Part I: Risk and uncertainty

Risk management

Risk is an inherent part of business, and risk management an operational priority of companies on both sides of the business equation – suppliers as well as customers. In fact, the different ways in which suppliers and customers deal with certain risks can create opportunities for both.

In this first article of a three-part tutorial on risk management, we look at the terms, definitions and methods used. The mathematical techniques for a quantitative analysis of risk will be explained in more detail in the second part. The final article will focus specifically on the evaluation of project risks.

The dictionaries tell us that risk is 'the possibility of loss or injury'. This definition is familiar to most of us, and whether we realize it or not, everything we undertake in our daily life is risky to some degree or another. When boarding an airplane, for example, many people think of the possibility of a plane crash, but when driving, almost nobody is consciously aware of the (much higher) risk of being killed in a car accident.

According to most definitions, risk refers only to the possible negative effects of a certain action. Risk, however, is always also connected with opportunities and benefits ('no risk, no fun'). The reason for this is that risk is a consequence of uncertainty, for example of uncertainties in our assumptions or of uncertainty about future developments and events. In some disciplines such as portfolio theory, risk is actually defined as a measure of uncertainty and thus refers to negative as well as to positive consequences. As an example, 1 shows risk versus return data for different investment possibilities. Here, risk is defined as the volatility (standard deviation) of the observed statistical price fluctuations. The graph illustrates the well-known fact that a higher expected return is usually associated with a higher uncertainty with respect to the actual return. This uncertainty, however, can have a positive or negative sign, so the actual return can just as easily be lower or higher than its expected value.

Dealing with risk is nothing new. As long as mankind has existed, men and women have constantly had to make decisions by weighing risks against expected benefits. What has changed significantly, however, is the complexity of these risks and the way we deal with them.

The risk of dying in battle or of being drowned at sea appears extremely simple and transparent when we compare it with present-day risks and their consequences. Such a risk could be that of a deadly virus spreading globally, or a wide-area electricity blackout like the one that affected large parts of the northeastern United States and Canada on August 14, 2003 2 and was estimated to have cost the economy billions of dollars.

The most important distinction between now and the past, however, is our ability today to analyze uncertainties and risks in mathematical terms. Instead of appealing to the gods, we can now use the instruments of probability theory and mathematical statistics to quantify and compare different risks and to evaluate the consequences of our decisions.

Despite these possibilities, most people do not attempt to evaluate their risks in a quantitative way. Instead, they still rely on intuition, doubtful logic, misinterpreted experience, and emotion.
As the famous American jurist, Oliver Wendell Holmes, put it: "Most people think dramatically, not quantitatively."

As far as personal everyday risks are concerned, this usually has no serious or far-reaching consequences. In our professional activities, though, a misjudgment of technical or economic risks may dramatically affect the fate of an entire company. The collapse of Enron and Barings Bank are only two recent examples of the spectacular consequences of an inadequate risk perception.

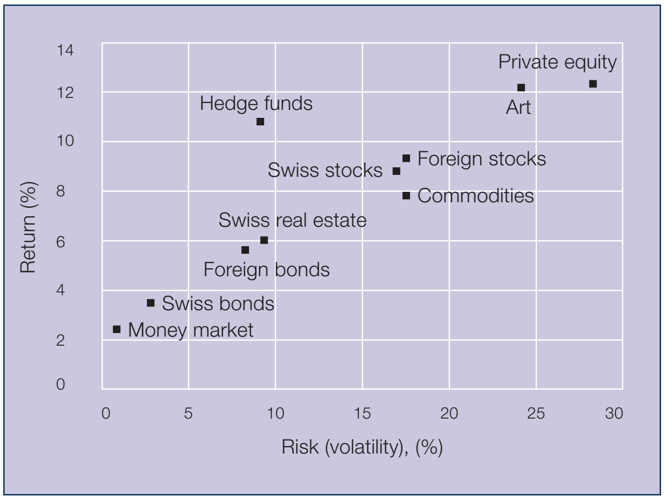
Quantification of risks

The most important instrument for quantifying risks is probability theory. Its history goes back to the 17th century when Blaise Pascal and Pierre de Fermat were confronted with the 'Problem of the Points', a famous unsolved problem that had been around for more than 200 years.

The 'Problem of the Points' can be stated as follows:
Two players, A and B, are playing a fair, repeated game (a game with equal winning chances for both). The winner is that player who first wins six rounds. The game, however, is interrupted when A has won five and B three games. How should the stakes be divided in this unfinished game?

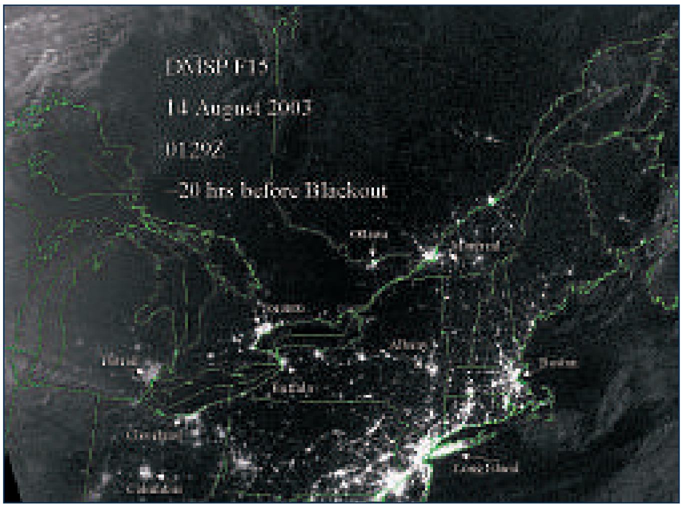
Pascal corresponded heavily with Fermat on this problem, and finally Pascal found a way to calculate the probability of any outcome in a game of chance (Pascal's Triangle). Although it is impossible to predict the actual outcome of a random event, by establishing their theory of probability, Pascal and Fermat were now able to quantify the odds of all possible outcomes. With respect to the 'Problem of the Points', they concluded that the stakes should be split according to the odds on each player winning the game at the point where it was interrupted.

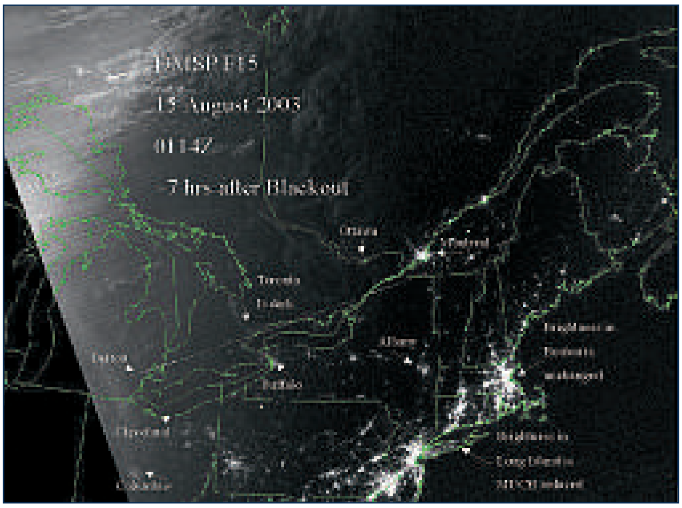
1 Risk vs. return profile of investment instruments (for a CHF investor)
Source: UBS Investment, May 2003



2 Satellite pictures of the US Northeast blackout, August 14, 2003

Source: Defense Meteorological Satellite Program (DMSP), processed by US Air Force Weather Agency. Posted online by National Oceanic and Atmospheric Administration





This gave player A 7/8 and player B 1/8 of the total stakes.

Pascal not only initiated what we now call probability theory; his work also represented a major revolution in thinking about uncertainty and in understanding the meaning of risk. He realized that the decision about a certain action should depend on both the impact of the possible outcomes and on the probabilities of these outcomes. In other words, risk has to be characterized in terms of (at least) two variables: the magnitude of the possible loss or damage and the probability of the corresponding event.

This simple measure of risk, risk = probability x effect (or exposure), is still used in many of today's risk evaluation procedures.

For risk management purposes, it may often be convenient to use simple and concise risk measures such as the one above. To obtain the full information about a certain risk, however, it is necessary to consider the entire probability distribution of the magnitude or severity of its implications. For well-defined random events, this probability distribution can easily be determined with the help of Pascal's methods.

The risks we have to deal with today, however, are much more complex than the simple risks in a game of chance. They often depend in a complicated way on a large number of uncertain factors, and their effects can usually not be described in terms of a few possible outcomes, but are represented by continuously varying variables. To analyze such risks, Pascal's methods are no longer sufficient, and we then have to use more advanced techniques of probability theory and statistics.

Risk assessment

We now know that to quantify risks and uncertainties we have to determine the probability distribution of their implications. But how do we assess impacts and probabilities in a real-world situation, ie when there are no well-defined rules such as in a game of chance?

Before starting such an assessment process, it is important that we identify and specify the risks associated with our intentions as precisely as possible. This implies that we have to specify all factors that may influence the relevant probabilities. The risk of your house being damaged in an earthquake, for example, is certainly much higher if you live in Los Angeles than if you live in Zurich. Or consider the risk of being killed in a car accident. Here you have to specify whether you refer to the corresponding probability per year, per trip, or per kilometer, whether you live in Stockholm or in Rome, etc.

Also, complex risks may depend on a large number of uncertain factors and variables. The risk of losing money by generating and selling electricity, for example, depends on fuel and electricity prices, on failure and outage rates, on daily and seasonal temperatures, etc. These factors are all random variables and can thus only be described in terms of a probability distribution. To determine the ultimate quantity of interest, the probability distribution of profit and loss, we not only have to assess the individual uncertainties, but also need a model that quantitatively describes how our revenues depend on the different influencing factors. Only if such a model is available will we be able to use techniques from probability theory to correctly aggregate the individual probability distributions into the probability distribution for profit and loss.

So which of the available techniques for assessing the different probability distributions do we need to know to be able to quantify a specific risk? The preferred approach is to apply methods from mathematical statistics. For this, however, a sufficient amount of adequate historical data has to be available. In the case of traffic accidents or natural disasters, this is usually no problem. Likewise, there is abundant historical data for assessing market risks in the finance industry (ie, risks arising from movements in exchange rates, interest rates, etc).

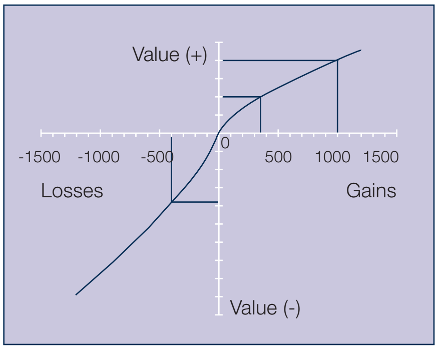
A basic problem of risk assessment is that the risks we are trying to estimate refer to future events, but the available data only refers to past observations. We thus assume that these risks do not change significantly over the period of time relevant for our analysis. We can, of course, observe trends and use them to forecast changes in certain risk characteristics, but while this may improve our estimates, it can never completely eliminate the inherent uncertainty associated with an assessment of risks in real-world situations.

If historical data are scarce, statistical methods become very unreliable, and in many cases there may be no historical data at all. Then, the assessment of risks has to be based on expert judgments. Experts, though, usually do not express their statements in terms of probability distributions. We thus need adequate procedures to transform their qualitative and quantitative information into an appropriate probabilistic description.

There are risks, however, for which it is virtually impossible to specify effects and probability to any reasonable degree of accuracy, eg the risk and the economic implications of a major terrorist attack. But even in such cases, we are not completely lost. In such situations we can perform a number of scenario simulations. Even if we are unable to specify the probabilities of the different scenarios, their implications can still provide us with valuable information about the possible effects of risk factors that are difficult or impossible to quantify. Banks, for instance, are actually required to use so-called 'stress scenarios' to analyze the impact of events or influences that cannot be quantified by historical data.

A particularly spectacular example of the consequences of an inadequate risk assessment was the Challenger space shuttle accident on January 28, 1986, which was caused by poor fitting of O-rings due to low temperatures at the time of launch. In his appendix to the Rogers Commission Report[1] on this accident, Richard Feynman concludes that because of the non-scientific assessment of risks by NASA officials ("the same risk has been flown before without failure"), "obvious weaknesses were accepted again and again, sometimes without a sufficiently serious attempt to remedy them." In particular, it turned out that a careful statistical analysis of O-ring performance had never been carried out, and so NASA "was not prepared to properly evaluate the risks of launching a mission in conditions more extreme than they had encountered before."

3 Typical value function for gains and losses [3]



Risk evaluation

The assessment of uncertainties and risks associated with an intended action is not, of course, the end of the story. We still have to evaluate and compare these risks according to the criteria on which we base our decisions. But what criteria do or should we use in our decision processes?

According to classical economic theories, rational decisions should only be based on the expected value of gains and losses. To illustrate this, assume that you can choose between two options: a sure gain of \$40 and a gamble that gives you a 50 percent chance of winning either \$100 or nothing. The expected value of the gamble (0.5×\$100 + 0.5×\$0 = \$50) is higher than that of the certain outcome (\$40), so that a rational player should prefer the gamble. A sure loss of \$40, on the other hand, should be preferred to a gamble that gives you a 50 percent chance of losing \$100 and a 50 percent chance of losing nothing. [The expected value of this gamble (-\$50) is worse than that of the certain loss (–\$40).] A person (or company) acting according to these principles is said to be 'risk-neutral.'

Recent investigations have shown, however, that most people behave in a risk-averse way with respect to gains and in a risk-seeking way with respect to losses. When confronted with the choices described above, most people prefer the certain gain of \$40 to the risky 50 percent chance of winning

1) NASA History Office. Information on the STS-51L/Challenger Accident. http://history.nasa.gov/sts51l.html

$100. In the case of losses, on the other hand, the majority prefer to risk the 50 percent chance of losing $100, rather than accept the sure loss of $ 40.

Risk preferences can conveniently be described in terms of a so-called utility or value function [3]. This function represents the subjective value of different gains and losses, and decisions are now based on a comparison of expected value, rather than on expected gain or loss.

A typical value function for gains and losses is reproduced in 3. It summarizes some general features of human risk preferences, eg risk aversion for gains and risk seeking for losses. The value of a gain of $350, for instance, is half the value of a gain of $1'000, so that a sure gain of $350 is just as attractive as a 50 percent chance of winning $1'000. The value function in 3, however, also reflects another non-rational feature in human behavior, namely the fact that the threat of a loss has a greater impact on a decision than the possibility of an equivalent gain. For example, only a gain of about $1'000 will compensate the negative value of a loss of $400.

Humans often act intuitively when they are confronted with risky choices. For companies, however, it is essential that a clear specification of risk preferences be included in their risk management policies. This is usually not done in terms of an explicitly specified value function, but rather in terms of well-defined criteria for business decisions (including risk limits, mitigation and reporting requirements, etc).

Risks and uncertainties can never be eliminated completely. Nevertheless, careful evaluation and analysis of risks, will enable us to minimize the risks involved in a given action, not only by choosing between different options, but often also by revealing ways to mitigate or reduce some of the unavoidable risks.

Risk management

Over the past two or three decades, demand for risk management has increased dramatically. The main reason is the growing number and complexity of risks we are confronted with in our private and professional lives. On top of this, the increased attention is linked to the recent development of powerful techniques for estimating and analyzing different types of risk, especially in the finance sector.

The purpose of risk management is to minimize the risks over which we have some control and, if possible, avoid or eliminate the risks that are beyond our influence. The main steps in a comprehensive risk management procedure are:

- Risk identification
- Risk assessment (quantification and aggregation of all relevant risk factors)
- Risk evaluation (in terms of well-defined risk measures and criteria)
- Risk control (according to a company-wide risk policy that includes a specification of risk limits and of mitigation and reporting requirements)

Quantitative risk analysis is therefore central to risk management: Thus, "to compare risks, we must calculate them [4]", and this will be the key theme of this three-part tutorial. It goes without saying, however, that an effective risk management concept for a company has to address a number of additional, equally important aspects, such as policy, communication and reporting.

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Further reading

[1] **P. L. Bernstein:** Against the Gods – The Remarkable Story of Risk. John Wiley & Sons, Ltd, 1996.

[2] **J. F. Ross:** The Polar Bear Strategy – Reflections on Risk in Modern Life. Perseus Books, Reading, Massachusetts, 1999.

[3] **D. Kahneman, A. Tversky:** The Psychology of Preferences. Scientific American, Jan 1982, 136–142.

[4] **Richard Wilson:** Analyzing the Daily Risks of Life. Technology Review, vol 81, no 4 (Feb 1979), 41–46.