

Practical Use of Monte Carlo Simulation for Risk Management within the International Construction Industry

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Abstract: A multiple of German contractors endeavor to develop new business segments in the international market as a result of the regressive construction activity in Germany since 1995, coupled with the high stress of competition in the domestic German market. Furthermore the Corporate Sector Supervision and Transparency Act (KonTraG) - operative since 1998 - demands the installation of an efficient risk management system for capital companies. Albeit shortages in the case of risk management are identifiable in the German construction industry, this situation is the initial position for an implementation of a risk analysis tool for construction project evaluation in the tender phase based on Monte Carlo Simulation. The result and conclusion is a contribution for the risk management of an international contractor based on project risk assessment. Risks for international construction projects are shown on a practical point of view and action alternatives will be discussed.

1 Introduction

1.1 Theoretic Model of Risk Management Circle

The theoretical deduction in the risk management circle and these phases show, that risks are in principle controllable and assessable. A risk identification at an early stage and an integrated in-house risk management is therefore an indispensable requirement for a monetarily positive result of a project.

The risk management circle according Figure 1 is the guideline for the establishing of a risk management system.

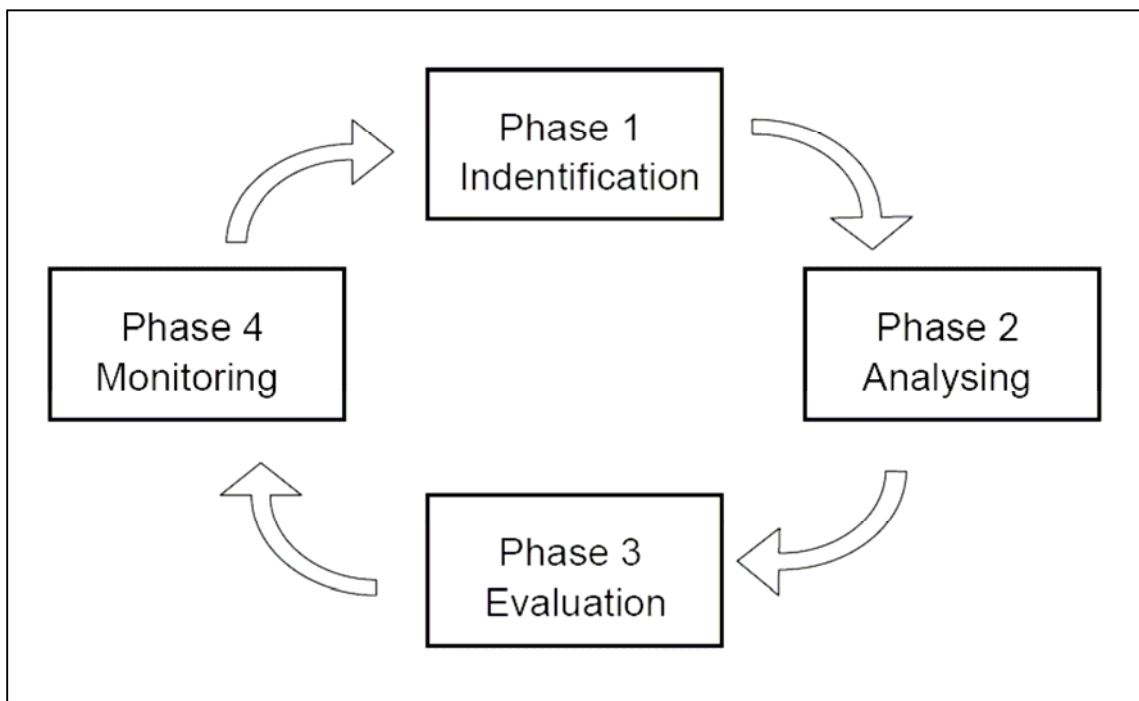


Fig. 1: Schematic Risk Management Circle according STEMPOWSKI [1]

The following definition of risk could be used in general:

$$\text{Risk} = \text{probability of risk occurring} \times \text{impact of risk occurring}$$

Several other definitions are published for instance by HÖLSCHER [2].

1.2 Objectives for Risk Management of Project Cost

The objectives for the implementation of a risk analysis tool in the tender process are as follows:

- Main specific project risks have to be identified in very early stage in the tender and acquisition phase
- Impacts of risks have to be monetarily analysed and have to be incorporated within negotiation of contract and within construction time
- Brings to light the impact of failures and overhasty acceptance of risks in regards of the risk & profit overhead of each individual project of an overall project portfolio
- Better risk awareness for the project
- Risky projects could be filtered at an early stage of the tender process and projects could therefore be withdrawn, or unacceptable contract conditions and knock-out-criterias could be discussed with the client

Results of these procedure in daily business:

- Higher performance rate in acquisition, because to risky projects are filtered and withdrawn
- In-house estimation and acquisition capacities will be used only for tender projects with a high chance to win a contract
- Reduction of internal estimation costs, because not all projects in the market will be followed
- Main risks are monitorable and controllable within construction process

2 Implementation of Risk Assessment in Estimation Procedure and Tender Process

2.1 Two-stage system and comprehension of Monte Carlo Simulation

The specific risks for a project are classified in categories and are respectively evaluated. Risks and their number diversify from project to project. But a risk with a knock-out-criteria is an important measure for assessment of each project.

Therefore a two-stage system for the aggregation of project risks is implemented. In the first stage all risks are analysed. Afterwards the critical risks for the project will be evaluated in detail.

The Monte Carlo Simulation is emphasized in this evaluation process, because the results of the Monte Carlo Simulation are significant when compared to other risk analysis methods.

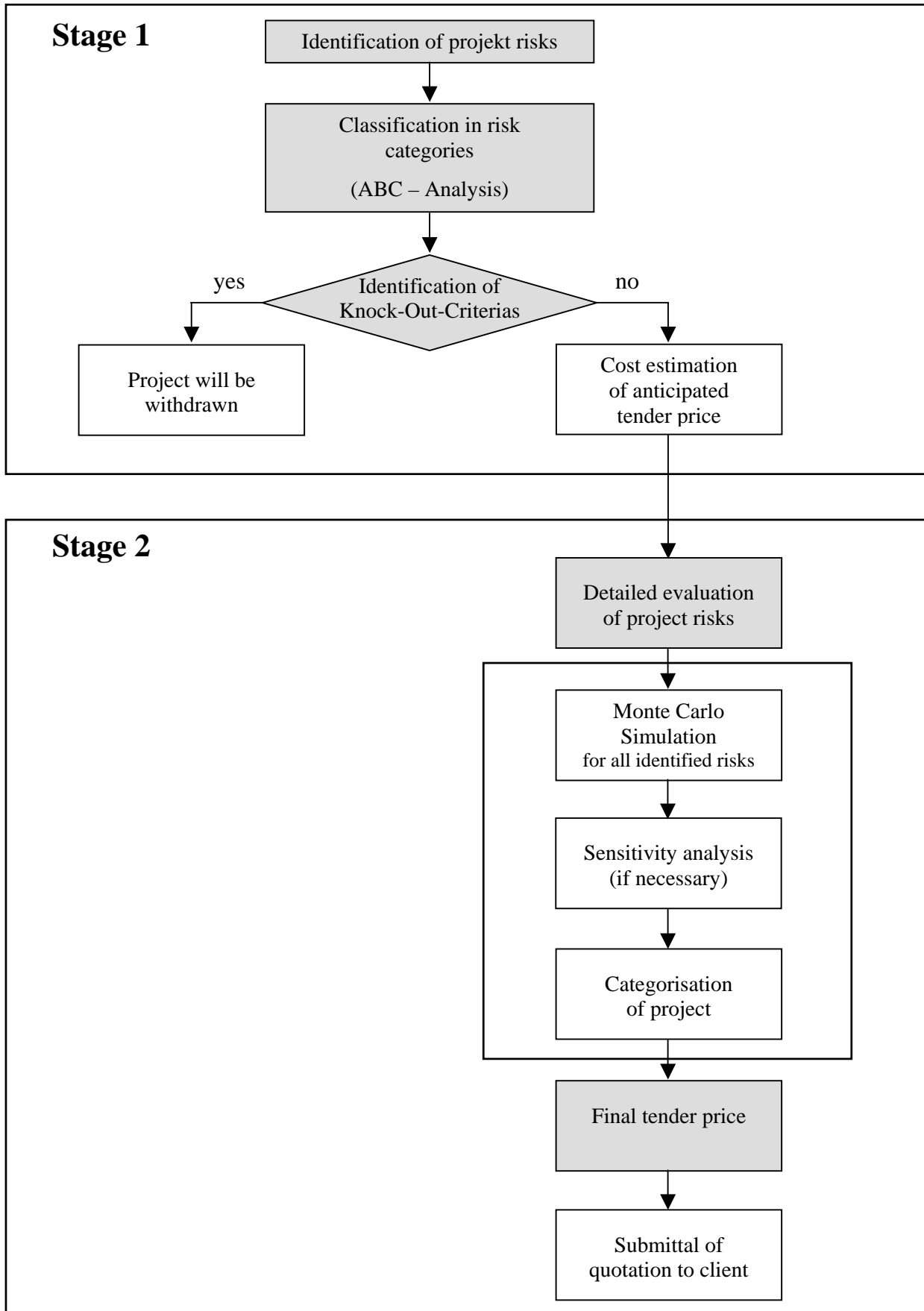
In this context and in regards to the risk management circle the stages are defined as follows:

Stage 1 = Phase 1 + 2 (identify and analyse the project risks)

Stage 2 = Phase 3 (evaluate the risks with MCS) and preparation for Phase 4 (monitoring)

The monitoring of the risks (Phase 4 of risk management circle) will be done within construction process. The results of the preliminary work within the tender process will be used therefore.

2.2 Practical Workflow within Cost Estimation Procedure



3 Example for daily use in business

3.1 Introduction

The following short and easy example shows a model to explain the procedure and the two-stage system as described in capture 2.

ARRIBA by RIB Software AG, Stuttgart is typically used as a software tool for the cost estimation. The results of the cost estimation have to be evaluated with a special dynamic simulation tool. Therefore the results of the cost estimation have to be transferred in an Excel spreadsheet. Furthermore @RISK by Palisade Corporation is used as software tool for the modelling of the Monte Carlo Simulation based on the inputs in the Excel spreadsheet.

The steps according stage 1 to find and classify the risks have to be done in advance. In regards of a simplification and to comprehend the procedure the example evaluate the sub-contractor risk only. In normal cases all risks within the different cost elements would be evaluated in detail and would be therefore part of the model.

3.2 Risk Evaluation

3.2.1 Stage 1 = Cost Estimation of Anticipated Tender Price

Table 1 shows the result of the cost estimation of the anticipated tender price as a result of Stage 1 ("Scenario 0" = Base Estimate). This estimation is based on the daily market prices and no dynamic effects are included.

Tab. 1: Cost Analysis for Scenario 0 = Base Estimate

		Scenario 0 Base Estimate
Directs (Site Costs)		
K.1	EMPLOYEE WAGES	2.000.000
K.2	MATERIAL	500.000
K.3	INDIRECT MATERIAL (PETROL, ETC.)	50.000
K.4	SUBCONTRACTORS	13.500.000
	SC 1	1.200.000
	SC 2	800.000
	SC 3	5.000.000
	SC 4	4.000.000
	SC 5	1.000.000
	SC 6	500.000
	SC 6	1.000.000
K.5	EQUIPMENT	50.000
K.6	FREIGHT	350.000
K.8	CUSTOM	250.000
	Sub-Total Directs:	16.700.000
Indirects (Site Costs)		
	Management, Yards, etc.	1.500.000
Directs + Indirects		18.200.000
Company Overhead + Risk & Profit		
Z.1	F.E. (8%) = eff. 8,70 % v. A.	1.583.400
	Total:	19.783.400
	Impact CO + Risk & Profit:	8,00 %

3.2.2 Stage 2 = Risk Evaluation with Monte Carlo Simulation

After the cost estimation (Scenario 0) every risk will be discussed in detail by the project team. For regular and practical cases the triangular distribution with the threshold values Minimum, Mean and Maximum are useful. Other continuous distributions, for instance rectangular distribution, beta distribution, normal distribution or uniform distribution, could be used in this context too.

Following the definition of the threshold values (Scenario 1) the Monte Carlo Simulation starts with the input values according table 2.

Table 3 shows the summary information in regards of the Monte Carlo Simulation procedure. A number of 10.000 iterations are useful and practicable.

Tab. 2: Threshold values as basis for Monte Carlo Simulation (Scenario 1)

	Scenario 1			
	Risk Evaluation of Subcontractor Cost			
Directs (Site Costs)				
K.1 EMPLOYEE WAGES				2.000.000
K.2 MATERIAL				500.000
K.3 INDIRECT MATERIAL				50.000
K.4 SUBCONTRACTORS	Minimum	Mean (Base Est.)	Maximum	13.761.667
SC 1	1.000.000	1.200.000	1.500.000	1.233.333
SC 2	780.000	800.000	825.000	801.667
SC 3	4.950.000	5.000.000	5.500.000	5.150.000
SC 4	3.800.000	4.000.000	4.300.000	4.033.333
SC 5	950.000	1.000.000	1.100.000	1.016.667
SC 6	400.000	500.000	650.000	516.667
SC 6	980.000	1.000.000	1.050.000	1.010.000
	12.860.000	13.500.000	14.925.000	
K.5 EQUIPMENT				50.000
K.6 FREIGHT				350.000
K.8 CUSTOM				250.000
Sub-Total Directs:				16.961.667
Indirects (Site Costs)				
Management, Yards, etc.				1.500.000
Directs + Indirects				18.461.667
Company Overhead + Risk & Profit				
Z.1 (<i>Factor of Influency</i>)				1.321.733
Total:				19.783.400
Mean CO + Risk & Profit:				6,68 %

Tab. 3: General simulation information

Simulation Summary Information	
Number of Simulations	1
Number of Iterations	10.000
Number of Inputs	7
Number of Outputs	1
Sampling Type	Monte Carlo
Simulation Start Time	6.24.08 14:04:57
Simulation Duration	00:00:16
Random # Generator	Mersenne Twister

3.2.3 Interpretation of the Results of Monte Carlo Simulation

The result of the Monte Carlo Simulation via @RISK is a probability distribution. Figure 2 shows the probability density for the example. Figure 3 shows the result under the cumulative ascending point of view.

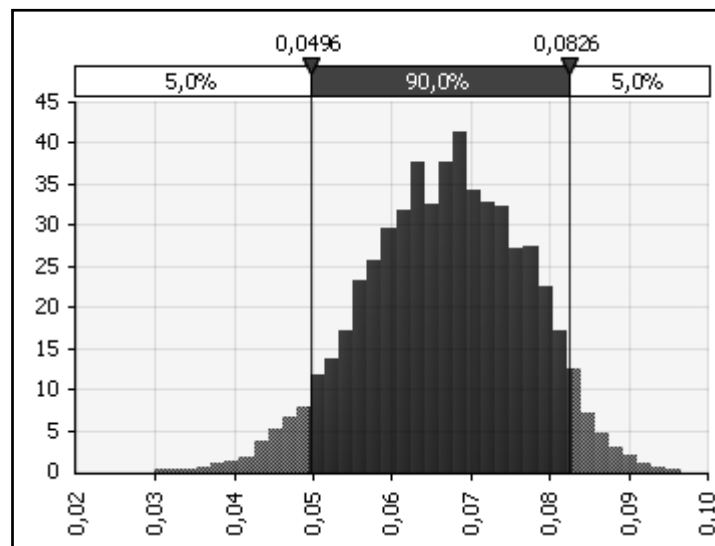


Fig. 2: Probability Density

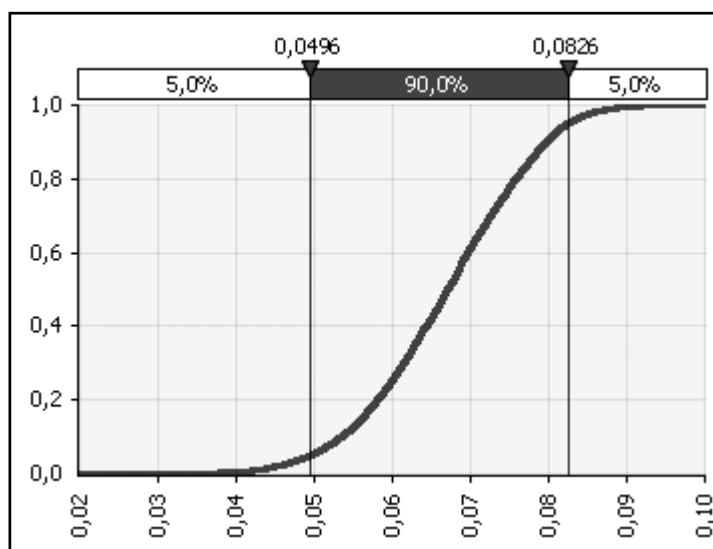


Fig. 3: Cumulative Ascending

Tab. 4: Summary statistics and results

Summary Statistics for Impact CO + Risk & Profit: / Risk Evaluation of Subcontractor Cost	
Minimum	2,63 %
Maximum	9,84 %
Mean	6,68 %
Median	6,71 %
Mode	6,88 %
Left X = VaR 5 %	4,96 %
Right X = VaR 95 %	8,26 %

The results according figure 2 + 3 and table 4 are interpretable as follows:

1. The mean figure for company overhead and risk + profit will be 6,68 %. That means, the simulated result will be 1,32 % lower as original estimated in the base estimate according Scenario 0.
2. The minimum figure for company overhead and risk + profit will be 2,63 %, but this figure is the bottom line and will only be achieved if all negative circumstances would occur. Therefore the implementation of Value at Risk (VaR) is necessary (cf. NEMUTH [3]). The result for VaR 5% is 4,96 %. That means with a probability of 5 %, the figure for company overhead and risk + profit will fall be-

low 4,96 %. Or in other words: with a probability of 95 % the figure for company overhead and risk + profit will not fall below 4,96 %.

3. The maximum figure for company overhead and risk + profit will be 9,84 %, but this figure is the upper limit and will only be achieved if all positive circumstances would occur. Therefore the implementation of Value at Risk (VaR) is also necessary under this point of view. The result for VaR 95% is 8,26 %. That means with a probability of 95 %, the figure for company overhead and risk + profit will not exceed 8,26 %. Or in other words: only with a probability of 5 % the figure for company overhead and risk + profit will exceed 8,26 %.

3.2.4 Additional Evaluations of the results of Monte Carlo Simulation

After the first simulation additional Monte Carlo Simulations are possible and the input values could be analysed via sensitivity analysis according stage 2 (cf. to chapter 2.2). That means, every input value has to be changed, for example in 10 % steps, and the Monte Carlo Simulation will be started successively with different input values. The results of the sensitivity analysis are interpretable and showing the influences of the alteration of every individual input value.

Another evaluation is possible to show which individual risk has a main influence of the final result for company overhead and risk + profit. Figure 4 shows the result of these evaluation as regression coefficients. That means, that Subcontractor 3, 1 and 4 have a huge influence of the company overhead and risk + profit. Therefore these subcontractors have to be monitored very carefully within the succeeding construction phase after potential contract award.

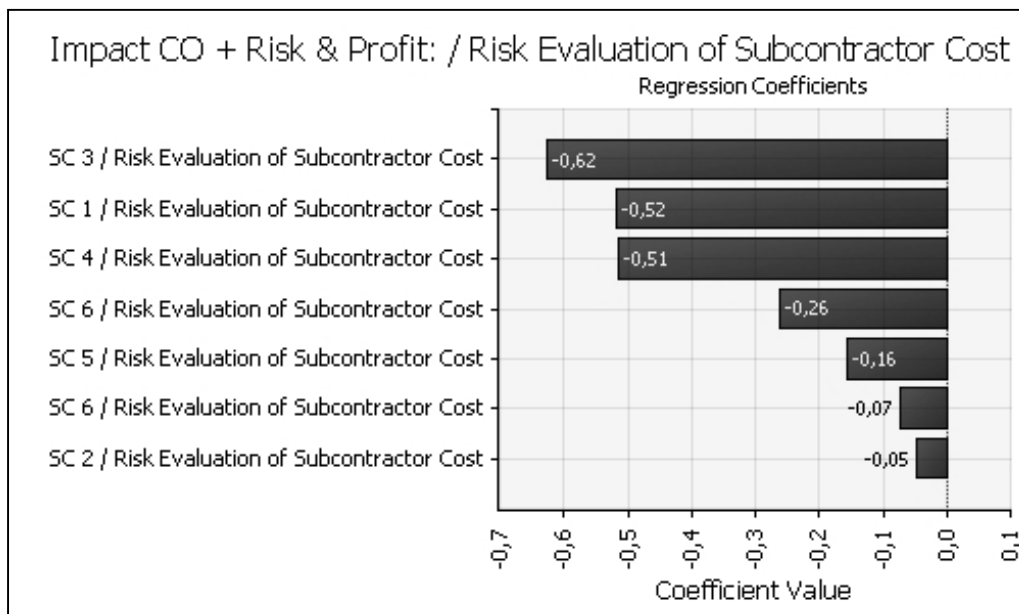


Fig. 4: Regression Coefficients

3.3 Conclusion

The introduced procedure shows that risks for construction projects are analysable and evaluatable. The procedure gives the management the possibility of a better overview of project risks and explains consequences of a too rash risk acceptance.

A construction project and its risks will be more transparent. After a contract award the identified and evaluated main risks are monitorable and controllable. Therefore a consequent concentration of the main risk items of a project is possible.

This procedure places the management in a better position for understanding and assessment of a project and its risks. Furthermore is it possible to filter high risk projects in a very early stage and monitor these projects separate.

3.4 Literature

- [1] Stempowski, R: *Risikomanagement – Entwicklung von Bauprojekten*. Graz: Nausner und Nausner Unternehmensberatung, 2002
- [2] Hölscher, R.: Von der Versicherung zur integrativen Risikobewältigung – Die Konzeption eines modernen Risikomanagements. In: Hölscher, R.; Elfen, R. (Hrsg.): *Herausforderung Risikomanagement – Identifikation, Bewertung und Steuerung industrieller Risiken*. Wiesbaden: Gabler-Verlag, 2002, S. 5–31
- [3] Nemuth, T.: *Risikomanagement bei internationalen Bauprojekten*. Renningen: Expert-Verlag, 2006