total number of fatalities, with approximately 20% percent of the subjects describing their strategy in a way that could be sorted into this category. Adding the number of fatalities of the two outcomes of an alternative gives quantities proportional to the expected values. Hence this strategy would be associated with a risk neutral risk attitude.

The third largest strategy was to avoid the alternative with the largest number of fatalities, 15 % of the open answers were sorted into this category. In the experimental setup this also meant avoiding the smallest number of fatalities. This strategy gives the smallest difference between the possible outcomes and therefore associated with less uncertainty and less risk taking. Consequently this strategy would be associated with a risk avert risk attitude.

• Do the population change their strategies while gaining experience in decision making from conducting the test, and if so, in what way?

No statistically significant change can be shown regarding the median β value as a function of increasing experience or education, although about 30% of the subjects radically changed their risk attitude during the experiment. About 40% of the subject also stated that they changed their strategy of judging the alternatives during the experiments.

This could indicate that the preferences of the general public are not in a settled state regarding multiple fatalities in large scale accidents. In order to reach a more settled state it is suggested that these questions are raised and brought to the public debate. Ultimately this could bring decisions closer to consensus and create a more transparent decision process. Moreover,

according to this study the general public believe experts in risk management to be best suited for this decision making. The results indicate that a more transparent decision process will justify experts in risk management as decision makers. This is supported by the first conclusion: The general public and experts in risk management have similar preferences regarding multiple fatalities in large scale accidents.

- Do the risk attitudes of the population change with different sizes of accidents?

The results from this thesis show that there is no statistically significant difference in risk attitude between accidents in the range of 0 to 100 fatalities compared to accidents in the range of 0 to 1000 fatalities. However, there are reasons for further investigation of the interval between the limit value of the central part of this thesis, i.e. 1000 fatalities and the largest reference value, i.e. 2400 fatalities. This is because the reference values of interest lies within this interval and the results of this thesis indicate, contrary to the theory of Wakker and Deneffe (1996), that the risk attitude of the subjects are affected by the chosen reference values.

8.3. Conclusions regarding the method

- The method used in this thesis is more time consuming than other methods for eliciting utility functions. About 30 % of the subjects found the experiment morally demanding and tiring. To decrease the impact of high time consumption and tiredness, further studies could be carried out in a home environment where the subjects feel free to take a break and get back to the choice situations later on. Another reason for this is that a sample population could be chosen that statistically reflected the population of Sweden if the experiment was distributed by mail or email.

- The experimental setup used in the empirical study included the use of choice buttons instead of open space for entering a preferred value of fatalities to reveal indifference. This increased biases associated with prospect. It is therefore suggested that future studies use open space for entering a preferred value instead of choice buttons.

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Appendices

Appendix 1: The study by Abrahamsson and Johansson

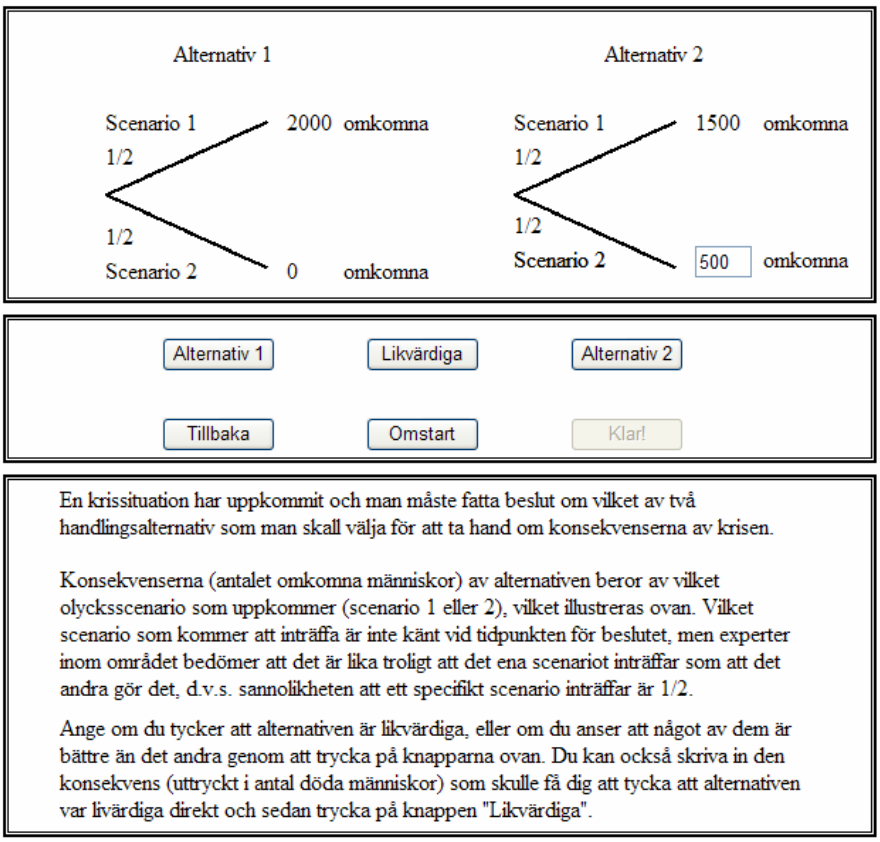
Värdering av stora olyckor – en undersökning av människors riskpreferenser

Under 2004 till och med 2006 kommer LUCRAM (Lunds Universitets Centrum för Riskanalys och Riskhantering) att genomföra ett större ramprogram rörande samhällets risk- och krishantering som är finansierat av Krisberedskapsmyndigheten.

Som en del i detta ramprogram skall en undersökning rörande människors riskpreferenser genomföras. Riskpreferenser har att göra med hur människor värderar olika osäkra situationer och i det aktuella projektet är vi intresserade av att veta mer om hur människor värderar risker med potentiellt stora mängder omkomna personer. Denna undersökning kommer att ge en bild av hur människor värdera risker med stort antal möjliga omkomna gentemot risker där ett mindre antal människor förväntas omkomma. Resultatet från undersökningen kan exempelvis användas som grund för diskussioner om hur samhället skall fördela resurser för risk- och sårbarhetsreduktion. I ett längre perspektiv kan sådan information även ligga till grund för framtagande av så kallade riskacceptanskriterier.

Undersökningen kommer att genomföras med hjälp av en metod som kallas ”tradeoff method” [1] och som innebär att en person vars värderingar man vill undersöka får svara på frågor angående vilket av två beslutsalternativ som han/hon tycker är det bästa.

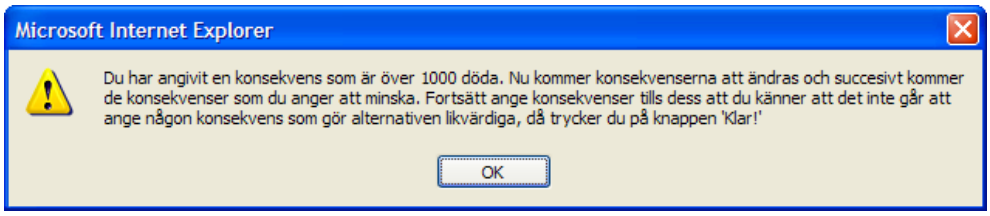
För att göra undersökningen har ett web-baserat datorprogram tagits fram och den person vars värderingar skall undersökas öppnar en hemsida i en webbläsare (exempelvis Internet Explorer) och får sedan göra val mellan olika handlingsalternativ. I den aktuella undersökningen får försökspersonen veta att en kris har uppkommit och att det finns två olika handlingsalternativ för att hantera konsekvenserna av krisen. Man får också veta att det finns två olycksscenarier som kan uppkomma. Vid tiden för beslutet om handlingsalternativ vet man inte vilket scenario som kommer att inträffa, men experter inom området bedömer att de båda scenarierna är lika troliga (d.v.s. sannolikheten att ett specifikt scenario uppkommer är 0.5). Beroende på vilket handlingsalternativ som försökspersonen väljer och vilket olycksscenario som inträffar kommer konsekvenserna i form av antalet omkomna att bli olika. Ett exempel på hur det kan se ut när man gör undersökningen finns i Figur 1, där de två alternativen som försökspersonen har att välja på illustreras.



Figur 1 *Fönster där undersökningspersonen skall göra val mellan olika handlingsalternativ.*

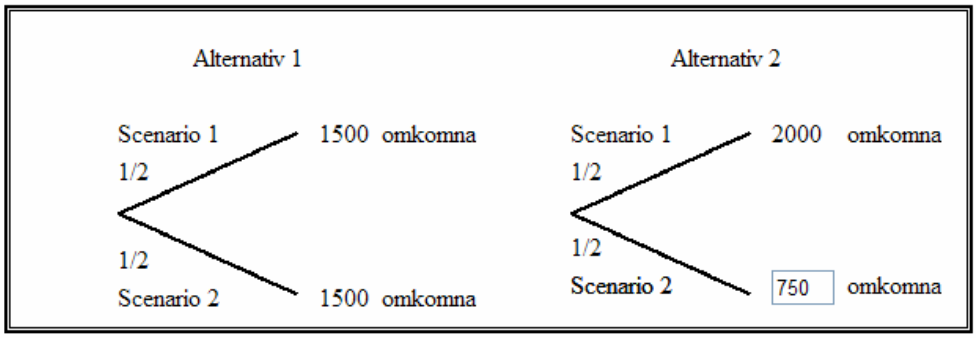
Det som hela undersökningen går ut på är att finna det antal omkomna för scenario 2 och alternativ 2 som gör att försökspersonen tycker att alternativen är likvärdiga (lika dåliga). Denna siffra, som är 500 i Figur 1, är den enda siffra som kan ändras av försökspersonen. För att finna detta antal kan försökspersonen antingen skriva in värdet direkt (om han/hon känner att han/hon kan det) eller välja vilket av alternativen som verkar bäst (minst dåligt) genom att trycka på någon av knapparna ”Alternativ 1” eller ”Alternativ 2”. Då man trycker på någon av dessa knappar kommer antalet omkomna (i rutan där det står 500 i Figur 1) reduceras eller ökas (beroende på om försökspersonen tryckt på ”Alternativ 1” eller ”Alternativ 2”) och försökspersonen får på nytt ta ställning till om han/hon tycker alternativen är likvärdiga. *Det är viktigt att påpeka att det inte finns några ”rätta” svar i denna undersökning utan att det gäller att svara utifrån hur man känner inför de båda alternativen.*

Då försökspersonen finner att alternativen är likvärdiga skall han/hon trycka på knappen ”Likvärdiga” och i och med detta kommer alternativen att ändras något och försökspersonen ställs inför ett nytt val. Försökspersonen kommer att ställas inför nya val ända till dess att han/hon angivit en siffra som är högre än 1000 omkomna, då avbryts första fasen av experimentet och dialogrutan i Figur 2 visas.



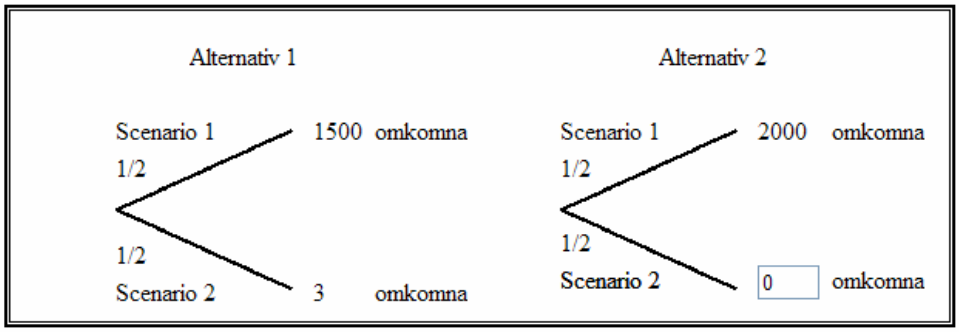
Figur 2 *När försökspersonen angivit en konsekvens som är över 1000 döda kommer denna dialogruta att synas.*

När man trycker på OK knappen kommer undersökningen att fortsätta med den andra fasen, och där kommer alternativen att ändras något. Alternativen kommer då att se ut på det sätt som illustreras i Figur 3.



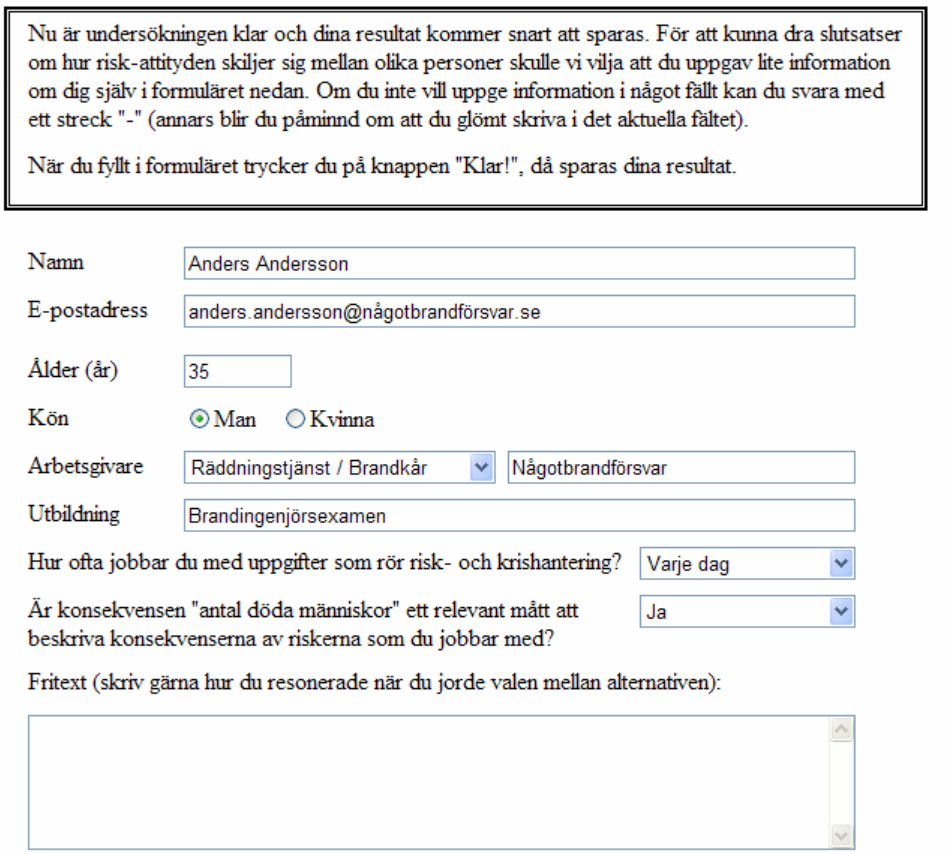
Figur 3Illustration av val mellan två alternativ i fas två av undersökningen.

Under fas två av undersökningen kommer antalet omkomna som försökspersonen anger att successivt minska och till slut kommer han/hon inte att kunna finna något värde som gör att alternativen är likvärdiga. Detta skulle exempelvis kunna inträffa om försökspersonen ställs inför de alternativ som visas i Figur 4. I detta fall kan det vara så att försökspersonen tycker att alternativ 1 är bättre än alternativ 2 och eftersom man inte kan ange ett negativt antal omkomna går det inte att få alternativ 2 likvärdigt med alternativ 1 och då avslutas försöket genom att försökspersonen trycker på knappen ”Klar!”. De andra två knapparna ”Omstart” och ”Tillbaka” används om man känner att man vill börja om hela undersökningen (”Omstart”), eller att man känner att man vill göra om föregående val (”Tillbaka”).



Figur 4Illustration av val mellan två alternativ i fas två av undersökningen.

Då man är klar med undersökningen kommer ett informationsformulär att presenteras i webbläsaren (se Figur 5). I det formuläret skall man fylla i lite uppgifter om sig själv som är viktiga för att kunna dra slutsatser från undersökningen (namn och e-postadress används bara för att kunna nå dig och meddela de bearbetade resultaten från undersökningen). Om du inte vill ange något i dessa fält kan du skriva ett streck ”-”. I rutan som heter fritext får du gärna skriva om hur du resonerade när du gjorde dina val, om du tyckte det var svårt, etc.



Figur 5Informationsformuläret.

När du fyllt i informationsformuläret trycker du på knappen ”Klar!” (den knappen syns inte i Figur 5) och då sparas dina resultat och du är klar med undersökningen.

Tack på förhand!

Henrik Johansson och Marcus Abrahamsson

Referenser

1. Wakker, P. and Deneffe, D., *Eliciting von Neumann-Morgenstern Utilities When Probabilities are Distorted or Unknown*, Management Science, **42**(8), p. 1131-1150, 1996.

Appendix 2: Part 1 of the empirical study (version A)

A

LUNDS TEKNISKA HÖGSKOLA
Lunds universitet

Undersökning av människors värdering av stora olyckor med många dödsfall

Denna undersökning är en del av ett examensarbete på civilingenjörsprogrammet i Riskhantering vid Lunds Tekniska Högskola. Undersökningen tar cirka 30 minuter att genomföra och som tack för din medverkan får du en biobiljett när du är färdig. Det finns inga kommersiella intressen förknippade med undersökningen.

Undersökningen syftar till att ta reda på hur allmänheten i Sverige värderar olyckor med många dödsfall och resultatet är tänkt att kunna användas för att fatta beslut om risker i samhället.

Förmodligen anser de flesta att ett människoliv är ovärderligt och att ett dödsfall i en olycka aldrig är acceptabelt. Dessvärre är dock samhällets resurser inte oändliga, och i vissa situationer tvingas man därför till moraliskt svåra beslut.

Hur själva undersökningen går till beskrivs mer ingående nedan. Först vill vi dock betona att undersökningen **inte** har några "rätta svar", utan att vi endast är intresserade av att få veta vad just du tycker och tänker. Undersökningen är helt anonym.

Undersökningen består av fyra delar. Den första delen är den introduktion du läser just nu som beskriver varför vi gör undersökningen och hur den går till. Del 2 och 3 utgörs av själva undersökningen. I del 4 försöker vi ta reda på om dina svar förändras efter ytterligare information. Del 4 består också av ett frågeformulär med uppgifter om din ålder, kön och utbildning, samt några frågor kring hur du resonerade när du gjorde undersökningen. Efter varje avslutad del ber vi dig att vända dig till försöksledaren för att få nästa del.

Beskrivning av undersökningen, del 2 och 3

Undersökningen, del 2 och 3, ställer dig inför flera olika valsituationer. Med hjälp av ett datorprogram ska du försöka att hitta alternativ som du tycker är likvärdiga. Datorprogrammet kommer hela tiden att försöka hjälpa dig att förändra alternativen så att de blir så likvärdiga som möjligt.

Föreställ dig att en krissituation uppstått och att många människor riskerar att omkomma. De som eventuellt drabbas kan vara vem som helst i samhället, helt oberoende av ålder, kön, inkomst och geografiskt läge etc. Det finns två möjliga sätt att hantera krisen; Alternativ 1 och Alternativ 2. Nedan följer ett exempel på hur alternativen kan se ut.

Om man väljer det första sättet att hantera krisen, Alternativ 1, så kommer resultatet antingen bli att 2000 människor dör, eller så dör ingen alls. Se bild till höger.

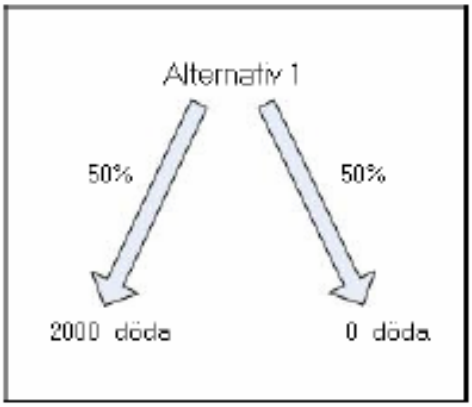


Bild av alternativ 1

Sannolikheten för att 2000 människor dör är exakt lika stor som sannolikheten för att ingen alls dör, det vill säga 50 %, och det går inte att på förhand säga något om vilket resultat som kommer att inträffa.

Om man istället väljer det andra sättet att hantera krisen, Alternativ 2, så kommer antingen 1500 människor att dö, eller så dör 500 människor. Se bild till höger.

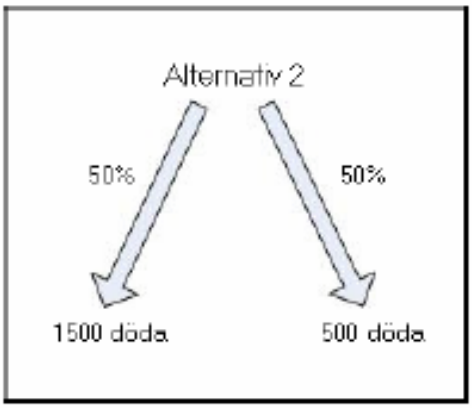


Bild av alternativ 2

Precis som för Alternativ 1 så är sannolikheten för att 1500 människor dör exakt lika stor som sannolikheten för att 500 människor dör, det vill säga 50 %. Det går inte att på förhand säga något om vilket resultat som kommer att inträffa.

Din uppgift

Antalet döda i Alternativ 1 och Alternativ 2 kommer att förändras under undersökningens gång. Din uppgift är att avgöra när Alternativ 1 och Alternativ 2 är **likvärdiga**, det vill säga när du tycker att de är lika dåliga. Detta gör du genom att klicka på knappen Likvärdiga i ett datorprogram (se bild på nästa sida).

Om du tycker att ett av alternativen är bättre än det andra, eller rättare sagt mindre dåligt, så klickar du på knappen för det alternativet. Datorprogrammet hjälper dig då att ändra alternativen så att de blir mer och

mer likvärdiga. Detta upprepar du till dess att du tycker att alternativen är likvärdiga, då klickar du på Likvärdiga.

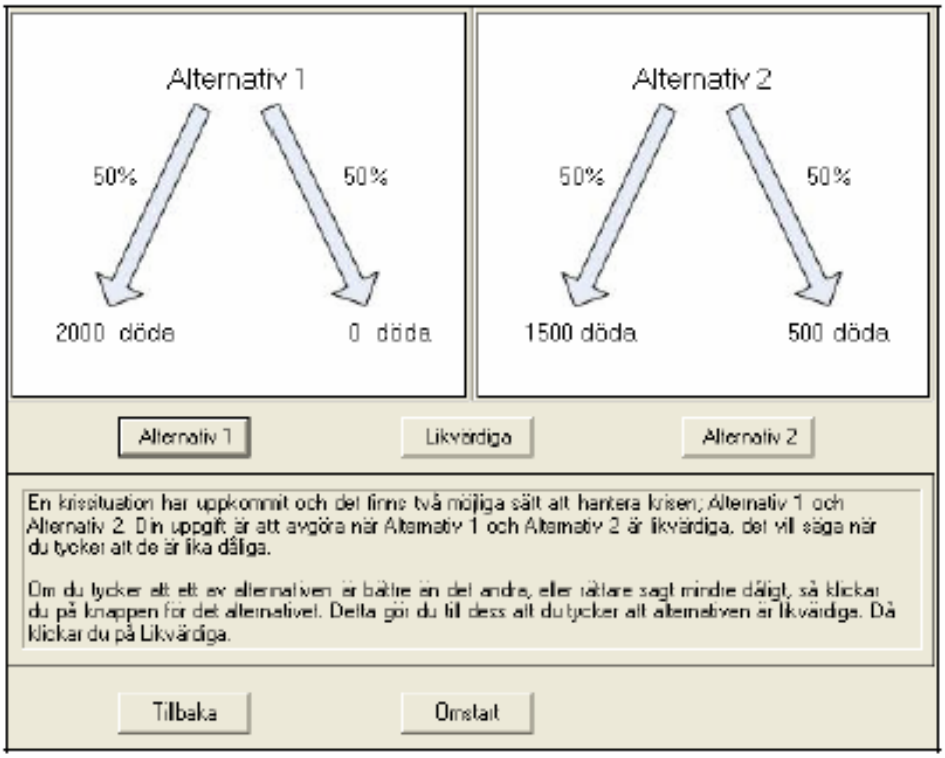


Bild av exempel på valsituation i datorprogrammet

Du kan när som helst gå tillbaka till ett föregående val genom att klicka på knappen Tillbaka. På samma sätt kan du när som helst starta om undersökningen genom att klicka på Omstart. Klickningar på dessa knappar lagras inte i resultatet av undersökningen.

Valsituationerna kommer att upprepas ett antal gånger, men antalet döda i de olika alternativen kommer att ändras. På detta vis fortsätter undersökningen tills följande text dyker upp: ”Du har nu kommit halvvägs i denna del. Nästa halva påminner om den första, men med en annan ordning på alternativen.” När även denna andra halva är klar kommer en text upp som säger: ”Du är nu klar med denna del!”. Därefter ber vi dig att vända dig till försöksledaren för att starta del 3. I del 3 görs undersökningen om på samma sätt som i del 2, men med större antal döda.

Om du stöter på problem eller om det är något som du inte förstår, så tveka inte att när som helst kalla på försöksledaren. Innan du sätter igång med undersökningen vill vi återigen betona att det **inte** finns några ”rätta svar”, utan att det är **vad just du tycker** vi vill veta!

Here follows part 1 translated into English

LUNDS TEKNISKA HÖGSKOLA
Lunds universitet

Investigation of people's assessment of accidents involving large numbers of fatalities

This investigation is a part of a Master's thesis at the Master of Science program in Risk Management and Safety Engineering at Lund University. The investigation takes about 30 minutes to carry out and as a reward you will receive a cinema ticket when you are finished. There are no commercial interests associated with the investigation.

The purpose of the investigation is to find out how the general public in Sweden assesses accidents involving large numbers of fatalities and the results are thought to be used for decision making regarding risks in society.

Probably most people consider that a human life is invaluable and that a death in an accident never can be acceptable. However, the resources in society are unfortunately limited, and in some situations morally demanding decisions are necessary.

Instructions for the investigation will be given later on. First we want to emphasise that the investigation **do not** have any "right answers". Rather, we are interested in finding out what you think. The investigation is anonymous.

The investigation consists of four parts. The first part is the introduction you are reading at the moment, which describes why we are conducting the investigation and how it is carried out. Parts 2 and 3 consist of the investigation. In part 4 we try to find out if your answers change after additional information. Part 4 also consists of a questionnaire where we ask you to specify your age, gender and education along with some questions about the way you reasoned when you carried out the investigation. After every finished part we ask you to contact the supervisor to receive next part.

Description of the investigation, parts 2 and 3

The investigation, parts 2 and 3, confronts you with a number of choice situations. By means of a computer program you are asked to try to find alternatives which you find equivalent. The computer program will try to help you change the alternatives to make them as equivalent as possible.

Imagine a crisis situation has occurred and many people are at risk to be killed. Those who possibly will be affected can be anyone in society, independent of age, gender, income or geographic location etc. There are two possible ways of handling the crisis; Alternative 1 or Alternative 2. Below is an example of how the alternatives can look like.

If you choose the first way of handling the crisis, Alternative 1, this will either result in 2000 fatalities or no fatalities. See figure to the right.

The probability of 2000 fatalities is exactly the same as the probability of no fatalities, i.e. 50 %, and there is no way to tell what alternative that will occur.

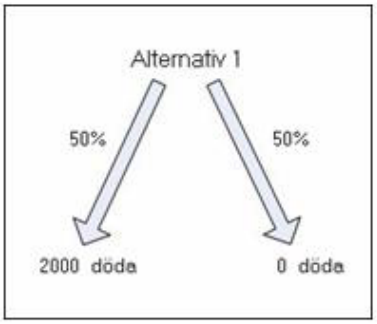


Illustration of Alternative 1

If you choose the other way of handling the crisis, Alternative 2, this will either result in 15 fatalities or 5 fatalities. See figure to the right.

As for Alternative 1 the probability of 15 fatalities is exactly the same as the probability of 5 fatalities, i.e. 50 %. There is no way to tell what alternative that will occur.

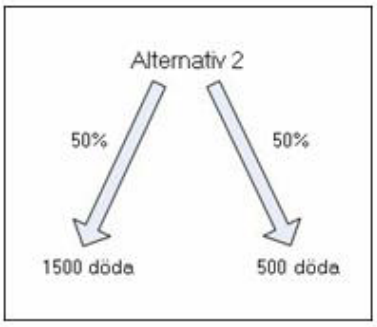


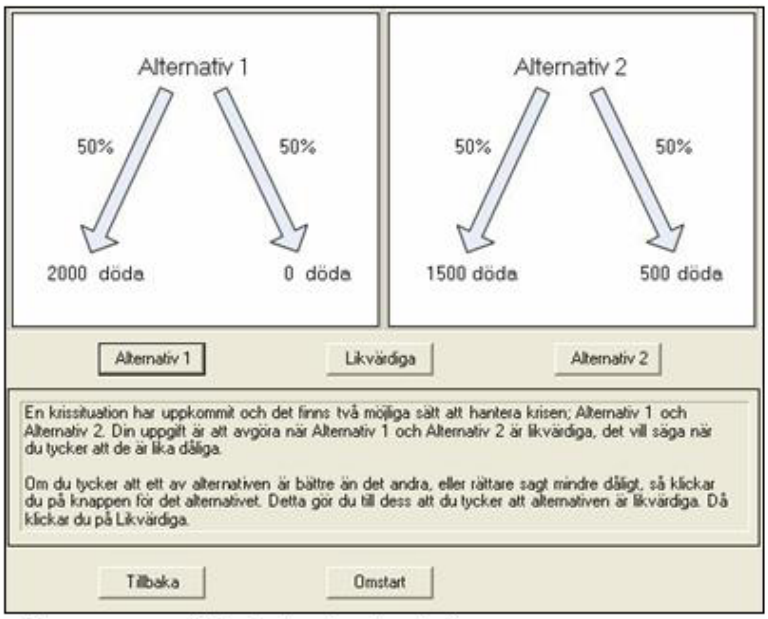
Illustration of Alternative 2

Your task

The number of fatalities in Alternative 1 and Alternative 2 will change during the investigation. Your task is to decide when Alternative 1 and Alternative 2 are equivalent, i.e. when you think they are equally bad.

This is done by pressing the Equivalent button on a computer (see figure on the top of next page).

If you think that one of the alternatives is better than the other, or rather less bad, you press the button for this alternative. The computer program will then help you to change the alternatives to make them more equivalent. This is repeated until you think the alternatives are equivalent, and then you press the Equivalent button.



The appearance of the choice situation in the computer programme

At any time you can go back to a previous choice situation by pressing the button Back. In the same way you can at any time restart the investigation by pressing the button Restart. Pressing these buttons is not saved by the computer and does not affect the results from the investigation.

The choice situations will be repeated a number of times, and every new choice situation is based on previous choices. The alternatives only change by the number of fatalities. In this way the investigation continues until the following text appears: "You have now reached half-way through this part. Next part reminds of the first one, but with the

numbers reversed." When also this second part is finished a text appears which reads: "You have now finished this part!". Thereafter we ask you to contact the supervisor to start part 3. In part 3 the investigation is carried out in the same way as in part 2, but with larger numbers of fatalities

If you come across any problems or if there is something that you do not understand, do not hesitate to ask the supervisor. Before you start the investigation we once again would like to emphasise that there are **no "right answers"**, rather, we are interested in finding out what you think!

Appendix 3: Part 4 of the empirical study

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Del 4

Vänligen fyll i formuläret nedan genom att kryssa i rätt ruta och/eller skriva på de tomma strecken. Om utrymmet inte räcker till får du gärna använda baksidan.

1. Ålder:_____

2. Kön
   - ○ Man
   - ○ Kvinna

3. Påbörjad utbildning
   - ○ Grundskola, folkskola eller motsvarande
   - ○ Gymnasium, komvux eller motsvarande
   - ○ Högskola/universitet
   - ○ Annat:_____

4. Tänkte du på någon eller några särskilda olyckor när du genomförde undersökningen?
   - ○ Ja, en speciell olycka
   - ○ Ja, flera olika olyckor
   - ○ Nej

Om ja, vilken eller vilka olyckor?

_____

_____

_____

5. Ägna en kort stund åt att fundera på om du hade någon strategi eller något särskilt sätt att resonera när du gjorde undersökningen, och försök att beskriva det.

---

6. Ändrade du din strategi under undersökningens gång?

- ○ Ja
- ○ Nej

Om ja, redogör gärna kort för hur och när under undersökningen din strategi förändrades:

---

7. Är du nöjd med dina svar i del 2 och 3, det vill säga själva undersökningen?

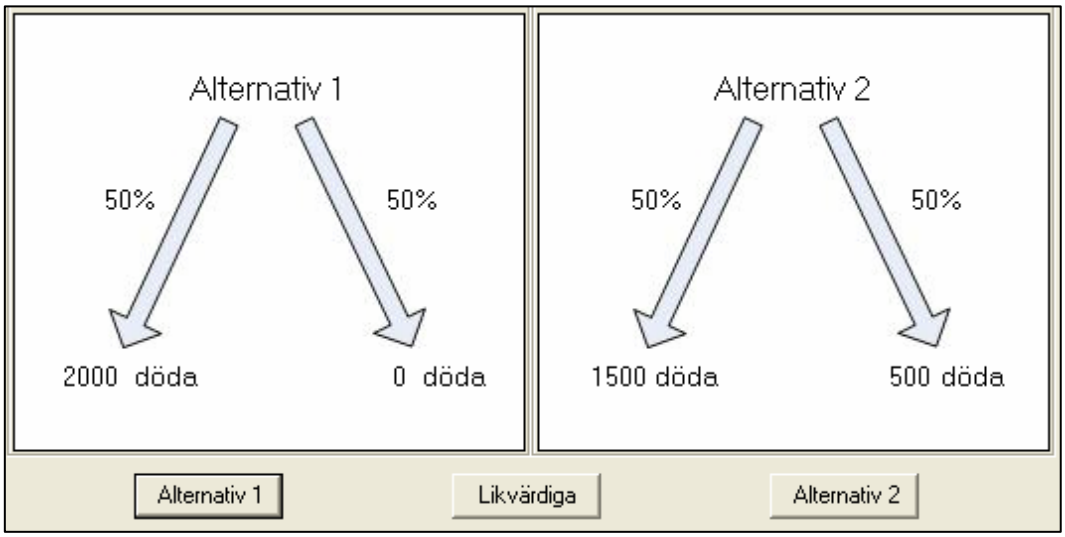
- ○ Ja
- ○ Nej (innebär inte att du måste göra om!)

Om Nej, på vilket sätt skulle du vilja ha svarat annorlunda?

Om du vill och är missnöjd med dina svar kan du nu få göra om undersökningen. Prata i så fall med försöksledaren.

Denna sida innehåller information som vi vill att du läser igenom, för att därefter svara på tre avslutande frågor.

Du har nu genomfört undersökningen och det finns som sagt inget sätt att tänka som är mer ”rätt” än något annat. Det finns dock några vanliga strategier för hur man kan resonera. Några av dessa strategier beskrivs nedan.



A. Att föredra alternativ som undviker det högsta antalet döda. I exemplet ovan väljs då Alternativ 2, eftersom detta alternativ undviker att 2000 människor dör, vilket är det högsta antalet i de två alternativen.

B. Att föredra alternativ som ger chans att få det minsta antalet döda. I exemplet ovan väljs då Alternativ 1, eftersom detta alternativ innebär en chans att 0 människor dör, vilket är det lägsta antalet i de två alternativen.

C. Att föredra alternativ som har det lägsta totala antalet döda. I exemplet ovan är då alternativen likvärdiga, eftersom summan av antalet döda i Alternativ 1 blir 2000 (2000 + 0), vilket är lika med summan av antalet döda i Alternativ 2 som blir 2000 (1500 + 500).

D. Att föredra alternativ vars högsta antal döda understiger en viss siffra. Om denna siffra valts till 1700 så väljs Alternativ 2, eftersom 1500 understiger 1700, men inte 2000.

Andra alternativ är till exempel att gå på sin ”magkänsla” eller strategier som är en kombination av ovanstående. Det finns också exempel på helt andra strategier.

8. Efter att ha funderat på det ovanstående, känner du igen dina val i någon av strategierna ovan, och i så fall vilken eller vilka?

---

9. Är du fortfarande nöjd med dina svar?

- ○ Ja
- ○ Nej (innebär inte att du måste göra om!)

Om Nej, på vilket sätt skulle du vilja ha svarat annorlunda?

Om du vill och är missnöjd med dina svar kan du nu få göra om undersökningen. Prata i så fall med försöksledaren.

10. Dina svar i undersökningen skulle kunna användas för att bestämma var man bör satsa resurser för att minska risker i samhället. Alternativet kan vara att låta personer som arbetar med riskhantering bestämma i dessa frågor.

Givetvis går det att låta en kombination av personer som arbetar med riskhantering och allmänheten bestämma, men om du var tvungen att välja ett av alternativen, vad skulle du då välja?

- ○ Personer som arbetar med riskhantering
- ○ Allmänheten, till exempel genom denna typ av undersökningar

Motivera gärna:

Tack så mycket för din medverkan, hoppas att du får en trevlig stund biomörkret!

Here follows part 1 translated into English

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Here follows part 1 translated into English

Part 4

Please fill in the questionnaire below. If the empty lines are not enough you can use the back of the sheet.

1. Age:_____

2. Gener
   - ○ Man
   - ○ Woman

3. Education
   - ○ Compulsory school
   - ○ Senior high school or equivalent
   - ○ University
   - ○ Other:_____

4. Did you think of any specific accidents when you carried out the experiment?
   - ○ Yes, one specific accident
   - ○ Yes, several specific accidents
   - ○ Nej

If yes, what accident/accidents?

_____

_____

_____

5. Take a short moment to reflect upon whether you used a specific strategy to carry out the experiment, and if so, try to describe this strategy.

_____

_____

_____

6. Did you change your strategy during the experiment?

- ○ Yes
- ○ No

If yes, try to describe how and when you changed your strategy:

_____

_____

_____

7. Are you satisfied with your answers in part 2 and 3, i.e. the experiment?

- ○ Yes
- ○ No (does not mean that you must restart the investigation!)

If No, in what way would you like to have answered differently?

_____

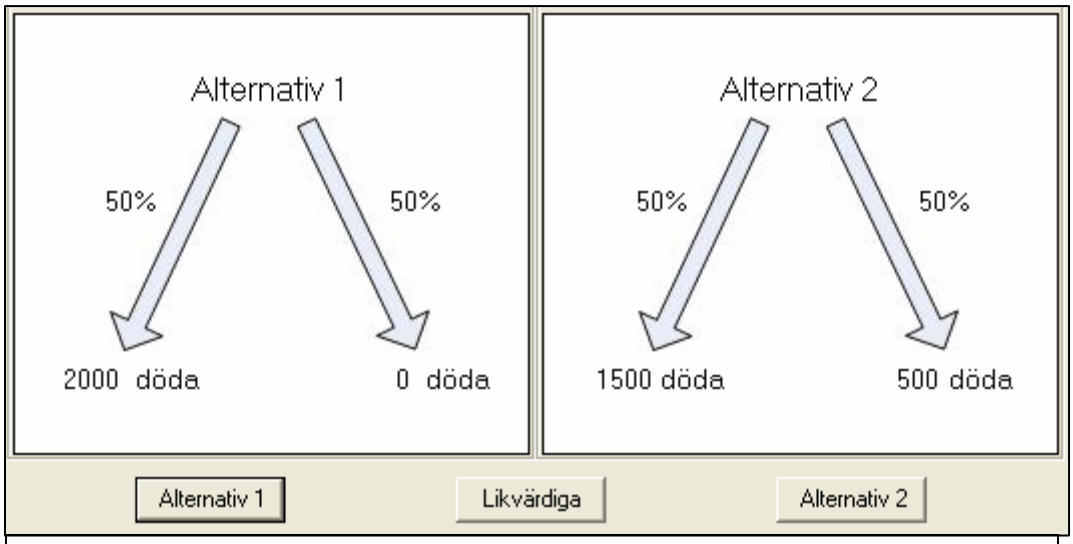
_____

_____

If you are unsatisfied with your answers you can restart the investigation if you would like to. In this case, please contact the supervisor.

This page contains information that we ask you to read through. Thereafter you are aksed to answer three final questions.

You have now finished the investigation and as we have mentioned earlier there are no ”right answers”. However, there are some common strategies on how to reflect the questions. Some of these strategies are presented below.



A. Avoiding the alternative with the largest number of fatalities. Using this strategy Alternative 2 is chosen in the example above, since this alternative avoids 2000 fatalities, which is the largest number in the two alternatives.

B. Preferring the alternative including the lowest number of fatalities. Using this strategy Alternative 1 is chosen in the example above, since this alternative involves a chance of 0 fatalities, which is the lowest number in the two alternatives.

C. Preferring the alternative with the lowest total number of fatalities. Using this strategy in the example above the alternatives are equivalent, since the total sum of Alternative 1 amounts to 2000 (2000 + 0), which equals the sum of Alternative 2 (1500 + 500).

D. Preferring the alternative with the number of fatalities below a specific number. If this number was set to 1700, then Alternative 2 is chosen, since 1500 is below 1700, but not 2000.

Other strategies are to use intuition or to combine the strategies presented above. There are also different strategies than those presented here.

8. Do you recognise your own strategy in any of the strategies presented above? If yes, which of the strategies?

_____

_____

_____

9. Having reflected the strategies presented above, are you still satisfied with your answers?

- ○ Yes
- ○ No (does not mean that you must restart the investigation!)

If No, in what way would you like to have answered differently?

_____

_____

_____

If you are unsatisfied with your answers you can restart the investigation if you would like to. In this case, please contact the supervisor.

10. Your answers from the experiment could be used to decide where risk reducing resources should be spent to reduce risks in society. The alternative could be to have experts to decide upon these issues.

Of course it is possible to have a group consisting of both experts and the general public to decide, but if you had to choose one of the alternatives which one would you choose?

- ○ Experts in risk management
- ○ The general public?

If you want to, please give reasons for your answer:

_____

_____

_____

Thank you for your participation!

Appendix 4: Answers from the questionnaire

Categorization of answers to the question in the questionnaire

Question		Category	Code
1	Age	[Number of years]	
2	Sex	Male	M
		Female	K
3	Level of education	Compulsory school	1
		senior high school or equivalent	2
		University	3
		Other	4
4	Did you think of any particular accident?	Yes, one particular accident	1
		Yes, several different accidents	2
		No	3
4b	Which one(s)?	**General**	
		Car accident, bus accident	11
		Fire, Industrial estate accident	12
		Ship accident, Plane crash	13
		War, Hostage situation, Air raids, Terror	14
		Natural disaster	15
		Starvation	16
		Epidemics	17
		Specific	
		"9/11"	21
		Tsunami	22
		Estonia (sinking ferry)	23
		The fire at Backaplan, Göteborg	24
		Israel and Libanon	25
		Titanic	26
		Combat Boat accident Sollenkroka	27
		Cancer	28
		Hypothetic scenarios	
		Made up scenarios	30

Question		Category	Code
5	Categorisation (by the authors)	Avoid the largest number	1
		Choose alternative with the smallest number	2
		Lowest sum of the outcomes	3
		Number below a certain limit	4
		Other strategies	5
		Intuition	6
		Do not know	7
6	Did you change your strategy?	Yes	1
		No	2
		Blank, do not know	3
6b	Categorisation of open answer (by the authors)	**How one changed strategy**	**A**
		From intuition to calculation	1
		From choosing alternative with chance on the smallest number to a balancing strategy (risk prone, avert or neutral)	2
		From expected value to evaluating the difference between small numbers highly	3
		From an evaluating strategy to smallest number of fatalties	4
		Increase the gambling	5
		From expected value to evaluating te difference between large numbers highly	6
		Become tired	7
		From calculation to intuition	8
		How one changed strategy (decision perspective)	**B**
		From personal involvement to societal perspective (related to societal resorces)	1
		From considering the deceased to be the group of concern to consider the deceased to be part of a largerr group	2
		When one changed strategy	**C**
		After some 10 decisions	1
		From part 2 to part 3	2
		At approximately 100 deceased	3
		After the first choice without the possibility of zero	4
		In the middle of the part	5
		Who much one changed strategy	**D**
		Changed strategy several times during the experiment	1
		How the conception of the problem problem was changed	**E**
		Started to understand the problem after a couple of decisions	1

Question		Category	Code
7	Are you satisfied with your answers?	Yes	1
		No	0
7b	Categorisation of open answers if no (by the authors)	Misinterpreted, misunderstood, uncertain if the subject understood the problem	1
		Did not feel consistent	2
		Would have wanted to aswer more out of moral principles rather than mathematical calculations	3
		Did not calcualate accurately enough, made too rough estimations	4
		Would have wanted to give more thought to the decisions	5
		Experienced technical obstruction for answering the wanted way	6
		Uncomfortable with the decision situations	7
		Would have wanted to aswer more out of mathematical calculations rather than moral principles	8
		Speak of actual change in personal preferences during the experiment	9
		Became tired	10
Question		**Category**	**Code**
8	Relate your strategy to the suggested category	Avoid the largest number	A
		Choose alternative with the smallest number	B
		Lowest sum of the outcomes	C
		Number below a certain limit	D
		Other strategies	E
		Intuition	M
9	Are you still satisfied with your answers?	Yes	1
		No	0
		Blank, do not know	2
	Categorisation of open answers if no (by the authors)	Misinterpreted, misunderstood, uncertain if the subject understood the problem	1
		Did not feel consistent	2
		Would have wanted to aswer more out of moral principles rather than mathematical calculations	3
		Did not calcualate accurately enough, made too rough estimations	4
		Would have wanted to give more thought to the decisions	5
		Experienced technical obstruction for answering the wanted way	6
		Uncomfortable with the decision situations	7
		Would have wanted to aswer more out of mathematical calculations rather than moral principles	8
		Speak of actual change in personal preferences during the experiment	9
		Became tired	10
		Became influenced by the suggested strategies	11

Question		Category	Code
10	Who is to decide? Justify if possible	**Experts should decide:**	**R**
		The general public is not rational	2
		Experts have the experience and knowledge needed	3
		The preferences of the public diverge	4
		Be able to see the problem in perspective	5
		To abstract question for the general public to understand	6
		Experts are risk conscious	7
		The General public should decide:	**A**
		Democratic rightättighet	1
		It is the lives of the general public that is at stake	2
		Experts are likely to neglect impossible choices	3
		Experts can not represent the opinion of the general public	4
		Did not take a stand:	**Ö**
		Societal risk management issues should be given more space in the public debate	1
		Plans for sacrificing human lives (implies misunderstanding)	2

Answers to the questions in the questionnaire

Version A

Group 1																	
1	2	3	4a	4b	5	6a	6b	7a	7b	8	8		9a	9b	10a+b		
Age	Sex	Education	Specific accident	Category	Strategy	Change	Category	Satified	Why not	Strategy	From:To		Satisfied	Why not	Decision + reason		
23	M	3	2	30	8	1	C	1		1 4			1		A1	9	
59	M	3	3		2	2		1		1			1		R3	3	
23	K	3	2	13, 16	1	2		1		1 2			1		R3	3	
53	K	3	3		2	1	B, C		1	2 4 6	2	4	2	5	Ö1	14	
21	K	3	3		6	2		0	2	2 3			0	11	A2	10	
69	M	3	3		2	2		1		2			1		A3	11	
34	M	3	2	21, 22	2	1	A5, D1	0	7	2 6			1		R3	3	
24	M	4	2	22, 14	2	2		1		3			1		A1	9	
46	K	3	3		2	1	A2, C3	1		2			1		R3, Ö2	3	15
23	M	3	3		3	2		0	4	3			1		R3	3	
20	K	3	3		2	1	-	1		2 3			1		R	1	
21	K	3	2	14	7	3		1		1			1		R3	3	
18	K	2	2	11	7	2		1		1 3			1		R4	4	
18	K	2	3		7	2		1		1			1		R3	3	
39	M	3	3		2	1	A2	1		2 3			1		R3	3	
25	K	3	1	13	3	1	A3	1		3			1		R3	3	
40	M	3	3		2	2		1		2			1		R6	6	
21	M	3	1	25	8	2		1		2 3			1		R3	3	
39	M	3	1	11	3	1	? A1	1		2 3			1		R3	3	

Group 2																
1	2	3	4a	4b	5	6a	6b	7a	7b	8	8		9a	9b	10a+b	
Age	Sex	Education	Specific accident	Category	Strategy	Change	Category	Satified	Why not	Strategy	From:To		Satisfied	Why not	Decision + reason	
24	M		3		1	2		1		3 4			1		R2	2
21	M		3		3	2		1		3			1		A2	10
20	M		1	12, 17	1	1	C	1		1 2 6			0	9	R3	3
21	M		3		2	2		0		2 3			1		R3	3
19	M		3		2	2		1					2			13
22	M		1	27	2	2		1		2			1		R3	3
20	M		3		3	2		1		3			1		R	1
22	M		3		6	2		1		3			1		R	1
22	M		3			1	A7	0	5				2		R	1
21	M		1	12	2	2		1		1 2			1		R	1
28	M		3			2		1		1 2			1		R	1
21	M		3		3	2		0	2	3 6			0	2	R	1
22	K		1	13	3	2		0	5	3			1	5	R2	2
25	M		3		2	2		0	9	1			0	9,11	Ö	13
22	M		3		3	2		0	7	3			1		R3	3
19	M		3		2	2		1		1			1		R3	3
22	M		3		3	2		1		3			1		R	1
21	K		3		2	2		0	1	3			2		R4	4
20	K		3		2	1	C	1		1 2	2	1	1		R	1
30	M		3		2	1	A2	0	7				2			13
27	M		1	22	6	1	C2, E1	0	1	4			0	1	R3	3
23	M		2	12, 13, 14, 17, 28	2	1	B2	1		5 6			1		A2	10
21	M		3		2	2		1		2			1		R	1

Version B

Group 1																			
1	2	3	4a	4b	5		6a	6b	7a	7b	8			8		9a	9b	10a+b		
Age	Sex	Education	Specific accident	Category	Strategy		Change	Category	Satified	Why not	Strategy			From:To		Satisfied	Why not	Decision + reason		
47	M	3	2	21, 22	2		1	A2, C1	0	5	5					0	5	R3	3	
17	M	2	3		2		2		1		1					1		A	8	
28	M	3	3		2		2		0	6	2	6				1		R	1	
28	K	3	3				1	A1	1		2	3		2	3	1		R3	3	
38	M	3	3		2		2		1		2					1		R	1	
35	K	3	3		2		1	A1	0	8	2	4				0	11	R5,2	5	2
19	M	3	3		3		2		1		3					1		R2	2	
29	K	3	2	12, 14	1		1	E1	0	1	5					0	7	R6	6	
35	M	3	3		2		2		0	7	2			2	6	0	7	Ö2	15	
48	M	3	1	11	2		1	-	1		2					1		A4	12	
16	M	2	2	11, 12			1	A	1		1	4				1		A4	12	
52	M	3	3		2		2		1		4					1		R3	3	
22	M	3	3		3		1	A6	1		1					0	1	RÖ2	1	15
63	K	3	3				1	C2, E1			6					2		R7	7	
59	M	4	1		3		2		0		3					1		R	1	
19	M	2	2	13, 14, 15	2		2		0	7	1	2	6			0	7	R3	3	
37	K	3	2	23, 24	2		1	A2	0	7	1	2	6	2	1	0	7	R3	3	
33	K	3	1	22, 14, 16	2		1	A4	1		2					1		R3	3	
26	K	3	3		3		1	A2	1		3					1		R3	3	
Group 2																				
1	2	3	4a	4b	5		6a	6b	7a	7b	8			8		9a	9b	10a+b		
Age	Sex	Education	Specific accident	Category	Strategy		Change	Category	Satified	Why not	Strategy			From:To		Satisfied	Why not	Decision + reason		
20	M		2	11, 14, 15			2		0	1	6					1		R	1	
18	K		3		1		2		1		2					1		R	1	
22	M		3				2		1		3	6		2	3	0	11	R3	3	
22	M		2	14	2		1	C4	0	5	2	3		2	3	1		R	1	
22	K		1	23	2	1	2		1		1	2				0	11	R3	3	
20	K		3		2		2		1		2	6	3			1		A4	12	
19	K		3		3		2		1		3					1		R3	3	
20	M		3		6		1	C3	0	2	5					0	10	A2	2	
18	M		3		6		2		0	7	6					0	7	R3	3	
22	M		3				3		-		2					1		R3	3	
22	K		2	12, 14, 15	2		2		1		2	3				1		R3	3	
21	K		3		2		1	A7, C1	0	10	2					1		R	1	
20	K		3		1		1	C5, E1	0	2	1	3		1	3	0	11	R3	3	
19	K		2	23, 26	3		1	C5	0	9	3	6				1	11	R3	3	
20	M		2	15	2		1	A1, C5	1		1	2		2	1	1		R3	3	
20	M		3		3		2		1		3					1		R3	3	
23	M		3		3		2		0	5	3					0		R3	3	
22	M		3		6		1	A8	0	7	3	4	6	3	6	1		R3	3	

Appendix 5: Beta values

BETA VALUES (β)	Version A		
	Outward	Inward	Outward
Subject no.	1500 and 2000	1500 and 2000	1500 and 2400
A1	2,702	0,192	1,470
A2	2,537	0,609	0,708
A3	0,449	0,486	NaN
A4	0,482	0,501	1,033
A5	0,732	0,731	0,917
A6	0,227	0,232	0,222
A7	0,553	0,351	0,921
A8	0,965	0,700	5,964
A9	0,259	0,215	0,532
A10	1,046	1,107	0,966
A11	0,263	0,210	0,723
A12	2,670	0,343	0,782
A13	0,715	0,255	3,365
A14	1,438	0,239	1,038
A15	0,368	0,052	0,581
A16	0,800	0,268	0,274
A17	NaN	NaN	0,290
A18	1,807	0,406	7,982
A19	1,102	0,261	0,590

BETA VALUES (β)	Version B		
	Outward	Inward	Outward
Subject no.	1500 and 2000	1500 and 2000	150 and 200
B1	0,789	0,323	0,838
B2	NaN	0,222	NaN
B3	0,745	0,432	1,207
B4	1,710	0,194	1,710
B5	0,917	0,292	0,488
B6	0,468	0,286	0,708
B7	0,857	1,034	1,358
B8	1,358	0,817	1,358
B9	0,931	0,266	1,000
B10	1,362	0,194	0,855
B11	0,368	0,212	9,859
B12	0,746	0,520	0,576
B13	11,907	0,305	1,247
B14	0,982	0,243	0,535
B15	1,000	1,000	1,000
B16	1,810	0,499	1,051
B17	3,354	0,365	0,445
B18	0,355	0,365	1,130
B19	0,999	0,999	0,972