**Monte Carlo Simulations and Corporate Risk Management in Germany**

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*Managing risks must be done for the company as a whole. However, aggregating risks into a reliable company-wide risk measure is extremely difficult because it cannot be done without building a model that incorporates the main risk factors, their impact on corporate earnings and their interdependencies. In this paper, we will perform a step-by-step risk analysis, from the identification of risk exposures to an appraisal of different risk taking strategies. We will focus on two company-wide risk measures. The first one is the probability of negative net earnings. The second one is Earnings at Risk (EaR). We will explain the different steps in the risk management process and illustrate them by a very realistic case study that, though fictional, is based upon actual figures of companies in the German automotive supply sector. We will assess the effectiveness of using Monte Carlo simulations for risk management purposes by taking a critical look at our case study: What additional insights have we obtained? Where are the limits of our risk forecasts?*

*Berlin, 24 January 2006*

## Introduction

> *"Risk and uncertainty are key features of most business and government problems and need to be understood for rational decisions to be made."*
>
> Vose, D. (2000). Risk Analysis: A Quantitative Guide. Chichester: Wiley & Sons Ltd., p. 1.

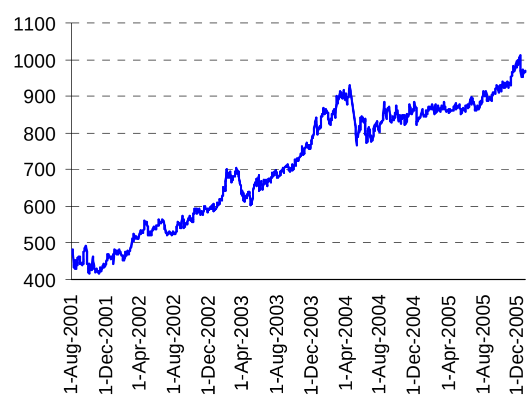
Against a background of dynamic markets and a changing business environment, companies everywhere face the challenge of taking strategic decisions on the basis of imperfect information. In the long run, no company can afford to bear more risk than its equity base can cushion. Therefore, market participants must plan strategically while keeping an eye on uncertain future developments that bring opportunities and risks for their companies. Risk management should thus be high on the corporate agenda.

German corporations in particular face important and urgent risk management issues. On the one hand, market price risks are a very important issue:

- Many market prices for those commodities widely needed by German corporations have become both higher and more volatile in the course of 2005. As an example, in the last few years the price of platinum has more than doubled. This is of serious concern to, among others, makers of auto catalysts.
- The dollar/euro exchange rate, the main foreign exchange rate for most German companies, has oscillated between 1.17 and 1.35 during the year - a range of more than 15%. Monthly moves of 2% or more were not exceptional (see graph on next page).
- In the energy sector, the business environment has become so much more dynamic that corporations in this sector nowadays have to manage complex portfolios of oil, gas, CO2 certificates and electricity.

**Expensive**

Platinum price in USD/oz from 1 August 2001 up to and until 29 December 2005

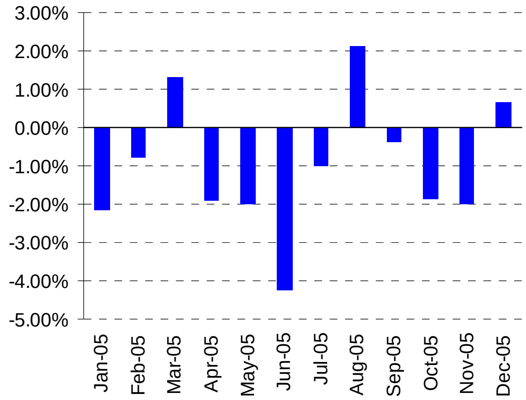


However, it were not just market price risks that kept German managers awake at night in 2005:

- An electricity shortage in December 2005 cut several companies off the power grid for a prolonged period.
- The German trade union IG Metall forced chip maker Infineon to accept an expensive redundancy package for its employees in a factory in Munich after a one-week strike.[1]
- German companies as a whole are faced with a "retreat" of so-called soft facts in the assessment of corporate credit risk by banks under the new Basel II regulations. More than ever before, "hard" financial figures and reliable cash flow and profit forecasts will be the prime determinants whether a company will get credit from German banks.

**Volatile**

Changes in the average monthly dollar/euro exchange rate in the course of 2005




The task of risk management is to identify, analyze and quantify risks as well as showing their impact on the cost of capital and thus the value of the company. However, while lots of impressively-titled books and glossy-covered presentations describe the concepts of risk management, corporations (especially midcaps) have few "how to's" to resort to when it comes to aggregating and simulating risks in such a concrete and reliable way that strategic decisions can be based on the results of the analysis.

A sound risk management process must include quantitative methods to aggregate interdependent risk factors. As a result of this aggregation, risk factors can be objectively measured and compared. As we will show, statistics play a vital role in this process. From a risk management perspective, such company figures as turnover and earnings are parameters underlying stochastic processes rather than best guesses.

The Monte Carlo simulation for our case study was performed using Crystal Ball. We chose Crystal Ball because it is an intuitive software tool incorporating analysis methods needed for our purposes. Particularly helpful are, to name a few, sensitivity analyses, overlay charts for net earnings in different hedging strategies and goodness-of-fit testing for market prices. Moreover, Crystal Ball's algorithms produce reliable random numbers. This means, among other things, that when a simulation is run several times, the results differ only marginally.

[1] Ehrensberger, W. (2005, December 14). AEG-Beschäftigte bereiten sich auf Arbeitskampf vor. *Die Welt.* Retrieved December 21, 2005, from http://www.welt.de/data/2005/12/14/817382.html

**Risk Management: A Case study**

> *"I believe we are all in a movie theatre. (…) Shortly before the sequence of events, the plot is rehearsed for us to see."*
>
> *Morshäuser, B. (1986). Die Berliner Simulation. Suhrkamp: Frankfurt am Main. p. 105. Free translation by the authors.*

Our fictional corporation is the *"Berliner Maschinen AG"*, a German supplier of components for car manufacturers. Though fictional, the relations in balance sheet and P&L of the Berliner Maschinen AG are similar to those of actual German companies that supply complex components to car manufacturers. The next few paragraphs are meant to give an overview of the company as well as to introduce some key factors in its risk landscape.

The company's risk management deliberations, which we will support with our simulation, take place in the last days of 2005. Projected annual sales for 2006 are 1.000 million euros. Supply contracts are long-term (generally, as long as the lifecycle of specific automotive models), so that fluctuations in actual demand are not a big issue, at least not for the next twelve months. Customers of the Berliner Maschinen AG are national as well as international. Asian and Latin American markets, where customers are billed in euros, absorb about 10% each of the company's sales. The US market, where customers are billed in US dollars, accounts for circa 20% of annual turnover. The single biggest customer is in Germany and accounts for approximately 15% of annual turnover. Berliner Maschinen AG's gross profits are subject to a corporate tax of 35%.

The company spends roughly 500 million euros yearly on raw materials and components. The main raw materials input is aluminium, 175 thousand tonnes of which are needed evenly during the year. At today's prices, the annual cost of aluminium is somewhat above 300 million euros. The actual price is determined by the notation of the 3-month aluminium forward contract on the London Metal Exchange (LME). The Berliner Maschinen AG's purchase price for aluminium in any given quarter follows from the LME average of the previous quarter. As LME notations are in US dollars per tonne, the Berliner Maschinen AG's suppliers charge an amount in euros that is calculated by multiplying the LME price by the average dollar-euro exchange rate for the same quarter.

Other costs include personnel costs of 200 million euros, miscellaneous costs of 175 million euros and depreciation of 70 million euros. The Berliner Maschinen AG has 300 million euros in equity, and another 300 million euros in interest-bearing debt. Total assets on the balance sheet are 1.000 million euros. The 300 million euros bond expires in April 2006 and will then be extended for another 10 years. The company pays an interest rate of 2% in excess of the Bund rate (German Treasuries).

We will go through the risk management process by combining theory and practice for each of the following steps:

1. Fundamental risk strategy
2. Identification of risk exposures
3. Measuring risk exposures & building a risk model
4. Aggregation
5. Definition of risk taking/retention strategies
6. Effectiveness testing
7. Risk monitoring.

***1. Fundamental risk strategy***

The fundamental risk strategy encompasses the choice of risk management objectives and methodologies.

Objectives

Risk management objectives should “fit” into an overall strategy aimed at maximizing the value of the company. The value created by risk management will generally include preventing bankruptcy, preserving elements necessary for future value creation by the company and minimizing costs associated with risks.[2] Defined in terms of a distribution of possible outcomes (earnings), risk management should eliminate costly “lower-tail outcomes” while preserving as much of the upside as possible.[3]

In Germany and elsewhere, social components (such as preserving jobs and protecting the environment) can play an important part in the public perception of the company and thus in its ability to portray a positive image. The risk management process should be able to anticipate important developments that might arise in the future and define an adequate response proactively.

> *„… although VaR could be quite useful in helping dealers price exotic options and measure daily trading risk, it was of limited use (and in some cases positively misleading) for non-financial corporates attempting to manage exposures in less liquid markets over longer time horizons.”*
>
> Culp, C. “The Revolution in Corporate Risk Management: A Decade of Innovations in Process and Products”. Journal of Applied Corporate Finance Vol. 14, No. 4 (Winter 2002), p. 15.

Methodology

The method of Monte Carlo simulations is one of several ways to calculate such risk measures as Value at Risk (VaR), Cash Flow at Risk (CFaR) or Earnings at Risk (EaR). Although a detailed comparison of risk quantification methods would go beyond the scope of this paper[4], we would like to point out that among quantification methods, Monte Carlo simulations are at their best when it comes to aggregating risks of different kinds (for instance, market price risks and business or operational risks). Among simulation methods, the particular appeal of the Monte Carlo method, as compared to a historical simulation, is that the possible range of “paths” for future developments of risk factors is not restricted to the historical data at hand.

In our model, we study how different risks influence the net earnings of the company. The management of the Berliner Maschinen AG wishes to preserve its equity base and set concrete risk limits. In particular, negative net earnings are to be avoided. It has chosen the Monte Carlo method for two reasons. First, management wants to aggregate different kinds of risks into a single risk figure (net earnings). Second, they want to know which risk factors net earnings are most sensitive to.

[2] Comp. Wolf, K. & Runzheimer, B. (2003). *Risikomanagement und KonTraG: Konzeption und Implementierung.* Gabler Verlag:Wiesbaden.

[3] For more details on what risk management can and cannot do for the value of the firm, we recommend Stulz, R. (1996). Rethinking Risk Management. *Journal of Applied Corporate Finance, 9 (Fall 1996)*,.p. 8-24.

[4] For a detailed comparison of different methods and their respective pros and cons, we recommend Jorion, P. (2001). *Value at Risk – The New Benchmark for Managing Financial Risk.* : New York**:** McGraw Hill.

***2. Identification of risk exposures***

This phase consists of a comprehensive collection of risks on a company-wide level. For the identification to be effective, the risks should be collected in a structured and systematic manner so that the resulting risk landscape is complete. While recording the risk factors, their impact on the company as a whole should be identified and roughly estimated. Risks can be classified in several ways, one of which is the distinction in

- market risk,
- credit risk,
- operational risk and
- business-volume risk[5]

As the information obtained in the identification phase will be used throughout the risk management process, gathering high-quality information on the risk landscape is a key prerequisite to successful risk management.

Some of the main ways of identifying the main risks facing a corporation are a risk assessment workshop, the classification of risks in a probability/impact graph, brainstorming sessions, etc. As an inspiration, such concepts as SWOT or Porter's Five Forces can be used, as well as checklists containing typical risks in the relevant business sector.

Through their individual knowledge and experience, a company's employees can make an important contribution to a comprehensive risk assessment. For this reason and because risk management is an ongoing process which requires regular reminding and motivation, it is very important to let the employees play a part in the identification phase.

Following thorough risk identification, the Berliner Maschinen AG has identified its main risks as follows:

| **Category** | **Risk factors in our case study** | **Description** |
|---|---|---|
| **Market risk** | Aluminium price | The aluminium notations on the LME can rise, leading to higher raw materials costs. |
| **Market risk** | Dollar/euro exchange rate | Some of the company's exports are in dollars, so the value of these exports (expressed in euro) depends on the dollar-euro exchange rate.<br>In addition, the aluminium notation on the LME is transferred into a euro amount via the dollar/euro exchange rate. |
| **Market risk** | Interest rate | The development of interest rates until April 2006 decides on the cost of interest-bearing debt after that date. |
| **Credit risk** | Bad debts | Because customers are large corporations that have a long business relationship with the Berliner Maschinen AG, management has decided not to focus on credit risk. |
| **Operational risk** | Machine breakdown | If an important machine breaks down, the company incurs costs for repairs and production delays. |

[5] This classification is derived from Buehler, K., & Pritsch, G. (2004). *Running with risk. McKinsey on Finance, 10 (Winter 2004)*, 7-11.

| | | |
|---|---|---|
| **Operational risk** | Reputation damage | Although a profound quality management system is in place, there is a risk that deliveries are held up by a wastewater pipeline issue that management has neglected over the last few years. If customers receive their components too late, the reputation of the Berliner Maschinen AG as a reliable supplier suffers. |
| **Operational risk** | Personnel cost | Company experts estimate that personnel costs can fluctuate by about 2% due to uncertainties regarding remuneration and working times. |
| **Business-volume risk** | Loss of an important customer | Although the company's sales contracts with its customers are long-term, it is not impossible that a customer stops producing a car model for which the Berliner Maschinen AG supplies components. In such an event, the customer is entitled to withdraw from the contract. Because the Berliner Maschinen AG cannot switch production so quickly, it is forced to sell the remainder to other car suppliers or trading companies, at an uncertain discount. |

### *3. Measuring Risk Exposures & Building a Risk Model*

In order for a risk model to be reliable and robust, special attention should be devoted to the assumptions underlying each modeled risk factor. For those risk factors for which historical data are available (in this case, market prices for aluminium, euro interest rate and dollar/euro exchange rate), these data can be used for distribution assumptions. We show this in detail for the market prices relevant to our case study (see appendix).

Monte Carlo simulations generally assume that the uncertainty of market price developments can be captured in a random walk. Behind this assumption lies the notion of a stochastic process in which the value of an item tomorrow is influenced by the value today, but not by earlier values (Markov process). For market prices, this is consistent with efficient markets: the current price includes all relevant information about a particular asset. If this holds, then all future price developments must be caused by new information that cannot be anticipated and must thus be uncorrelated over time (covariance of zero). Such a Markov process is modeled by the combination of a deterministic component (drift) and an uncertain component. If market prices behave according to a random walk, than the uncertain component of market price changes is automatically normally distributed[6]. It can also be shown that when positions are constant and returns are identically and independently distributed, then adjustments of volatility to different horizons can be based on a square root of time factor.[7]

Still, several things need to be considered. One issue is whether a theoretical distribution fits empirically observed market data. How reliable is the assumption of a normal distribution for changes in market prices? Statistical tests offer an answer to this important question. What

[6] See Deutsch, H-P. (2001). *Derivate und Interne Modelle – Modernes Risikomanagement.* Stuttgart: Schäffer-Poeschel Verlag, pp. 26-29.

[7] Jorion, P. (2001). *Value at Risk – The New Benchmark for Managing Financial Risk.* : New York**:** McGraw Hill, p. 103.

these tests do is examining whether observed data differ from an assumed hypothesized distribution and/or parameters of this distribution. Relevant tests that verify whether distributions from empirical data fit assumed distributions include Chi-square, Kolmogorov-Smirnov and Anderson-Darling tests.

A particular risk inherent in assuming a normal distribution is that of underestimating the frequency of extreme amplitudes. These so-called fat tails are particularly worrying for estimating the risk of market price movements because the actual probability of risky market situations is systematically underestimated. As an example, under the normal distribution assumption, events as the stock market crash of 1987, the collapse of the European Monetary System in 1992 or the bond market crisis in the spring of 1994 could only occur once every 100 years.[8] This underlines the need for stress testing and additional scenario analyses for financial portfolios such as those managed by banks and insurance companies.

Another issue is the definition of the relevant time horizon. Market developments from a distant past might be less relevant for the near future as recent market developments. This disadvantage can be partially offset by a decay factor that increases the statistical weight of recent data.[9]

It is important to bear in mind that even with the best historical data, the future can still not be foretold. It can never be guaranteed that historical data are representative for the future. For many risk factors, no historical data are available anyway (or past data are no longer relevant). This is true for most business and operational risks and even market risks that are new (such as CO2 emission trading). Subjective estimation by experts will then have to be relied upon. These subjective estimates have an inherent uncertainty that arises both from the incertitude of the risk itself and from experts' errors and/or heuristic biases. The resulting variability should be accounted for in the risk model, particularly in the assumption parameters of the (mostly operational) risk factors.[10] One approach (and the one used in our case study) is to distinguish between the probability of an event occurring and the impact of the event. The latter can be assumed to be either in a range of equally likely values (uniform distribution). An alternative is the definition of a most likely value and a minimum/maximum bandwidth (triangular distribution).

It is of paramount importance that interdependencies in the business model (functions) and in the assumptions (correlations) are correctly modeled.

The planned P&L for the Berliner Maschinen AG in 2006, subject to the risks and opportunities outlined above, is shown on the next page. In the appendix "Assumptions" we show how we have incorporated the uncertainties facing the Berliner Maschinen AG in the model.

[8] Merbecks, A., Stegemann, U. & Frommeyer, J. (2004). *Intelligentes Risikomanagement – Das Unvorhergesehene Meistern.* Frankfurt/Wien: Redine Wirtschaft/ueberreuter, p. 128.

[9] Comp. Merbecks, A., Stegemann, U. & Frommeyer, J. (2004). *Intelligentes Risikomanagement – Das Unvorhergesehene Meistern.* Frankfurt/Wien: Redine Wirtschaft/ueberreuter, p. 120.

[10] For more details on this issue, we recommend Chapter 10 of Vose, D. (2000). Risk Analysis: A Quantitative Guide. Chichester: Wiley & Sons Ltd., pp. 263-290.

| P&L of Berliner Maschinen AG over 2006 (numbers in Mio €) | |
|---|---|
| Turnover | 1,002.30 |
| Aluminium cost | 304.59 |
| Other raw materials | 175.00 |
| Gross margin | 522.71 |
| Personnel cost | 200.00 |
| Other costs | 175.00 |
| Depreciation and amortization | 70.00 |
| Interest | 17.64 |
| Target profit before taxes | 60.07 |
| *Market price risks:* | |
| Charge to P&L to reflect aluminium forward curve | -20.41 |
| Hedging | 0.00 |
| *Operational risks:* | |
| Loss of an important customer | 0.00 |
| Compensation for loss of an important customer | 0.00 |
| Damage to reputation | 0.00 |
| Machine breakdown | 0.00 |
| Earnings (before taxes) | 39.66 |
| Taxes | 13.88 |
| **Net earnings** | **25.78** |
| **Return on equity** | **13.2%** |

In a Monte Carlo simulation, random numbers are generated from “known” (assumed) distributions of system elements. These random numbers create a large number (typically 10,000-100,000 simulation runs) of artificial samples. These samples are then used to draw conclusions about the “population” of possible outcomes.

In this context, the distinction between real and pseudo random numbers plays a role. Real random numbers can only be created by rolling dices, playing roulette or playing lotto, so for risk management purposes we have to rely on pseudo random numbers that can be generated by a computer. Pseudo random numbers are generated in a uniform distribution in an interval between 0 and 1, in which each individual value has the same probability. Starting from this uniform distribution, any distribution can be mathematically created.

For a simulation to be reliable, it is paramount that generated random numbers comply with certain requirements as regards to computer speed, statistical properties and reproducibility of random number series (in order to prove the hypothesis of uniformly distributed and stochastic independent numbers)[11]. In Crystal Ball, these conditions are met: simulations are fast and the data of every single run can be reproduced.[12]

### *4. Risk Aggregation*

The purpose of risk aggregation is to define the overall risk exposure of the company as well as the relative importance of each individual risk factor. Risk aggregation results show whether some risks can put the existence of the company in peril. Risk management regulations in Germany (KonTraG)[13] require an early warning system for these risks.

However, it is not only existence threatening developments that are cause for concern. The accumulation of individual risks might have a similar impact on the overall risk exposure. Knowing and correctly modeling the interdependencies of the individual risks is therefore a vital prerequisite for risk aggregation. The impact of the different risk factors comes to the surface in a sensitivity analysis.

In the next few paragraphs, we will apply the concept of risk aggregation to our case study. Our major forecast is net earnings, thus one of the most important outputs of the simulation is the distribution of this forecast. This is the distribution of net earnings in thousands of independent simulation runs. In our case study, the mean is 17.4 Mio €, significantly below the expected net profit of 25.8 Mio €. The entire range is between a loss of 227 Mio € and a profit of 84 Mio €. With 90% certainty (cutting the left-hand and the right-hand 5% off the distribution), the range is between a loss of 43.9 Mio € and a profit of 51.6 Mio €.

As preserving the equity base is the prime risk management objective of the firm, Berliner Maschinen AG's managers will be particularly interested in the likelihood of positive net earnings. This turns out to be 85% (blue columns in chart on next page).

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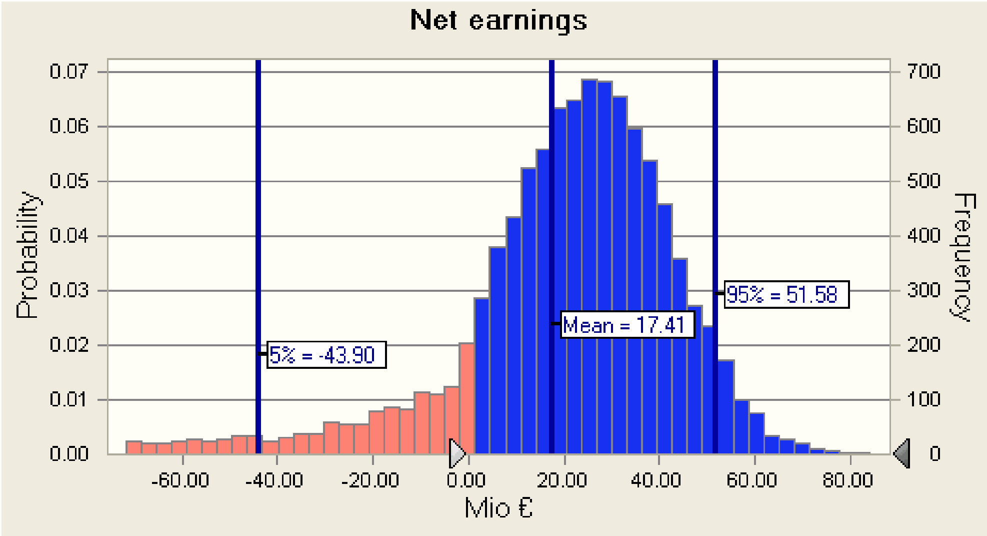
[11] Runzheimer, B. (1999). *Operations Research: Lineare Planungsrechnung, Netzplantechnik, Simulation und Warteschlangentheorie.* Wiesbaden: E.Mändle/Gabler Verlag, p. 263.

[12] For more details, see the Crystal Ball Reference Manual that comes with the software.

[13] In Germany, the "Gesetz zur Kontrolle und Transparenz im Unternehmensbereich" (Law for the Control and Transparency in the area of organizations), which applies to quoted stock corporations and companies of comparable complexity, requires that the Board of Directors take "appropriate measures" to detect "existence threatening developments" in time. In particular, the law requires implementation of an early warning system in order to detect such risks. Further implications of the law include the consideration of the risks of future developments in the annual report and the definition of a role of the auditors in examining implementation of risk management and disclosure of risks.




In other words, with a probability of 15%, the company will face a loss over 2006. Earnings at Risk, defined here as the difference between the mean and the left-hand 5% percentile for net earnings, is 61.3 Mio € (17.4 Mio € - (- 43.9 Mio €).

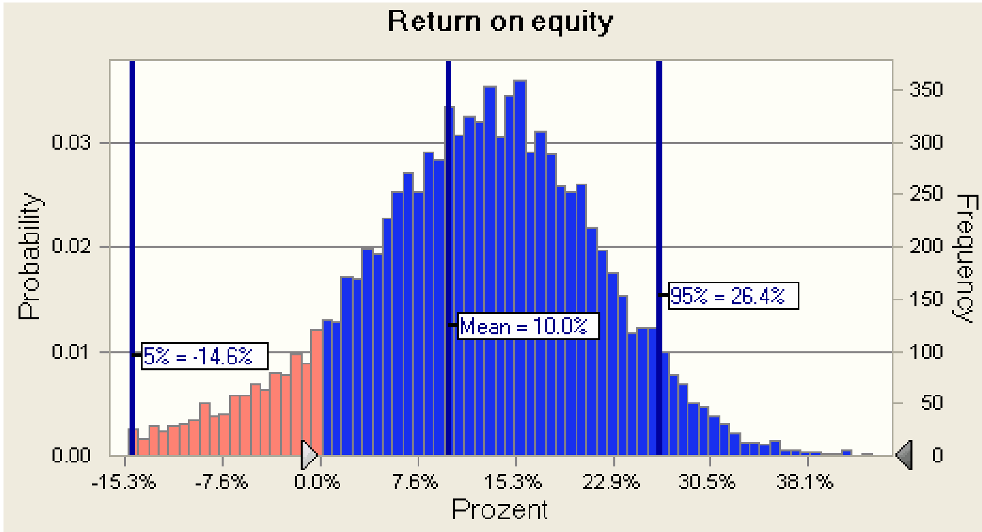
The statistical properties of the distribution show negative skewness (-2.54%[14]), which means that the distribution has a long left tail. The distribution also shows leptokurtosis (kurtosis of 12.96)[15], which means that the tails decay less quickly than for the normal distribution. Thus, unlikely losses can be large (compared to normally distributed net earnings).

| **Statistic** | **Forecast values** |
|---|---|
| Trials | 10,000 |
| Mean | 17.41 |
| Median | 23.22 |
| Mode | --- |
| Standard Deviation | 31.83 |
| Variance | 1,013.08 |
| Skewness | -2.54 |
| Kurtosis | 12.96 |
| Coeff. of Variability | 1.83 |
| Minimum | -227.34 |
| Maximum | 84.02 |
| Mean Std. Error | 0.32 |

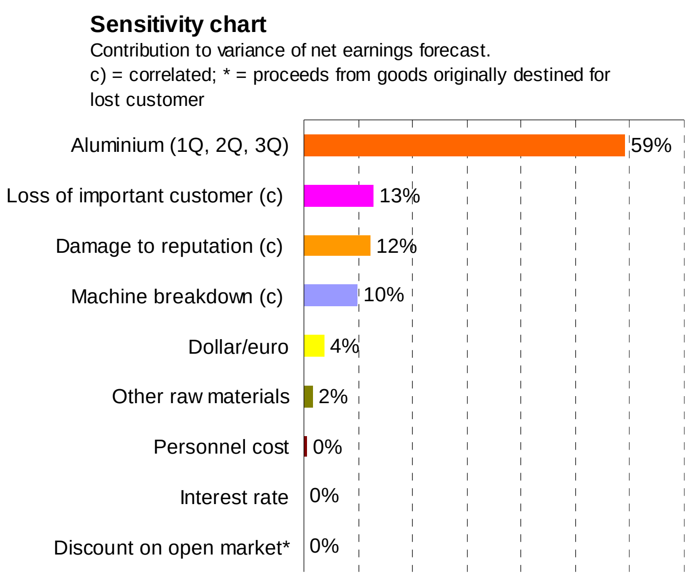
As to the return on equity, the distribution of the forecast is shown in the graph on the next page (although the information can also be derived from the distribution of net earnings). The expected return on equity (mean) is 10%. The 90% confidence interval is between -14.6% and 26.4%. As before, the blue columns show a positive return on equity and the red columns show a negative return on equity.

[14] Comp. a normal distribution has a skewness of zero.

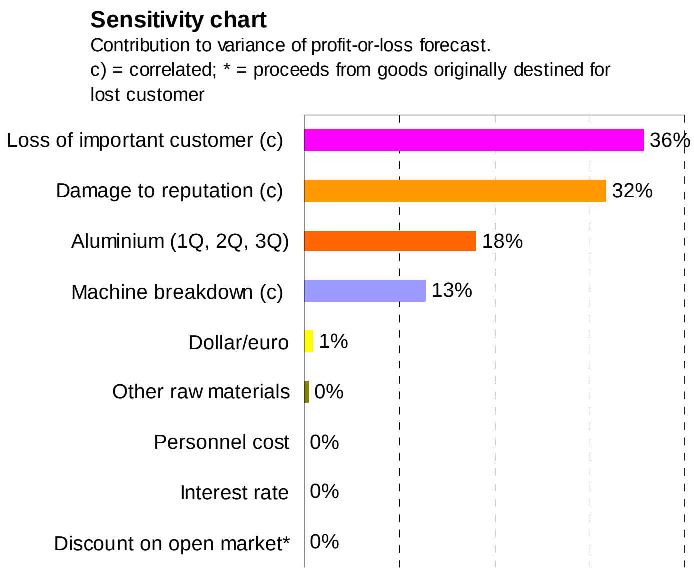
[15] Comp. a normal distribution has a kurtosis of 3.




Sensitivity analyses allow studying the contribution of individual risk factors to the variance of the target forecast. Thus, the question “What are the most important risk factors?” can be answered. Intriguingly, in our case study the answer depends decisively upon the risk measure employed. The variance of the net earnings distribution is mostly influenced by the aluminium price, as shown in the sensitivity chart on the next page. However, it is important to note that the operational risks are correlated.




However, when Berliner Maschinen AG’s management remains fateful to its goal of preserving equity, then the decisive risk measure would be whether net earnings are positive. For this risk measure, market prices play a surprisingly small role compared to the operational risk. The biggest risk factor is the loss of an important customer, followed by damage to the company’s reputation.




It thus appears that although market prices (in particular, aluminium) are the main contributors to overall variance, it is the operational risks that can really put the company into red figures.

### *5. Risk Retention Decision & Risk Taking Strategies*

The result of the risk aggregation phase allows a comparison of the actual risk exposure with the desired risk profile of the corporation. In this phase, the risk factors are actively influenced in order to bring the aggregated risk exposure more in line with the defined risk objectives. Management has to decide which risks to transfer or otherwise reduce (or avoid altogether) and which ones to retain. There are several ways to classify risks taking strategies, one of which is the distinction shown on the next page.

| Risk-taking strategy | Explanation | Example for Berliner Maschinen AG |
|---|---|---|
| **Risk avoidance** | renounce from risky operations | Sell in Latin America, but bill only in US dollars and euros (and not in Latin American currencies) |
| **Deliberate risk taking** | Accept risks (possibly in combination with pricing or diversification strategy) | Let US customers pay in US dollars (and use the resulting "net hedge" from long and short dollar position – see "Hedging" below) |
| **Risk minimization** | Minimize the likelihood or impact of a risk factor (e.g. quality management) | Repair wastewater system |
| **Risk transfer** | Transfer risks to third parties (insurers, banks, suppliers, customers, etc.) | Insure against machine breakdown; hedge aluminium price risk |

Most of the risks that are transferred to banks or insurers are likely to be so-called non-core risks, especially when such risks expose the firm to the possibility of financial distress[16]. In the case of Berliner Maschinen AG, this would mean hedging the market price risks. We will look into this risk reduction strategy and into a risk minimization strategy for an operational risk more in detail.

> *„**Why** a Firm Manages Risk Should Affect **How**."*
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> Culp, C. "The Revolution in Corporate Risk Management: A Decade of Innovations in Process and Products". Journal of Applied Corporate Finance Vol. 14, No. 4 (Winter 2002), p. 26.

Hedging

Berlin Maschinen AG's management has invited one of its banks to submit a hedge proposal for its market price risk. The bank's capital markets team has identified the "natural hedge" inherent in the company's business model. Since the company buys aluminium that is quoted in dollars on world markets but converted into euros for Berliner Maschinen AG's raw materials payments, the company has in fact a short position in dollars. On the other hand, the company converts its US export proceeds to euros. As the company is simultaneously long and short in US dollars, it has a natural hedge against foreign exchange risk. An optimal hedging strategy should therefore comprise aluminium (dollar prices) and the dollar/euro exchange rate, but the latter only to the degree of net cash flow in US dollars.

Berliner Maschinen AG can transfer these market price risks to the bank by accepting a hedging proposal that consists of fixing the aluminium prices and dollar/euro exchange rates that are relevant for the year 2006.

Repair Wastewater System

On the basis of the profit-or-loss sensitivity chart, the management of Berliner Maschinen AG looks into the possibility of reducing the likelihood and impact of a damage to the company's reputation. The company could invest in the wastewater system in such a way that the

[16] Culp, C. "TheRevolution in Corporate Risk Management: A Decade of Innovations in Process and Products". *Journal of Applied Corporate Finance Vol. 14, No. 4 (Winter 2002)*, p. 13.

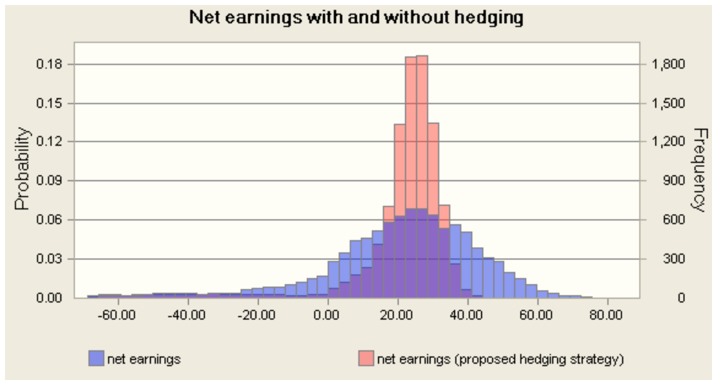
probability of reputation damage falls to 2.5% (from 5%) and the potential impact to a range of 25-75 Mio € (from 25-125 Mio €).

### *6. Effectiveness Testing*

The effectiveness of risk taking strategies can be assessed by incorporating the proposal into the model and re-running the simulation. In this way, the effect of the risk management measures becomes visible (ex ante). For the two strategies outlined above, the effectiveness testing results follow.

Hedging

The effect of hedging is shown on the graph to the right. As can be seen, the left tail of the distribution is relatively unchanged, so even though overall variance is less than half (46%) than without hedging, the risk of losing money is not very much reduced. The surprising insight is that hedging does not contribute to meeting the risk objective of preventing lower-tail outcomes.




Invest in Wastewater System

The expected value of net earnings would then be 2.6 Mio € higher than before, so this would be the amount that can be invested without the company actually losing value. The risk of losing money would drop by 2%, and other risk figures would improve even more – for instance, Earnings-at-Risk (at the 5% left quantile) would be 48.6 Mio € instead of 61.3 Mio €[17].

| | **Without investing in reputation** | **With investing in reputation** |
|---|---|---|
| Expected value (mean) | 17.4 Mio € | 20.0 Mio € |
| Probability of loss | 15% | 13% |
| Earnings at Risk | 61.3 Mio € | 48.6 Mio € |

[17] The new Earnings-at-Risk figure would be the difference between +20.0 Mio € (new mean) and -28.6 Mio € (new 5% quantile) = 48.6 Mio €

## *7. Risk Monitoring*

Risk Monitoring consists of ongoing risk reporting and ex post risk controlling.

Risk Reporting

Risk reports give a precise view of the risk structure of the company, and thus play an indispensable role within the risk management process. Deviations between the firm's actual risk exposures and risk tolerances should be detected and reported as timely as possible. Risk reports should be targeted to the user. While *senior management* should get a view of company-wide earnings and risk (with details on the major risk factors only), the people working in the *risk management division* need more detailed information. In particular, they need to be able to see impacts and interdependencies of individual risk factors behind the overall risk exposure. *Traders* require real-time information and a real-time signal when warning levels are reached.[18]

Risk Controlling

Risk Controlling means a critical ongoing appraisal of every phase of the risk management process. Had all risks that have occurred been identified in the initial risk map? Has the impact of the risks been inside the defined range? Did the adopted risk management measures have the desired effect (ex post)?

A prerequisite to effective risk monitoring is the integration of the risk management function in the overall organization of the company. Process control, collecting and distributing information about risks and ensuring a lively communication about risks and opportunities are vital tasks for an effective risk monitoring. If this is done well, risk management "lives" in the organization, that is to say,

- every step in the risk management process is based on the previous steps and the available data
- adequate measures are taken shortly after a warning level has been reached
- oversight, audit and realignment of risk management is a continuous process, a "closed loop"

**Conclusion**

In this conclusion, we fill first discuss the main pros and cons of Monte Carlo Simulations. We will then review the results from our case study.

> *"Those who live by the numbers may find that the mathematically inspired techniques of modernism have sown the seeds of a destructive technology in which computers have become more replacements for the snake dancers, the bloodlettings, the genuflections, and the visits to the oracles and witches that characterized risk management and decision making in days of yore."*
>
> Bernstein, P. (1996). The new religion of risk management. Harvard Business Review, March-April 1996, p. 51.

Pros and Cons

Monte Carlo simulations can form an integral part of managing the value of a company:

1. The adequate use of Monte Carlo simulations improves the forecasting quality of a company's development. Simulation results can improve the information base upon which management decisions are made.
2. Simulations offer a high degree of precision, especially when market and credit risks are concerned. However, the particular appeal of a Monte Carlo simulation is the inclusion of all risks, even such hard-to-define ones as event risks and operational risks that can only be modeled via expert opinions.

[18] Jorion, P. (2001). *Value at Risk – The New Benchmark for Managing Financial Risk.* : New York**:** McGraw Hill, p. 442.

3. Results from a Monte Carlo simulation, in particular the sensitivity analysis, offer a systematic approach to value-oriented corporate planning and controlling.
4. Thinking about risks and opportunities as ranges and probability distributions can enhance the acceptance of risk management concepts within the organization.
5. Risk models that are built on this basis can pragmatically and effectively be simulated in such software tools as Crystal Ball. Existing spreadsheets can be "upgraded" to a risk model by defining assumptions and forecasts. Monte Carlo simulations are immensely flexible: models can be constructed and assumptions defined as seen appropriate. For this reason, Monte Carlo simulations can be used in a wide range of applications and industries.

Still, some caveats and "side effects" should be taken into consideration:

1. One of the major caveats of Monte Carlo simulations is the creation of a false impression of accuracy[19]. The truth is that there is indeed no way to provide an estimate of the absolute worst outcome. What's more, the accuracy of any forecast is critically dependent on the model used.
2. This leads to the second (and related) inconvenience of model risk. Mathematical and optimization models have the inconvenience of not being able to reflect the high level of complexity inherent in economic reality. They are also prone to errors (e.g. in Excel formulas).
   It is important to be aware that the success of a risk management process depends on the resulting transparency about risk factors and risk exposure rather than on calculating every possible risk figure to the last digit. A model can only be interpreted as an attempt to mirror economic reality as authentically as possible. The output of a simulation enables a company to quantify the impact of different developments under predefined assumptions rather than being an image of the future.
3. Errors are easy to make. Expert opinions in particular are prone to errors, and may also be influenced by such psychological factors as biases and company culture[20]. Some parameters such as correlations and conditional probabilities are almost impossible to estimate.
   That said, subjectivity as such is not a method-specific problem: subjective estimates are needed in any model that captures uncertainty. The results of a simulation can only be as good as the quality of the assumptions behind each risk factor. We recommend that senior management explicitly rubber-stamp the assumptions behind the major risks.
4. Where historical data are used to model uncertainties in the future, the reliance on these historical data severely limits the legitimacy of the use of simulations. The behavior of developments in the past cannot be assumed to hold in the future. As we have seen before, the normal distribution assumption for market prices seriously underestimates the actual risk. For most operational and business-volume risks, relevant historical data are not available or not representative.

<u>Case study review</u>

For the Berliner Maschinen AG, the future remains uncertain, but this uncertainty can be better measured than before thanks to the output of the simulation. The company has a transparent view of the uncertainty surrounding its net earnings in 2006 and of the individual and combined impact of the major risk factors. One of the surprising insights from our case study is the counterintuitive (and thus all the more revealing) effect of a hedging strategy that

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[19] Jorion calls this the "man in the white coat" syndrome. See Jorion, P. (2001). *Value at Risk – The New Benchmark for Managing Financial Risk.* New York**:** McGraw Hill, p. 498.

[20] For an elaborate discussion of the role of psychology and fears in risk management (advisory) processes, we recommend Müller, M. (2005). *Ängste als kritische Erfolgsfaktoren in Beratungsprojekten: Ursachen- und Wirkungsanalyse, Implikationen für die praktische Arbeit als Berater.* FernUniversität Hagen (master studies thesis).

at first seemed to make perfect sense. Indeed, a major advantage of Monte Carlo simulations is the ability to perform what-if-analyses and thus greatly improve the informational basis upon which to base risk management decisions.

As we have shown, a Monte Carlo simulation can greatly help a company to cope with uncertainty by enabling the corporation to consciously deal with risk in a structured way. Quantitative methods do not make the future any more certain, but they enable managers to make well-informed decisions in their aim to maximize the value of the company.

Some critical notes must, however, be taken into account. In particular, the possibility of an unjustified sense of control over uncertainty associated with models describing a (more complex) reality is a very serious issue. By embedding the model in a comprehensive risk management process and by letting senior management explicitly rubber stamp the assumptions, this problem can be mitigated.

Therefore, our overall impression is optimistic and deeply in favor of midcap corporations using Monte Carlo simulations. We can also personally recommend Crystal Ball as a software tool for Monte Carlo simulations.

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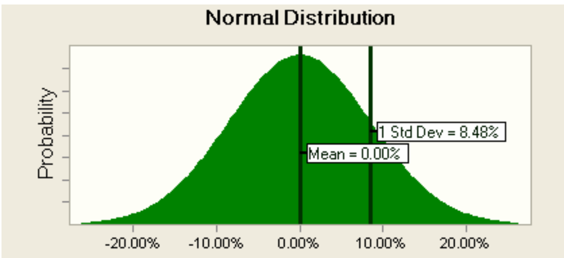
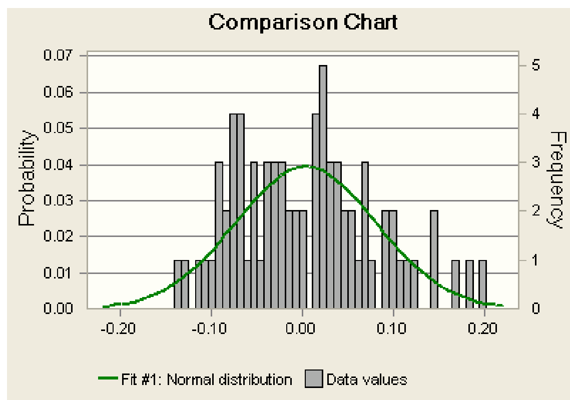
In this appendix, we will go through the assumptions of our model in more detail. The main focus will be on how we modeled uncertain variables and interdependencies, why we chose specific distributions and which aspects of the definition of assumption are especially relevant for the interpretation of the simulation results.

**Aluminium prices**




Changes in market prices are often assumed to be normally distributed with a standard deviation calculated from the market changes of the last 100 days. This lets the market price follow a random walk. For aluminium this would mean a standard deviation of 8.48% for quarterly price changes[21]. In our simulation, aluminium prices follow a random walk starting at 2,069$ (level that was fixed on the LME in the last quarter of 2005 so that the company will pay this price in the first quarter of 2006) and changing after every quarter by an uncertain price move that is normally distributed with a mean of 0% and a standard deviation of 8.48% (the graph shows the assumption for the second quarter).

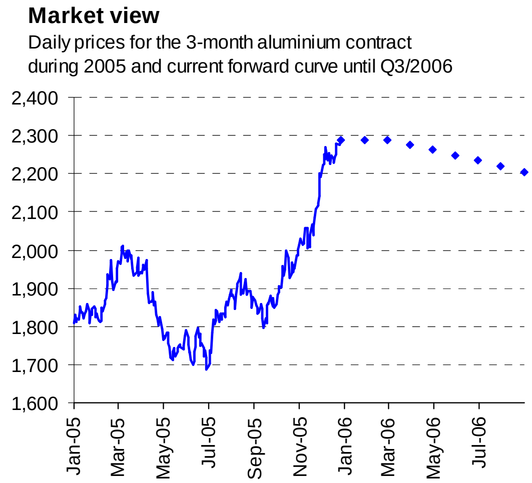



When comparing actual quarterly price changes with the assumption of a normal distribution, it becomes apparent that the normal distribution can only be an approximation. The graph (actual quarterly changes since September 1987 versus normal distribution) shows some "outliers" on the right-hand side. This means that a big change in market prices is somewhat more likely than the normal distribution suggests (so-called "fat tails"). The actual data values have a mean of 0% (no upward or downward trend over the whole period) and a skewness of 0.39. The positive skew is clearly visible in the graph (the higher tail is longer; for a normal distribution, skewness is zero). Still, as an approximation the normal distribution will do, as the statistical test results are satisfying. Most importantly, the Anderson-Darling statistic is 0.44.[22]

[21] The standard deviation of daily aluminium price changes over the last 100 days of 2005 was 1.09%. This was converted to a standard deviation for quarterly price changes of 8.48%. The long-term standard deviation for quarterly price changes since September 1987 was 7.74%.

[22] The Crystal Ball software package offers several goodness-of-fit statistics. Over other tests (e.g. Kolmogorov-Smirnov), the Anderson-Darling test has the advantage of giving more weight to the tails than does the Kolmogorov-Smirnov test. The Anderson-Darling test is considered a more powerful alternative to Kolmogorov-Smirnov for testing normality. For details on the Anderson-Darling test we can recommend the online Engineering Statics Handbook: NIST/SEMATECH e-Handbook of Statistical Methods (n.d.). *Anderson-Darling Test.* Retrieved January 5, 2006, from http:/www.itl.nist.gov/div898/handbook/eda/section3/eda35e.htm.

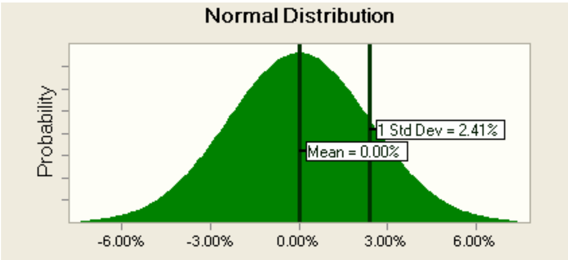
An important issue for this market risk is to distinguish uncertainty regarding the future development of aluminium prices from the absolute price level that can be fixed for 2006. Following an aluminium price rally in December 2005, the current forward curve for aluminium is far above the average of the last quarter of 2005 (2,069$). If it would hedge its aluminium purchases in 2006, the Berliner Maschinen AG would pay an average price of 2,209$. The company is aware that forward prices are, in practice, not very good predictors of actual prices in the future, but it does wish to plan its P&L for 2006 in accordance with current market prices. For this reason, the random walk for aluminium starts at 2,069$, but the company charges 20.4 Mio € to its P&L[23] in a separate entry.




### Other raw materials

The cost of other raw materials is considerably less uncertain than that of aluminium. They are considered to behave according to a triangular distribution with 175 Mio € as most likely value, 165 Mio € as minimum value and 185 Mio € as maximum value.

### Dollar/euro exchange rate




As with aluminium, we let the dollar/euro exchange rate follow a random walk starting at the current price level (the average rate in December 2005, which was 1.186 $/€), with uncertain monthly changes that are normally distributed with a mean of 0% and a standard deviation of 2.41%[24]. The graph shows the assumption for the second month. Contrary to aluminium, the Berliner Maschinen AG has decided not to adjust its planned P&L for the current level of dollar/euro forward rates as these differ only marginally from the current level.

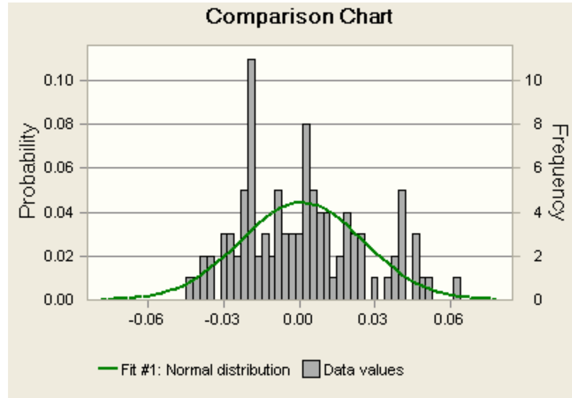
[23] For the period comprising the second up to fourth quarter of 2006, the aluminium price per ton and the $/€ exchange rate can be fixed via a forward hedge at 2,256 $/ton and 1.20 $/€ respectively. The charge to the P&L is thus calculated in two steps:

1) 9/12 year * 175.000 tons/year * (2,069$ – 2,256$) = -24.53 Mio $

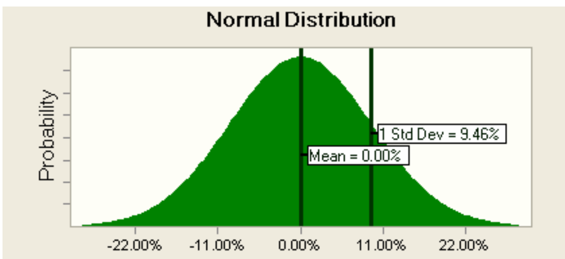
2) -24.53 Mio $ / 1.20 = -20.41 Mio €

[24] The standard deviation of daily dollar/euro price changes over the last 100 days of 2005 was 0.54%. This was converted to a standard deviation for monthly price changes of 2.41%. The long-term standard deviation for monthly price changes (last 100 months) was 2.43%.

The comparison chart shows the normal distribution and actual data values for the past 100 months (changes in the monthly dollar/euro exchange rate). Over this period, the development of the dollar/euro exchange rate had a slight upward trend (mean of 0.07%). The Anderson-Darling statistic is 0.89. Thus, the actual data values are somewhat less “normal” than those of the quarterly aluminium price changes that we have seen before. A comparison of the statistics show that the actual data values are skewed (skewness of 0.42).

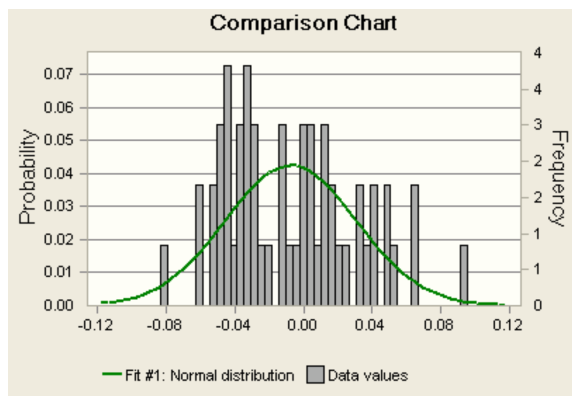



**Interest rate**




As the interest rate for Berliner Maschinen AG’s debt will be fixed in four months, the risk factor in this case is the change in market interest rate until then. To this rate a certain credit risk premium of 2% will be added. Again, the market price is modeled as a random walk with normally distributed changes around a mean of 0%. The standard deviation is 9.46%[25].

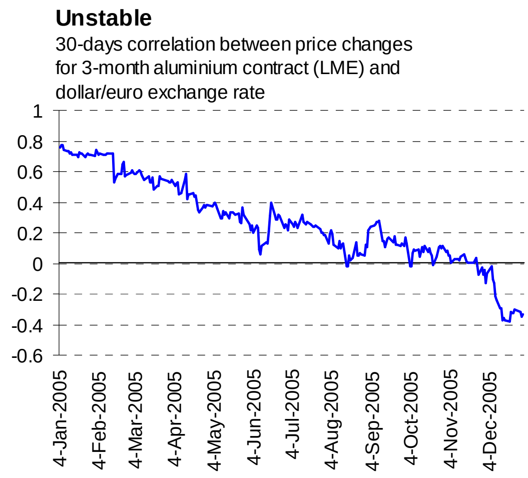
The comparison chart shows the distribution of *monthly* interest rate changes (10-year euro government yield) since the launch of the euro (55 observations). The mean is negative (-0.74%), reflecting the downward interest rate trend of the last few years. The Anderson-Darling test result (0.65) is satisfying. Again, the actual data values are positively skewed (skewness of 0.45).




[25] The standard deviation of daily interest rate changes (10-year Bund) over the last 100 days of 2005 was 1.06%. This was converted to a standard deviation for monthly price changes of 4.73% and four-monthly price changes of 9.46%. The long-term standard deviation for monthly price changes (since the launch of the euro) was 3.82% which would correspond to a four-monthly change of 7.63%.

## Correlation between market prices

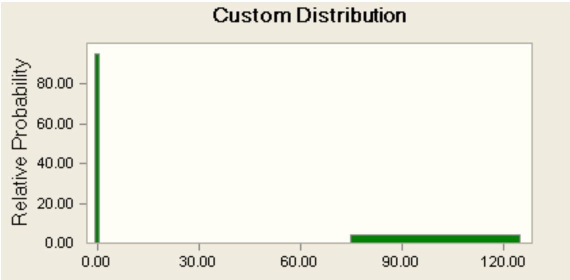
The company has looked into the correlation between relevant market prices, but has decided not to incorporate correlations between the different market prices for two reasons. The first one is that these correlations are highly instable in the course of time. As an example, the graph shows the correlation between the price changes of the past 30 days over the last calendar year for the two major market rates: the dollar/euro exchange rate and the aluminium price on the LME. While the movements of these two market prices were quite parallel in the beginning of the year, the correlation fluctuated wildly and even turned negative towards the end of 2005. The second reason not to incorporate correlation between the price of aluminium and dollar/euro exchange rate is that the company's exposure to adverse dollar/euro rate movements is actually not that big once the "natural hedge" described in this paper under "Hedging" is taken into account.




## Personnel cost

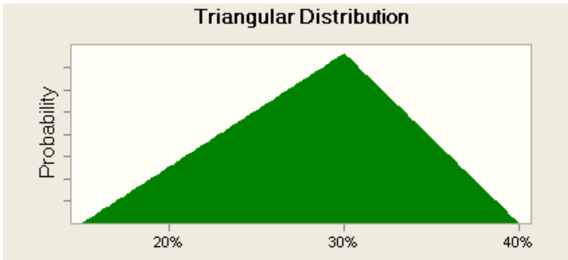
Personnel cost for 2006, planned to amount to 200 Mio €, are certain to a high degree. However, some uncertainty remains. In the simulation, a uniform distribution is used with a range between 196 Mio € and 204 Mio €.

## Loss of an important customer

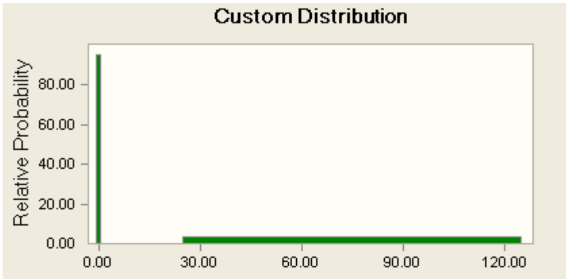



An analysis of Berliner Maschinen AG's existing sales contracts and cost structure has revealed that when an important customer is lost, the damage to the company will be somewhere between 75 and 125 Mio €. The probability of this event is estimated at 5%. This assessment is reflected in the custom distribution depicted in the graph to the left.

The damage from the loss of an important customer is somewhat mitigated by the fact that the goods already produced can be sold in the open market, albeit at a high discount. Trading companies will pay around 30% for the goods. This discount of 70% compared to the original price cannot be taken for granted, however, and in good market conditions it may be even a bit better for Berliner Maschinen AG. Market experts suggest that although 30% is the most likely value for the proceeds, these can actually oscillate between 15% and 40%. The proceeds are thus assumed to behave according to the triangular distribution shown above.

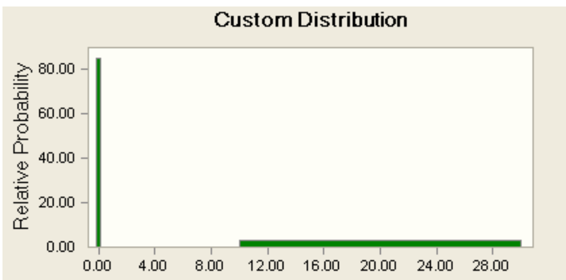


**Reputation damage**




The probability and effect of damage to a company's reputation is notoriously difficult to estimate. Experts guess the probability to be around 5% and the effect to be somewhere between 25 Mio € and 125 Mio €, depending on the cause of the reputation damage. In the simulation, a custom distribution is used to reflect the opinion of the experts.

**Machine breakdown**




Technical experts of the company estimate that a major machine could break down in 2006.
The likelihood of this event is around 15%, and the resulting cost to Berliner Maschinen AG would be in the order of 10-30 Mio €. Again, we used a custom distribution to replicate the opinion of the experts.

**Correlation between operational risk factors**

The breakdown of an important machine could cause quality issues that make the loss of an important customer more likely. Therefore, these two events are correlated. Experts estimate this correlation to be 0.5. The same is true for the operational risk of reputation damage – again, the loss of an important customer would be more likely. The correlation between the risk factors "reputation damage" and "loss of an important customer" is also modeled as 0.5.

When Monte Carlo simulation is applied to risk assessment, risk appears as a frequency distribution graph similar to the familiar bell-shaped curve, which non-statisticians can understand intuitively. Monte Carlo simulation also has important limitations, which have restrained EPA from accepting it as a preferred risk assessment tool: Available software cannot distinguish between variability and uncertainty. Some factors, such as body weight and tap water ingestion, show well-described differences among individuals. Simulated VAR at its core is quite simple. You basically take the moments (say mean and standard deviation if you assume a normal distribution), generate a simulated set of data with Monte Carlo simulation, and then get the required percentile. What this means is that we could also assume a non-normal distribution, say a t-distribution, and use that for simulation and to compute VAR. First, letâ€™s get market prices of AAPL from Quandl again, and compute the returns. end = datetime.datetime.now(). The Monte Carlo simulation is an important technique in risk management that many PMP and PMI-RMP exam study books do not describe in detail. Most of the guides say it is a complex technique that requires a computerâ€™s assistance, and so aspirants donâ€™t dig further. This assumption is not true; it is a straightforward technique. Monte Carlo Simulation.Â  Monte Carlo Simulation is a mathematical technique that allows you to account for risks in decision-making. It helps you determine the impact of the identified risks by running multiple simulations and finding a range of outcomes. Every decision has a degree of uncertainty, and Monte Carlo Simulation helps you in such situations. It makes your decision sound and avoids surprises later. Monte Carlo Simulation is a statistical method applied in financial modelingWhat is Financial ModelingFinancial modeling is performed in Excel to forecast a company's financial performance. Overview of what is financial modeling, how & why to build a model. where the probability of different outcomes in a problem cannot be simply solved due to the interference of a random variableIndependent VariableAn independent variable is an input, assumption, or driver that is changed in order to assess its impact on a dependent variable (the outcome).. The simulation relies on the repetition of random sa