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Introduction

1.1 The importance of risk and uncertainty assessments

The concept of risk and risk assessments has a long history. More than 2400 years ago the Athenians offered their capacity of assessing risks before making decisions. From the Pericle's Funeral Oration in Thurcydidas' 'History of the Peloponnesian War' (started in 431 BC), we can read:

> We Athenians in our persons, take our decisions on policy and submit them to proper discussion. The worst thing is to rush into action before consequences have been properly debated. And this is another point where we differ from other people. We are capable at the same time of taking risks and assessing them beforehand. Others are brave out of ignorance; and when they stop to think, they begin to fear. But the man who can most truly be accounted brave is he who best knows the meaning of what is sweet in life, and what is terrible, and he then goes out undeterred to meet what is to come.

Peter Bernstein describes in Against the Gods (Bernstein 1996) in a fascinating way how our understanding of risk has developed over centuries. Bernstein asks rhetorically, What distinguishes the thousands of years of history from what we think of as modern times? The past has been full of brilliant scientists, mathematicians, investors, technologists, and political philosophers, whose achievements were astonishing; think of the early astronomers or the builders of the pyramids. The answer Bernstein presents is the mastery of risk; the notion that the future is more than a whim of the gods and that men and women are not passive before nature. By understanding risk, measuring it and weighing its consequences, risk-taking has been converted into

Foundations of Risk Analysis, Second Edition. Terje Aven.

one of the prime catalysts that drives modern Western society. The transformation in attitudes towards risk management has channelled the human passion for games and wagering into economic growth, improved quality of life, and technological progress. The nature of risk and the art and science of choice lie at the core of our modern market economy that nations around the world are hastening to join.

Bernstein points to the dramatic change that has taken place in the last centuries. In the old days, the tools of farming, manufacturing, business management, and communication were simple. Breakdowns were frequent, but repairs could be made without calling the plumber, the electrician, the computer scientist or the accountant and the investment adviser. Failure in one area seldom had direct impact on another. Today the tools we use are complex, and breakdowns can be catastrophic, with far-reaching consequences. We must be constantly aware of the likelihood of malfunctions and errors. Without some form of risk management, engineers could never have designed the great bridges that span the widest rivers, homes would still be heated by fireplaces or parlor stoves, electric power utilities would not exist, polio would still be maiming children, no airplanes would fly, and space travel would be just a dream.

Traditionally, hazardous activities were designed and operated by references to codes, standards and hardware requirements. Now the trend is a more functional orientation, in which the focus is on what to achieve, rather than the solution required. The ability to address risk is a key element in such a functional system; we need to identify and categorize risk to provide decision support concerning choice of arrangements and measures.

The ability to define what may happen in the future, assess associated risks and uncertainties, and to choose among alternatives lies at the heart of the risk management system, which guides us over a vast range of decision-making, from allocating wealth to safeguarding public health, from waging war to planning a family, from paying insurance premiums to wearing a seat belt, from planting corn to marketing cornflakes.

To be somewhat more detailed, suppose an oil company has to choose between two types of concepts, A and B, for the development of an oil and gas field. To support the decision-making, the company evaluates the concepts with respect to a number of factors:

- *Investment costs*: there are large uncertainties associated with the investment costs for both alternatives. These uncertainties might relate to the optimization potential associated with, among other things, reduction in management and engineering man-hours, reduction in fabrication costs and process plant optimization. The two alternatives are quite different with respect to cost reduction potential.

- *Operational costs*: there is greater uncertainty in the operational cost for B than for A as there is less experience with the use of this type of concept.

- *Schedules*: the schedule for A is tighter than for B. For A there is a significant uncertainty of not meeting the planned production start. The cost effect of delayed income and back-up solutions is considerable.

- *Market deliveries and regularity*: the market has set a gas delivery (regularity) requirement of 99%, i.e. deliveries being 99% relative to the demanded volume. There are uncertainties related to whether the alternatives can meet this requirement, or in other words, what the cost will be to obtain sufficient deliveries.

- *Technology development*: alternative A is risk-exposed in connection with subsea welding at deep water depth. A welding system has to be developed to meet a requirement of approximately 100% robotic functionality as the welding must be performed using unmanned operations.

- *Reservoir recovery*: there is no major difference between the alternatives on reservoir recovery.

- *Environmental aspects*: alternative B has the greater potential for improvement with respect to environmental gain. New technology is under development to reduce emissions during loading and offloading. Further, the emissions from power generation can be reduced by optimization. Otherwise the two concepts are quite similar with respect to environmental aspects.

- *Safety aspects*: for both alternatives there are accident risks associated with the activity. The accident risk for A is judged to be higher than for B.

- *External factors*: concept A is considered to be somewhat advantageous relative to concept B as regards employment, as a large part of the deliveries will be made by the national industry.

Based on evaluations of these factors, qualitative and quantitative, a concept will be chosen. The best alternative is deemed to be the one giving highest profitability, no fatal accidents and no environmental damage. But it is impossible to know with certainty which alternative is the best as there are risks and uncertainties involved. So the decision of choosing a specific alternative has to be based on predictions of costs and other key performance measures, and assessments of risk and uncertainties. Yet, we believe, and it is essentially what Bernstein tells us, that such a process of decision-making and risk-taking provides us with positive outcomes when looking at the society as a whole, the company as a whole, over a certain period of time. We cannot avoid 'negative' outcomes from time to time, but we should see 'positive' outcomes as the overall picture.

As a second example, let us look at a stock market investor. At a particular moment, the investor has x million dollars with which to buy stocks. To simplify, say that he considers just three alternatives: A, B and C. What stocks should he buy? The decision is not so simple because there are risks and uncertainties involved. As support for his decision, he analyzes the relevant companies. He would like to know more about how they have performed so far, what their goals and strategies are, what makes them able to meet these goals and strategies, how vulnerable the companies are with respect to key personnel, etc. He would also analyze the industries to which the companies belong. These analyses provide a basis for making judgments about the the risks and

uncertainties, and next making a decision. When the investor makes his choice, he believes he has made the right choice, but only time will tell.

As a final example, let us consider a team of doctors that consider two possible treatments, A and B, for a patient who has a specific disease. Treatment A is a more comprehensive treatment, it is quite new and there are relatively large uncertainties about how it will work. There are some indications that this treatment can give very positive results. Treatment B is a more conventional approach, it is well proven but gives rather poor results. Now, which treatment should be chosen? Well, to make a decision, risks and uncertainties first have to be addressed. The team of doctors have thoroughly analyzed these risks and uncertainties, and to some extent reduced them. For the patient it is important to hear the doctors' judgments about the chances of being cured and about the possible side effects of the treatments. Then the patient makes a decision.

More examples will be presented in the following chapters.

1.2 The need to develop a proper risk analysis framework

Bernstein concludes that the mastery of risk is a critical step in the development of modern society. One can discuss the validity of his conclusion, but there should be no doubt that risk and uncertainty are important concepts to address for supporting decision-making in many situations. The challenge is to know how to describe, measure and communicate risk and uncertainty. There is no clear answer to this. We cannot find an authoritative way of approaching risk and uncertainty. We do need one. We all have a feel of what risk means, but if we were asked to measure it, there would be little consensus. Webster's Dictionary (1989) has several definitions of 'risk', including:

- exposure to the chance of injury or loss;
- a hazard or dangerous chance;
- the hazard or chance of loss;
- the degree of probability of such loss.

These are just a few examples. Other dictionaries have other definitions. If we consult the scientific literature on risk, the situation is similar: a huge number of definitions reflecting many different and also conflicting ideas. We are not yet ready to define what we mean by risk in this book, but the definition in Chapter 3 is closely related to uncertainty, a concept that is equally difficult to define as risk. Webster's Dictionary refers, among other things, to the following definitions of 'uncertainty':

- not definitely ascertainable or fixed;
- not confident;

- not clearly or precisely defined;
- vague, indistinct;
- subject to change, variable;
- lack of predictability.

Again, these are just illustrations of the many definitions that can be found.

The ambiguity surrounding the notions of risk and uncertainty is also reflected in the way the different applications and disciplines approach risk and uncertainty. This will become apparent in Chapter 2, which reviews some common thinking about risk in different applications and disciplines.

The terminology and methods used for dealing with risk and uncertainty vary a lot, making it difficult to communicate across different applications and disciplines. We also see a lot of confusion about what risk is and what should be the basic thinking when analyzing risk and uncertainty within the various applications. This is not surprising when we look at the risk literature, and the review in the next chapter will give some idea of the problems. Reference is made to so-called classical methods and Bayesian methods, but most people find it difficult to distinguish between the alternative frameworks for analyzing risk. There is a lack of knowledge about what the analyses express and the meaning of uncertainty in the results of the analyses, even among experienced risk analysts. The consequence of this is that risks are often very poorly presented and communicated.

Nowadays there is an enormous public concern about many aspects of risk. Scientific advances, the growth in communications and the availability of information have led to greater public awareness. Few risks are straightforward; there are competing risks to balance, there are trade-offs to make and the impacts may be felt across many sections of society and the environment. Science, medicine and technology can help us to understand and manage the risks to some extent, but in most cases the tasks belong to all of us, to our governments and to public bodies. Therefore we need to understand the issues and facilitate communication among all parties concerned. The present nomenclature and tools for dealing with risk and uncertainty are confusing and do not provide a good framework for communication.

Furthermore, aspects of society with inherent risk and uncertainty have changed in recent years. This applies, among other things, to complex technology with increased vulnerability, information and communication technology, biotechnology and sabotage. People require higher safety and reliability, and environmental groups have intensified their activities. The societal debate related to these issues is characterized by people talking at cross purposes, by mistrust as objective facts are mixed with judgments and values, and the cases are often presented in a nonsystematic way as far as risk and uncertainty are concerned. More than ever there is a need for decision-support tools addressing risk and uncertainty.

It is our view that the concepts of risk and risk analysis have not yet been sufficiently developed to meet the many challenges. A common approach is needed that can give a unifying set-up for dealing with risk and uncertainty over the many

applications. It is necessary to clarify what should be the basis of risk analysis. We search for a common structure, and philosophy, not a straitjacket. Business needs a different set of methods, procedures and models than for example medicine. But there is no reason why these areas should have completely different perspectives on how to think when approaching risk and uncertainty, when the basic problem is the same to reflect our knowledge and lack of knowledge about the world.

This book presents such a unifying approach, which we believe will meet the many challenges and help to clarify what should be the definition of risk and the basis of risk analysis. To deal with risks related to the profit from one or several investment projects or stocks, production loss and occurrence of accidental events, it is essential that economists, finance analysts, project managers, safety and production engineers are able to communicate. Currently this communication is difficult. The typical approaches to risk and risk analysis adopted in engineering and in business and project management represent completely different views, making the exchange of ideas and results complicated and not very effective. In traditional engineering applications, risk is a physical property to be analyzed and estimated in the risk analysis, the quantitative risk analysis (QRA) and the probabilistic safety/risk analysis (PSA/PRA); whereas in business and project management, risk is seen more as a subjective measure of uncertainty.

We need to rewrite the rules of risk and risk analysis. And our starting point is a review of the prevailing thinking about risk in different applications and disciplines.

Bibliographic notes

The literature covers a vast number of papers and books addressing risk and uncertainty. Many provide interesting examples of real-life situations where risk and uncertainty need to be analyzed and managed. Out of this literature we draw attention to Hertz and Thomas (1983), Moore (1983), Clemen (1996), Koller (1999a, 1999b) and Vose (2008) as these books are closely linked to the main applications that we cover in this book.

The challenges related to description, measurement and communication of risk and uncertainty have been addressed by many researchers. They will be further discussed in Chapter 2, and more Bibliographic Notes can be found there.