Part III: Risk Analysis in Practice

The mathematical tools for a quantitative analysis of uncertainties and risks have been introduced in Part II of this tutorial on risk management[1]. In the present and final article of this series, we shall demonstrate how these concepts can effectively be applied in practice. Rather than giving a general overview of the different issues, we shall restrict our discussion to a specific type of risk management problem: the evaluation of project risks.

Risk Management of industrial projects

The main economic performance indicators of an industrial project are its net result and the corresponding net margin:

- Net Result = Revenues – Costs
- Net Margin = Net Result / Revenues.

Revenues and costs of a prospective project are already estimated in the planning phase and are thus subject to a considerable degree of uncertainty. It is therefore important that the corresponding risks are evaluated very carefully before a tender is issued.

A comprehensive risk evaluation process includes the following steps:

- Risk identification
- Risk quantification
- Risk evaluation and analysis
- Risk monitoring, control, and management

Project risks are thus not evaluated once and for all, eg, in the pre-tendering phase. They have to be continuously monitored and re-evaluated during the tendering and execution phases of a project.

Typical project risks

The exact nature and form of potential risks is, of course, highly project-specific. In the following list, however, we summarize and briefly describe some generic types of risks that may occur in almost any industrial project:

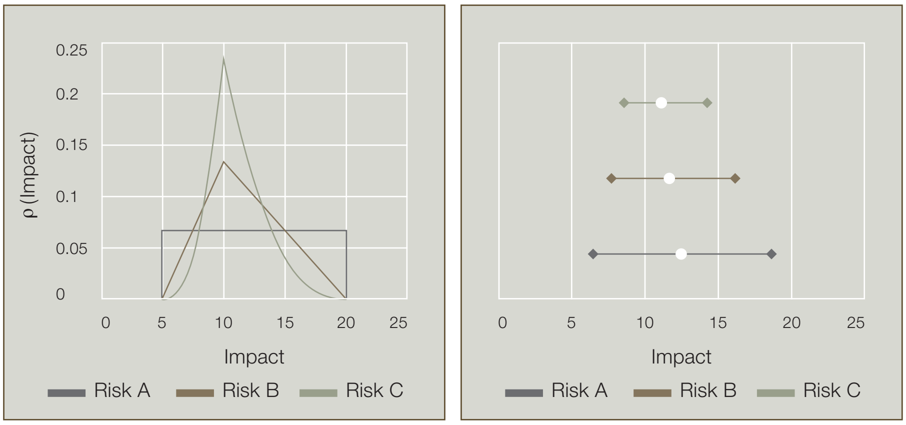
- *Technical risks:*
  - *Uncertainties associated with new designs, new technology, new materials* (eg, additional R&D work, additional tests, use of more expensive components).
  - *Manufacturing risks* (eg, equipment breakdown).
  - *Transportation and installation risks* (eg, bad weather, unexpected soil conditions).
- *Commercial / financial risks:*
  - *Contractual risks*, eg, penalties for delivery delays or non-fulfillment of performance guarantees ('liquidated damages').
  - *Market risks*, eg, currency risk, interest rate risk, material costs (metal prices etc.) etc.
  - *Default and credit risks* (risk that a customer or supplier may become insolvent or go bankrupt)
  - *Delayed payments, approval delays, delay of permits*, etc.
- *Political and legal risks:*
  - These risks are usually very hard to quantify and will not be included in our present discussion.

Risk reports

Risk reports play an important role in any risk management process. They are used, in particular, to inform decision makers about the inherent risks of a planned project. It is often criticized, however, that such reports are very difficult to decipher by the intended recipients[2]. The two main points of this criticism can be summarized as follows:

- Risk reports are often too complex and do not contain visual representations of risk figures. (A risk report should be understandable 'at a glance'.)
- Risk reports usually do not offer any interactive facilities. (For example a member of the risk review committee is not able to quickly check the implications of different assumptions or to perform a 'what-if' analysis.)

1 Three risk factors with the same minimum, most likely, and maximum impact, respectively, but with different probability densities.



Probability densities (see text)

Mean impacts (circles) and 80% confidence intervals

To demonstrate the usefulness of an interactive evaluation of project risks, we first describe possible methods for a simple but adequate quantification and analysis of such risks and then the results are presented of some scenario simulations ('what-if simulations') for an illustrative generic project example.

Quantitative evaluation and analysis of risks

To define a concise measure of project risk, we determine the impact of the different risk factors on the anticipated net margin of the project. This can be expressed as

Net Margin = (Revenues – Costs – Risks) / Revenues,

where 'Risks' refers to an adequate aggregation of the individual risks, and where it is assumed that the impact of all risk factors can be expressed in terms of potential additional costs.

If net margin (NM) is chosen as the relevant quantity of interest, the risks of a project are described by the probability distribution of possible NM values. This, in turn, can be determined from the probability distributions of the individual risk factors, eg, by using Monte Carlo simulation techniques. If the individual risks are all expressed as potential additional costs, however, it is usually accurate enough to approximate the net margin probability distribution by a normal (Gaussian) distribution. This Gaussian approximation of the NM probability distribution, on the other hand, is completely determined by its mean value μ_{NM} and its variance σ_{NM}^2, (see Part II of this tutorial[1)]), and these quantities are easily calculated from the mean values and variances of the individual risks.

Convenient measures to characterize the net margin risk of a project are, for example, the expected net margin μ_{NM}, the corresponding 10 and 90% confidence limits, and the probability that the net margin falls below its target value (or becomes negative).

Quantification of individual risks

In the case of industrial projects, statistical data is usually only available for some special types of risk (currency risk, metal prices, etc.). The majority of risks, however, are judged by experts in terms of a few characteristic quantities, and we are then left with the task of extracting the information needed for an adequate quantitative analysis.

A widespread practice is the characterization of individual risks by their impact R (in monetary terms) and by an estimated probability of occurrence, p. This corresponds to a binary probability distribution, ie, the additional cost R will either materialize (with probability p) or not (with probability 1-p). The expected risk (mean value) is then simply given by p·R, and the corresponding variance by $p(1–p)R^2$.

For some types of risk, this may be an adequate description, but in most cases, the potential impact of a risk can vary over an entire range of values. It is thus often more appropriate to characterize risks in terms of their minimum, most likely, and maximum potential impact (R_{Min}, R_{ML}, and R_{Max}). The form of the corresponding probability distribution, however, is not yet specified by these quantities, ie, we need additional information to determine an appropriate mean value and variance.

One approach to this problem is to select the most suitable probability distribution from a corresponding library. Another is to use a pre-specified form

Table 1 Currency Information.

Budget currency	CHF	
Bid currency	USD	
Cost Structure	CHF	60.0%
	EUR	20.0%
	SEK	20.0%
Exchange Rates	USD/CHF	1.2600
	EUR/CHF	1.5300
	SEK/CHF	0.1675

for the probability distribution and to adjust it to the appropriate minimum, most likely, and maximum values.

In the following, we propose and use an intermediate approach. The form of the risk probability distribution between R_{Min} and R_{Max} is specified by a single parameter, γ, that can be varied between zero and infinity 1. γ = 0, for example, corresponds to a uniform probability density, and γ = 1 to a triangular distribution. With increasing γ, less and less weight is given to the extreme risk values close to R_{Min} and R_{Max}. The examples shown in 1a refer to γ = 0 (Risk A), γ = 1 (Risk B), and γ = 2.5 (Risk C). It is assumed that R_{Min} = 5, R_{ML} =10, and R_{Max} = 20 for all three risks. From 1b, it can be seen that mean value and variance of a risk are strongly affected by the form of the chosen probability distribution.

This approach has the advantage that, with an appropriate graphical feedback, an expert can easily adapt the form of the risk probability distribution according to his expectations. We further note that with a small modification, binary risk distributions can also be included in this scheme.

There are some types of risk, however, that cannot easily be expressed as on additional cost. Currency risk, for example, depends on the probability distribution of exchange rate fluctuations and on the project-specific currency structure of revenues and costs. It is thus often preferred to analyze the corresponding impact on the project result via scenario simulations.

The characterization and quantification of default and credit risks is even more complex. A simple estimation of revenues and costs is no longer sufficient to determine these risks. They rather depend on the cash flow and project value exposure over the entire project execution period, as well as on information about the default probabilities of customers and suppliers. As such information is usually very hard or impossible to obtain, these risks are often only characterized in terms of a maximum potential exposure.

Analysis of an illustrative example

Based on the risk quantification and analysis procedures described above, we have realized a simple prototype of an interactive project risk simulation tool. The tool is presently being tested and evaluated by project managers and risk officers. We have used it here to analyze the risks of a simplified generic project example (see *Table 1, 2* and *3*).

Table 1 refers to the information required to evaluate the currency risk of the project, and *Table 2* summarizes the minimal input needed for an analysis of the prospective net margin. The risk figure quoted in *Table 2* refers to the mean (expected) value of the total risk, which is determined by aggregating the mean values of the individual risks specified in *Table 3*.

In our generic example, we have assumed that there are six major risk factors that might affect the profitability of the project: Additional R&D costs for a new design, use of more expensive components to satisfy project specifications, uncertainty about transportation costs, volatility of material prices, payment delays by the customer, and the possible payment of contractual penalties (liquidated damages).

Table 2 Revenues and Costs.

	[kCHF]	[kCHF]	[%Total Rev.]
Total Revenues:	140,000		100.00%
Total Production and Overhead Costs	129,000		92.14%
Risks (expected value):	5,550		3.96%
Full Cost:		134,550	96.11%
Net Result / Margin:		5,450	3.89%
Net Margin Target:			4.00%

Table 3 Specification of Risks.

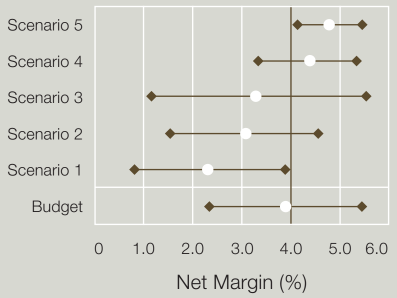
Risks [kCHF]	Impact Min	Impact Most Likely	Impact Max	γ
Additional R&D costs (new design)	0	500	1,000	0.0
More expensive components	0	400	1,600	1.0
Transportation costs	-100	100	350	1.0
Material Prices	-3,500	800	5,400	2.5
Payment delays	250	680	1,100	2.5
LD for delivery delay (0.5% / week)	0	2,100	7,000	2.5

The corresponding risks are specified in terms of their estimated minimum, most likely, and maximum impact, as well as by γ (a parameter indicating the expected form of the probability distribution form, see above). In the case of liquidated damages (LDs), for example, we have assumed a contractual penalty of 0.5% of the contract value for each week of delivery delay and a maximum liability of 5% of the contract value.

Currency risk is not included in this list of risk factors but will be analyzed via scenario simulations. Default and credit risks are not considered in our example.

The impact of our risk assumptions on the net margin

2	Project example: Graphical representation of budget and scenario risks.



Expected net margin values and corresponding 80% confidence intervals are indicated, respectively, by open circles and horizontal bars.

of the project is expressed in terms of the expected net margin, the corresponding 80% confidence interval, and the probability that the prospective net margin is smaller than the specified target value of 4% (see 2 and *table 4*).

To analyze the sensitivity of the results with respect to our budget assumptions, we have also evaluated five alternative risk scenarios:

- *Scenario 1:* CHF/USD rate decreases from 1.26 to 1.24
- *Scenario 2:* The most likely value of LDs is doubled (six weeks delay instead of three weeks)
- *Scenario 3:* All LD values between 0 and LD_{max} are equally likely (ie, $\gamma = 0$)
- *Scenario 4:* Material prices are hedged (hedging costs = 200 kCHF)
- *Scenario 5:* Material prices are hedged (as in Scenario 4) and LD_{max} is reduced to 4,200 kCHF (maximum liability of 3% of contract value)

In *table 4* and in 2, the net margin risks of the different scenarios are compared with those calculated from the budget assumptions.

This comparison shows that the most important risks in this project example are exchange rate fluctuations and liquidated damages. A decrease of the CHF/USD rate from 1.26 to 1.24 (scenario 1), for example, already reduces the expected net margin from 3.9% to 2.3% and increases the probability that the net margin is below target from 0.54 to 0.91. With a CHF/USD rate of 1.22, we even have a significant probability (0.28) that the net margin becomes negative.

More conservative estimates of delivery delays (scenario 2) as well as the impossibility of estimating the extent of potential delays (scenario 3) also lead to a significant increase of net margin risks. A hedging of material prices (scenario 4), on the other hand, increases the expected net margin and decreases the risk of falling below target. An additional reduction (if negotiable) of the LD cap to 3% of the contract value (scenario 5) would then finally eliminate this risk almost completely (provided, of course, that currency risk has also been eliminated by hedging against exchange rate fluctuations).

In connection with our choice of risk measures, we finally note that the lower bound of the NM confidence interval (see 2) can be interpreted in terms of the 'Value at Risk' concept discussed in Part II of this tutorial[1]. In the case of scenario 1, eg, the corresponding 'Net Margin at Risk' value is 0.8%, and it indicates that with a confidence level of 90%, the net margin of the project should not fall below this limit.

Table 4	Comparsion of budget and scenario risks.

	Expected NM	Prob (NM < Target)
Budget	3.9%	0.54
Scenario 1	2.3%	0.91
Scenario 2	3.1%	0.78
Scenario 3	3.3%	0.65
Scenario 4	4.4%	0.33
Scenario 5	4.8%	0.07

Conclusions

By analyzing the risks of a simple generic project example, we have tried to illustrate the importance of an adequate quantitative risk analysis, eg, for bid/no bid decisions, for risk monitoring, or for evaluating the impacts of hedging and risk mitigation strategies. The analysis shows, in particular, that 'expected risk' alone is not a sufficient measure to characterize the risks of a given project (although it may represent a meaningful quantity in a statistical context).

Finally, we have also tried to point out the possibilities and the usefulness of an interactive scenario simulation tool, for project managers as well as for risk controllers and decision makers.

Footnotes

1) See ABB Review 3/2004, pp. 66–70.

2) For example, T. Helenius and T. Groenfeldt, 'Deciphering Risk Reports', Derivatives Strategy Magazine, Vol. 3, No. 6 (June 1998), www.derivativesstrategy.com.

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