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Major accident prevention decision-making: A large-scale survey-based analysis

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ABSTRACT

Decision-making under risk and uncertainty is not straightforward. This paper investigates how people make decisions when they need to choose between prevention and production investments and the decision involves risks and uncertainties that could have major negative consequences. A questionnaire was conducted among 405 students at the University of Antwerp, in Belgium. With regard to decision-making under risk, the findings reveal that the respondents behaved in a more risk-averse manner than predicted by the theory of expected values. Concerning decision-making under uncertainty, the respondents also displayed more risk-averse decision-making behaviour than anticipated, especially under circumstances of complete uncertainty. The study also shows that men are more likely to behave in a more risk-seeking manner than women are, and that people with a high intuitive thinking style are less risk-averse than people with a low intuitive thinking style. Furthermore, people with a high rational thinking style are more risk-averse than people with a low rational thinking style, and respondents with a high sensation-seeking style make decisions in a more risk-seeking way than respondents with a low sensation-seeking style.

1. Introduction

Making decisions generally requires choosing among alternatives and their possible outcomes. The various alternatives and possible outcomes are frequently associated with risk and uncertainty. The same applies to decisions that companies need to make concerning investments in safety. Not investing in safety entails risk and uncertainty: it can result in loss, in the event of an accident, or in hypothetical gain, if the accident does not occur (Barkan et al., 1998).

There is no simple means of evaluating and managing the risks and uncertainties that are associated with decision-making (Klinke and Renn, 2002). In addition, decision-making under uncertainty is not the same as decision-making under risk. Under risk, all outcomes are known, as are the likelihoods of each outcome occurring. Under uncertainty, some of the alternatives, outcomes and likelihoods may be unknown (Mousavi and Gigerenzer, 2014). However, the distinction between risk and uncertainty remains unclear, as risks are very uncertain. After all, likelihoods are only an approximation of a prediction and predictions of risk are therefore characterised by uncertainty (Klinke and Renn, 2002; Aven and Kristensen, 2005).

2. Literature study

There is an extensive body of literature on decision-making under risk and uncertainty (Aliev et al., 2012). Several disciplines have formulated a wide range of perspectives, theories, models and mathematical formulas for modelling human behaviour under conditions of risk and uncertainty (Aven and Kristensen, 2005; Aliev et al., 2012). As a detailed overview would lead us too far, we discuss only those disciplines related to the focus of this study and their prevailing perspectives concerning decision-making. For example, engineers perform risk analyses to support their

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decision-making. This risk assessment can serve as a basis for rational decision-making about risks, allowing for the evaluation and classification of a risk situation as either acceptable or unacceptable (Rodrigues et al., 2014). Risk comprises two dimensions: (a) the possible consequences or extent of the loss; and (b) its associated likelihood, for example expressed as a probability (Aven and Kristensen, 2005; Meyer and Reniers, 2013). Based on these constitutive elements of risk, the value of the risk can be estimated (Meyer and Reniers, 2013). The simplest model for calculating the value of risk is a combination of the extent of the loss and the probability of occurrence (Klinke and Renn, 2002). Multiplying these two dimensions of risk together generates the expected value of the risk. The results of this risk assessment are often presented in a matrix-like form (Meyer and Reniers, 2013), which allows the risk to be classified as, for example, normal, intermediate or intolerable risk (WBGU, 2000).

Risk analyses are often used in combination with risk acceptance criteria in order to support decision-making (Aven and Kristensen, 2005; Rodrigues et al., 2014). Risk acceptance criteria are defined as the upper limits of acceptable risk and can be used to decide on the need for risk-reducing measures (Rodrigues et al., 2014). The criteria may result from the user's own risk appreciation, be legislation-driven or based on corporate guidelines. Defining risk acceptance criteria is difficult, however. A range of concerns need to be balanced in order to determine acceptable risks concerning the safety of assets, employees and third parties such as the external population (Abrahamsen and Aven, 2008). After all, acceptability should also consider the positive aspects of taking the risk, for example the benefits that such an activity would generate in terms of income and employment (Aven and Kristensen, 2005). A further element of complexity is that risk stakeholders are often divided in three categories: risk managers, risk receptors and risk beneficiaries (Freeman, 1984).

A number of mathematical theories and models with strong analytical power have been designed for decision-making under risk and uncertainty. For example, one of the predominant paradigms for decision-making under uncertainty is the expected utility theory (Abrahamsen and Aven, 2008). According to this theory, individuals tend to maximise expected utility; agents are motivated by material incentives (self-interest) and make decisions in a rational way (Aliev et al., 2012). However, mathematical theories and models define human behaviour as ideal and inanimate (Aliev et al., 2012). Decision-making tools can be useful in many cases, but it should be kept in mind that they are based on normative theories and models which structure decisions in a rational way (Aven and Kristensen, 2005). Obviously, people do not always act in a purely rational manner and it is often not possible to predict how people will make a choice. In recent decades, researchers have sought to identify and describe how people make decisions under risk and uncertainty and how actual behaviour diverges from the predictions of normative theories and models (Aven and Kristensen, 2005). For example, the prospect theory developed by Kahneman and Tversky includes psychological aspects linked to human behaviour. The theory assumes that people make decisions based on the potential value of losses and gains rather than the final outcome (e.g. Tversky and Kahneman, 1974, 1992).

It is not only psychological factors that have an influence on the decision-making process. The perception, acceptance and tolerability of risk and uncertainty are shaped by a number of factors, both individual and organisational. Some examples include the context, the environment, the safety culture of an organisation, knowledge, the source of information and the personal characteristics of the decision maker (e.g. emotions and consideration of social issues such as responsibility) (Slovic et al., 2004; Aven and Kristensen, 2005; Naqvi et al., 2006; Rodrigues et al., 2014). The process is even more complicated when the decisions have to be made in a corporate environment: managers have to take decisions that relate not only to their own lives, but also to the company, its employees and environment (Busenitz and Barney, 1997).

The goal of this paper is to examine how people make decisions when they have to choose between prevention and production investments and the decision involves risks and uncertainties that may have major negative consequences (up to billions of euros worth of losses). We investigate the parameters of consequence and probability within which people judge investment in production to be worth taking a major accident risk for, and the parameters within which they consider a risk or uncertainty unacceptable and opt instead for major accident prevention investment. The paper explores how this decision-making evolves when the probability of an accident increases, when the possible loss increases, and when uncertainty about the probability of occurrence and possible loss increases. Obtaining insights into how these decisions are made (in general) is important for the understanding and management of activities involving potential major accidents (Aven and Kristensen, 2005).

In our analysis of decision-making under risk, we include accidents with major negative consequences, as mentioned above, as well as a variety of probabilities of occurrence. When both the probability of occurrence and the disaster potential are perceived as high, such risks are normally rejected (Klinke and Renn, 2002). Acceptance of accidents with high disaster potential and a low probability of occurrence, known as HILP accidents (High Impact Low Probability), is far less straightforward (Chichilnisky, 2000; Hastie, 2001). It could be argued that the occurrence of large-scale accidents may be unacceptable regardless of their probability. On the other hand, it is unfeasible for organisations to spend unlimited amounts of money on reducing or eliminating accident scenarios. Therefore, a certain level of risk and uncertainty has to be accepted (Rodrigues et al., 2014).

Besides decision-making under risk (in which the outcomes and their probabilities are known), we also consider decision-making under uncertainty. In an uncertain situation, the probability that an accident can occur is unknown and/or the extent of the loss should the accident occur is unknown. When these uncertainties remain, subjective judgements are inevitable (Klinke and Renn, 2002). This makes it difficult to predict decision-making.

3. Methodology

3.1. The questionnaire

A closed-question self-administered questionnaire was conducted among students at the University of Antwerp in Belgium in November and December 2014. The questionnaire was distributed during lectures at the university to students studying a range of disciplines (communication studies, political science, sociology, socioeconomic sciences, film studies and visual culture, linguistics and literature, philosophy, safety sciences, business engineering and medicine).

The questionnaire consisted of three parts. The first part covered socio-demographic variables: gender, year of birth, highest level of education achieved to date, work status (student or employed student, i.e. studying and working more than 50 days per year) and study programme. In the second part of the questionnaire, the respondents were asked to imagine they were responsible for taking decisions concerning investments within a company. They received the following background information about the company, which is based on data from an existing international petrochemical company: