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EVALUATION OF THE BENEFIT YIELD OF TECHNOLOGY PROJECTS

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ABSTRACT

This paper describes a potential procedure model for the evaluation of technology projects. Usually, experience figures from previous projects are hardly available for developing innovative products and services. That is why the net present value method and the value-based management approach, which are often applied in practice, cannot give a forecast of prospective netto cash flows and cannot estimate the expected yield of the technology project. By the help of this procedure model and the BAPM®-method from [Schabacker, 2001], which evaluates the benefit yield of the applied technologies, the benefit yield of a technology project can be evaluated now.

INTRODUCTION

The short-term development of new products combined with an early time-to-market has become a decisive criterion for the success on the market for a company. Especially, in strong innovation oriented sectors, often the „first offerer" secures the market leadership for his company, which also means the opportunity for quick amortization of investments by considerable profits.

Further important key indicators for a company's future are creativity and the ability to innovate in the sector of product development. The effort of, on the one hand, developing products which are innovative and qualitatively of higher and higher value, and on the other hand, the continuous shortening of the period between idea and introduction to the market, means an enormous challenge concerning reactions to changing market conditions and customer requirements, for the companies. Successful products are characterized by

- mature or new functions,
- the immediate and obvious customer's benefit and
- a mostly staggering simplicity.

The brainstorming process especially has to be executed in consideration of methodical, organizational, and technological aspects for developing products, which fulfill these requirements [Gehringer, Rust, Leibundgut, Ebert, 1998]. In the same way, the human becomes the focal point of the efforts of improvement and the progression of efficiency. In addition to professional competence, more and more method and social competence are required [Kaplan, Norton, 1997].

PROCESS MANAGEMENT

In the 90´s of the last century companies changed traditional structures and a consolidated work flow organization into process organization. The concentration on processes demands the creation of an integrated structure, in which the functionally defined departments are more open and more aligned with the expectations of the consumers and the other stakeholders (e.g. staff members, providers of capital, suppliers, society). In the same extent, thinking and operating in separated functions are losing importance; the need for interfunctional structures arises [Hinterhuber, 1996]. So, the companies become networks:

- Individuals from different departments, echelons of authority and units work together to satisfy all stakeholders.

- Strategic business units are grouped around the key abilities of a company.
- If required, suppliers deliver components, semi-finished goods, and services.

As a process consists of connected activities with the indicated duration of each activity, or of sub processes for the treatment of a task [Schabacker, 2001], Gaitanides focuses on "planning, organizational and controlling measures for the decisive control of the value chain of a company concerning quality, time, costs, and customer´s satisfaction" [Gaitanides, Scholz, Vrohlings, Raster, 1994]. For this concept, Gaitanides established the term process management, which has its origin in the investigation of movement studies by Frank B. Gilbreth and Lilian M. Gilbreth ([Gilbreth, F.B., Gilbreth, L.M., 1924a], [Gilbreth, F.B., Gilbreth, L.M., 1924b]).

In numerous publications (e.g. [Aichele, 1997], [BINNER, 1997], [Gaitanides, Scholz, Vrohlings, Raster, 1994], [Hammer, Champy, 1995], [Lang, 1997], [Pepels, 1998]) the processes in the corporate environment are denoted as business processes, too.

In the process organization, activities and goals can be coordinated, i.e. "goals describe targeted states respectively wanted effects of the sector which has to be organized" [Fischermanns, Liebelt, 1997]. These goals are denoted as process goals in this paper. Some examples are the

- Minimization of process time, i.e. the minimization of the throughput time of a process
- Minimization of process costs, i.e. the minimization of those costs, which arise from the handling of the process
- Improvement of the process quality, i.e. quality improvement of a process, that does not require rework

PROJECT MANAGEMENT

However, especially in the field of product development process management is not enough, because it is only an inflexible illustration of activities. In product development, too, there was a turn-away from rigidly separated tasks and activities, not only to functionally defined departments, but also to project work in teams (e.g. in [Vajna, Burchardt, 1998], [Vajna, 1999]). Following [Bullinger, Warschat, 1997], a project is a plan consisting of a set of work packets, which is characterized by [Mönch, 1996]

- Clearly defined goal-setting
- Limited period for the work with an unambiguously defined point of beginning and end
- High complexity with regard to the problem, the way of solving, or the involved stakeholders
- New goals or methods concerning technology, market and organization, or for the participants
- Interdisciplinary processing of different work packets
- Corporate political range with regard to effect, costs, risk, and success
- Exactly defined financial framework.

Following [Bullinger, Warschat, 1997], management is the leadership of socio-technical systems in respect of persons and equipment by the help of methods. So, project management means the leadership of a project and the project leading institution.

In general, the diverse goals which are connected with the application of the project management, can be delimited to three basic project goals [Schmelzer, 1999]:

- Project time, i.e. to keep deadlines
- Project costs, i.e. to limit the costs, which arise from the handling of the process
- Project quality, i.e. quality improvement of a project, which does not require rework.

Figure 1 shows the delimitation between process and project management.

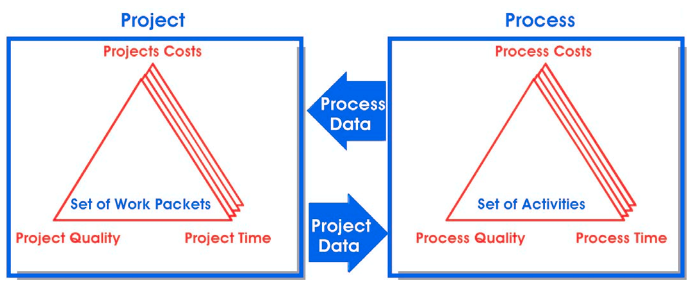


Figure 1: Delimitation between Process and Project Management

Examples for processes, where project management has already proved itself often, are:

- Development of new products or services
- Design projects
- Transaction of customer orders
- IT projects
- Social events

Below, the development of new products or services will be called *technology project*.

CONTEMPORARY EVALUATION OF TECHNOLOGY PROJECTS

When a new product or service is developed, executives are interested in whether and which technology projects they should approach or not. Therefore, they have to choose between different options. For a *rational* choice, they have to be able to determine the contribution of the competitive investment opportunities to the corporate value and choose the option with the highest contribution. The net present value method is very often applied for this. In this case, the company realizes those projects, which have a positive net present value respectively, when the capital is limited, the project with the highest net present value. Although, the net present value method is the economical right investment criterion, some other approaches do exist in practice, which more or less differ from the net present value method [Loderer, Jörg, Pichler, Roth, Zgraggen, 2002].

They are known as value-based management approaches [Schabacker, 2001]:

- *Shareholder-Value-Analysis* is a method for corporate evaluation, which estimates the economic value of an investment by the predicted cash-flows [Rappaport, 1995], i.e. quantifying of corporate strategies as link between qualitative strategy planning and operational medium-term planning [Hoffmann, 1996].
- *Stakeholder-Value-Concept* is an expansion of the shareholder-value-analysis, for being able to take in account interests of, e.g. staff members, and not only interests of capital owners [Hoffmann, Niedermayr, Risak, 1996].
- *Economic Value Added* (EVA) for a future oriented evaluation of projects or companies, as well as for historic performance measurement [Hostettler, 1998].
- Other Shareholder-Value oriented approaches (compiled in [Hostettler, 1998]): *Discounted Cash Flow* (DCF), *Economic Profit*, *Cash Flow Return on Investment* (CFROI), *Added Value*, *Market Value Added* (MVA).

However, the net present value method and the value-based management approaches have two serious disadvantages: firstly, in forecasting the netto cash flows, and secondly, in estimating the expected yield of a technology project. As the knowledge and experience from former projects cannot be applied, the evaluation of the expected yield of new technology projects is very difficult. Below it is described, how the expected benefit yield of a technology project can be determined by using the second capital market variable *risk* with the concepts of risk management.

RISK ANALYSIS OF TECHNOLOGY PROJECTS

Risk is a negative, an unwanted and unexpected occurrence, which causes damage and can be determined by the two dimensions damage potential and probability of occurrence/ expected frequency. This definition of risk has its origin in the engineering sciences. Risk as an occurrence (e.g. the financial loss in a certain scenario) can be described as

$$R = W * A,$$

with

R = risk ratio
W = probability of occurrence/ expected frequency
A = extent (damage potential)

W as well as A mostly can be quantified (examples see **table 1 and 2**).

W	Classification of the Probability of Occurrence	Probability of Occurrence
1	• Application of available methods and procedures in design and manufacturing • Great experience in product use	unlikely
2	• Modification of available methods and procedures in design and manufacturing • Little experience in product use	rarely
3	• Significant deviation from available methods and procedures in design and manufacturing • No sufficient experience in product use	possible
4	• New methods and procedures in design and manufacturing • Possibly negative experience in product use	frequently

Table 1: Values for Variable W (Probability of Occurrence)

A	Characterization of the Extents	Extent
1	• No or very little effects on project time, project costs, and project quality • No influence on competitive situation of the company	negligible
2	• Little effects on project time, project costs, and project quality • Little influence on competitive situation of the company	noticeable
3	• Obvious effects on project time, project costs, and project quality • Obvious influence on competitive situation of the company	critical
4	• Big effects on project time, project costs, and project quality • Jeopardized competitive situation of the company	catastrophic

Table 2: Values for Variable A (Extent)

After having determined the risk ratio R by multiplication of the variables W and A, a *grid* is built, from which the line of action for the technology project can be derived [Brühwiler, Stahlmann, Gottschling, 1999] (**figure 2**).

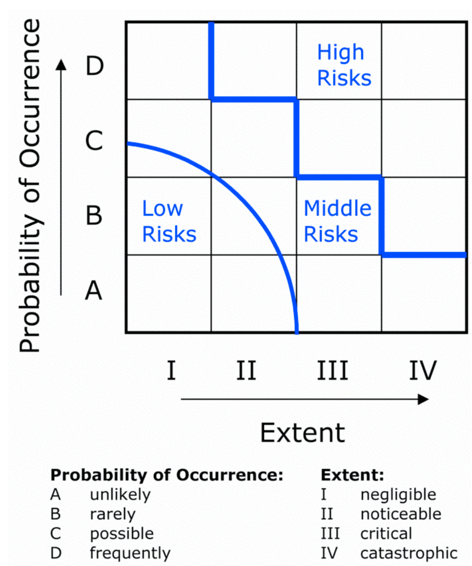


Figure 2: Classification of Risk Occurrences [Brühwiler, Stahlmann, Gottschling, 1999]

However, no monetary quantifiable figures can be derived from the risk ratio R for being confronted with the costs of a technology project for an economic feasibility reflection [Brühwiler, Stahlmann, Gottschling, 1999]:

> „A probability distribution of events is determined by the average and the dispersion of events around this average. The *dispersion*, also called standard deviation, is the measure for the risk."

This definition of risk is widely held and is not only often applied in the decision theory, but also in the actuarial sciences and in the modern theory of portfolio selection after Markowitz [Markowitz, 1952]. In the actuarial sciences it is applied for describing the loss profile, in the capital market for describing the risk of single capital market investments, as e.g. of shares (dispersion of the quotation around the average). The term for this spread is the *variance* or the *volatility*.

When a great number of risks is combined in one portfolio, the insurance risk decreases. In the sector of capital market investments it is exactly the same: when a great number of capital market investments with different dispersions is combined in one portfolio, a part of the *non-systematic risks* (that means the individual risks, which are not depending on each other) can be eliminated. Similar to an insurance portfolio, the risks go to 0 in the case of a rising number. Another part of the risks, the so-called *systematical risks*, maintains, because the factors with influence on the risk effect several individual investments of the portfolio at the same time. The reasons can be found e.g. in the business activity or in the change of the market rate of interest.

PROCEDURE MODEL FOR THE EVALUATION OF TECHNOLOGY PROJECTS

With the following procedure model, the benefit yield of a technology project can be evaluated monetarily within five steps:

- *Definition and Modeling of the Technology Project*: In the first step, the technology project will be started with a project description, which has been developed with regard to the process activities to be executed, which contain qualification profiles of the resources, the hourly rates and times, as well as the necessary tools and materials for executing. This guarantees a systematical procedure for reaching the project goals.
- *Determination of the Costs of the Technology Project*: Secondly, a first simulation can determine the throughput time and the costs of the technology project. The determined costs are relevant for noting the monetary benefit yield.
- *Identification of Risk*: Thirdly, „worst-case" reflections are made concerning the goals of the technology project and the implementation of the individual process activities, and risks are derived. This procedure can be supported by checklists, which guarantee a systematical procedure. The goals of the technology project can be corporate goals as well as technical goals.
- *Risk Analysis*: In the fourth step, the variable W with the help of table 1 classifies the risks according to their identification. As indications in % are needed for determining the expected yield, the willingness to risk by the investor and a risk (interval) will be assigned to the variable W according to their probability of occurrence. From that, equivalent yield intervals can be allotted, because of experience from the capital market (**table 3**). Here, the duration of the activities in the technology project, which includes the goals with the allotted risks, have to be taken into account.

W	Probability of Occurrence of the Risk	Willingness to Risk by the Investor (Risk Class)	Risk [%] [Spremann, 2001]	Capital Market Investment following [Spremann, 2001]	Effective Annual Yield Interval [%] (determined by Trust Funds – Annual Reports from the last 5 Years)
1	unlikely	In passing noticeable	0%	cash, money market funds	1% - 3%
2	rarely	middle	0% - 7%	domestic bonds	2% - 7%
3	possibly	high	7% - 30%	shares	4% - 20%
4	frequently	extreme	> 30%	shares in emerging markets, warrants	20% - 40%

Table 3: Determination of the Expected Yield

- *Determination of the Benefit Yield of a Technology Project*: Instance five combines the risks according to their probability of occurrence to risk classes for each activity in the technology project. So, the risk classes form one portfolio. Now, the BAPM®-method[1] from [Schabacker, 2001] can be applied (**figure 3**). The result of evaluating the portfolio is the expected benefit yield of the technology project with the according shortfall risk, which is measured with the shortfall probability, so that a certain given yield will not be reached.

[1] Benefits of different benefit classes form a *Benefit Asset Pricing Model* (BAPM®) portfolio. BAPM® is a model, which calculates the monetary value of the benefit portfolio with corresponding procedures and methods from the money market.

In analogy to the benefit portfolio, an investor creates an investment portfolio of money market stocks. The quantitative evaluation of these investments results under yields and risk codes. Beside the yield and the risk, the liquidity of an investment has also some meaning. Liquidity is understood as the possibility to sell the transacted money investment at any time at fair prices. Because an investor will not buy a single money market stock, he will divide his money among several alternatives of investments in order to decrease the risk of individual stocks. He creates his investment portfolio consisting of the asset classes stocks and bonds.

The BAPM® model described here is partly based on the Portfolio Selection Model of Markowitz [Markowitz, 1952], which provides a way of reviewing quantitatively an investment portfolio. Following Markowitz, stock investments are to be determined at the invested money to such an extent, that the set of the feasible portfolios can be reduced to the set of *efficient* portfolios.

The BAPM® model was originally applied for benefit evaluation of tools (e.g. CAD/CAM systems). A tool evaluation exemplary showed on EDM/PDM systems can be found in [Schabacker, 2002] and [Schabacker, Wohlbold, 2002].

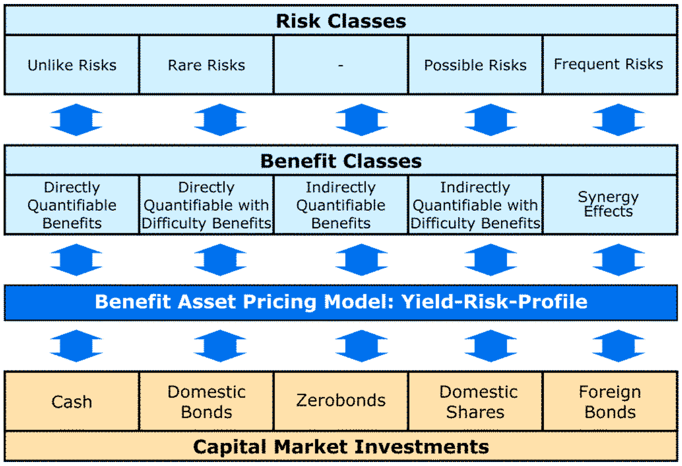


Figure 3: Benefit Mapping in BAPM®

By means of an example evaluation the procedure model will be explained, now.

EXAMPLE EVALUATION

When new materials are applied in aircraft design, e.g. the attributes and the influences of these materials have to be examined very extensively to determine the effects on weight savings etc.. Now, a technology project will be developed and described more or less in detail. It contains the following points:

- Project description with the associated work packets
- Goals (e.g. weight saving, progression of the competitive position), from which financial, organizational, and technical risks arise
- Costs (e.g. personnel and material costs, outsourcing)
- Risk analysis

Definition and Modeling of the Technology Project

The technology project contains the design process of a turbine blade and includes the following work packets: "layout of the turbine blade" and "development of a product data model" (**figure 4**). The work packet "layout of the turbine blade" contains an iterative loop with the activities "design", "thermodynamics", "aerodynamics", "structural mechanics" and "optimization". In each activity the working time is included.

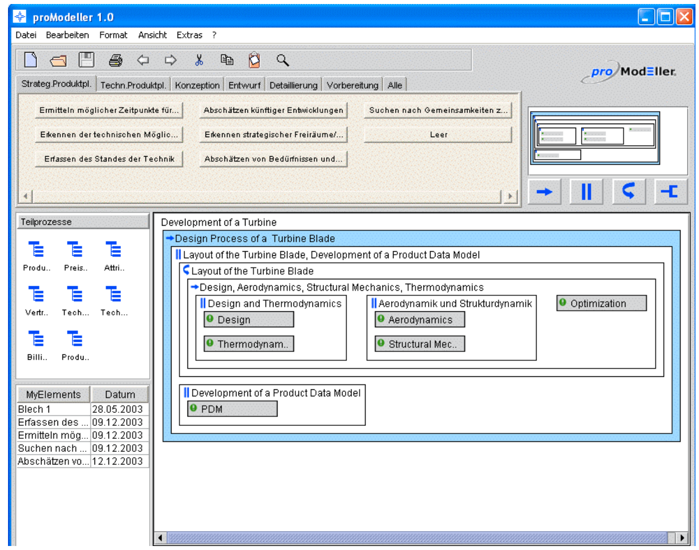
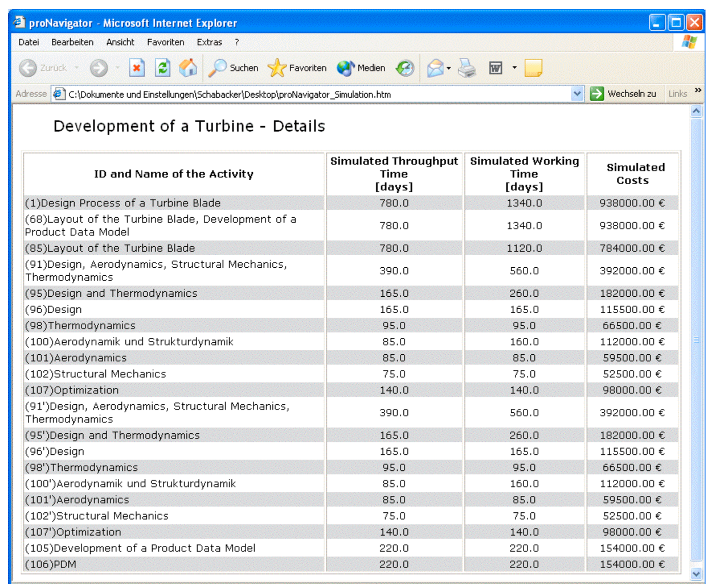


Figure 4: Process of a Technology Project

Determination of the Costs of the Technology Project

Now, in a first technology process simulation, the throughput time and the costs of a technology project are determined. It is assumed that the iterative loop passes twice. In **figure 5** the process and the throughput times by means of the process structure are listed, as well as the process times of the sub processes and activities, and the according costs.



Development of a Turbine - Details

ID and Name of the Activity	Simulated Throughput Time [days]	Simulated Working Time [days]	Simulated Costs
(1)Design Process of a Turbine Blade	780.0	1340.0	938000.00 €
(68)Layout of the Turbine Blade, Development of a Product Data Model	780.0	1340.0	938000.00 €
(85)Layout of the Turbine Blade	780.0	1120.0	784000.00 €
(91)Design, Aerodynamics, Structural Mechanics, Thermodynamics	390.0	560.0	392000.00 €
(95)Design and Thermodynamics	165.0	260.0	182000.00 €
(96)Design	165.0	165.0	115500.00 €
(98)Thermodynamics	95.0	95.0	66500.00 €
(100)Aerodynamik und Strukturdynamik	85.0	160.0	112000.00 €
(101)Aerodynamics	85.0	85.0	59500.00 €
(102)Structural Mechanics	75.0	75.0	52500.00 €
(107)Optimization	140.0	140.0	98000.00 €
(91')Design, Aerodynamics, Structural Mechanics, Thermodynamics	390.0	560.0	392000.00 €
(95')Design and Thermodynamics	165.0	260.0	182000.00 €
(96')Design	165.0	165.0	115500.00 €
(98')Thermodynamics	95.0	95.0	66500.00 €
(100')Aerodynamik und Strukturdynamik	85.0	160.0	112000.00 €
(101')Aerodynamics	85.0	85.0	59500.00 €
(102')Structural Mechanics	75.0	75.0	52500.00 €
(107')Optimization	140.0	140.0	98000.00 €
(105)Development of a Product Data Model	220.0	220.0	154000.00 €
(106)PDM	220.0	220.0	154000.00 €

Figure 5: Throughput Time and Costs of a Technology Project

Risk Identification

During the layout of the turbine blade and the development of the product data model, existing design methods and procedures from thermodynamics and aerodynamics, as well as structural mechanics, are applied. **Table 4** shows examples for risks, not only for the single activities, but also for the technology project.

Activities for the Development of a turbine blade	Description of the Activities	Identified Risks of the Activities
Design	Modeling of the turbine blade in a 3D-CAD system	• Not all the required geometrical information is available. • Design methods cannot be applied in a sufficient extent.
Thermodynamics	Layout of the turbine blade by the means of thermodynamic methods	• Operating life of the product cannot be determined.
Aerodynamics	Testing of the turbine blade concerning aerodynamic aspects	• Aerodynamics cannot be determined in a sufficient quality.
Structural Mechanics	Testing of the turbine blade concerning structural-mechanic aspects	• Structural mechanics cannot be determined in a sufficient quality.
Optimization	Optimization of the turbine blade	• The optimization of design cannot be executed in a sufficient quality.
PDM	Development of a product data model	• A homogeneous product data model cannot be developed.
Design Thermodynamics Aerodynamics Structural Mechanics Optimization PDM		• Financing of the project cannot be ensured. • Personnel resources are not available in a sufficient extent. • Required figures from parallel projects are not/ not in time available.

Table 4: Examples for Identified Risks

Risk Analysis

The activities differ in duration and the return flow of the investment not starts before the technology project has finished. That means, that for the identified risks from the previous step, the so-called *period compliant yields* have to be determined by the help of the following formula in finance mathematics (e.g. http://math.la.asu.edu/~kolossa/114/finance/financeform.html):

$$r_n = (1+r)^{1/n} - 1 \quad \text{with}$$

r_n = *period compliant yield*

r = *effective annual yield*

n = *duration of an activity respectively throughput time of the technology project*

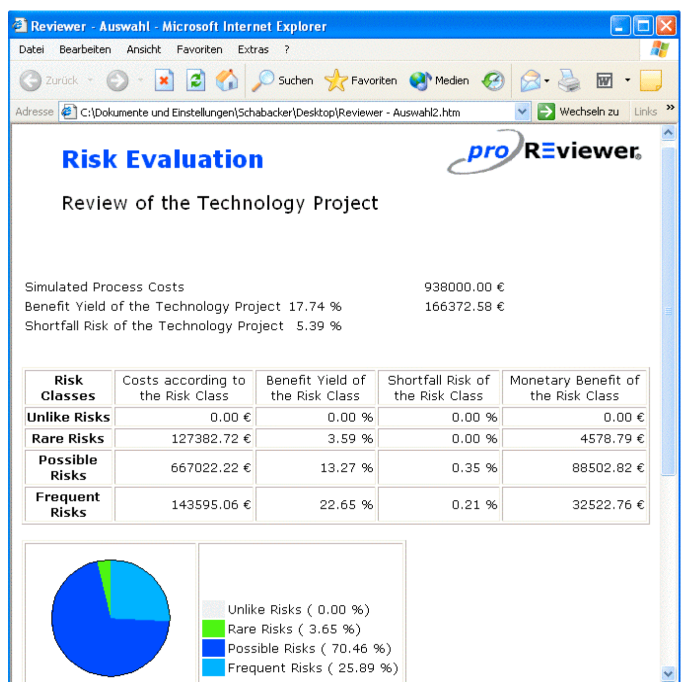
and the effective annual yield intervals from table 3 (**table 5**). For recalculating days into years, it is assumed for the variable n, that one project year means 220 days.

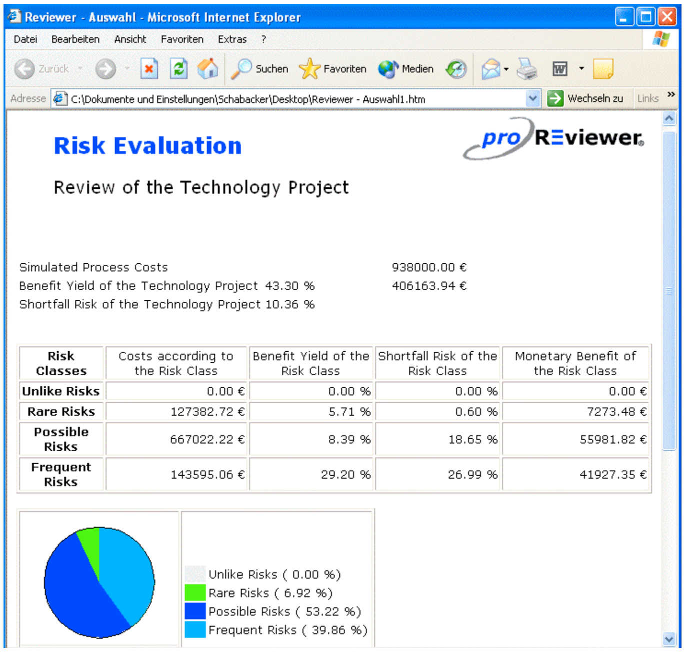
Risk Class	Risks	Throughput Time of the Activities respectively of the Technology Project (see figure 5)	Period Compliant Yield Interval
Unlike risks	none	-	-
Rare risks	• Not all the required geometrical information is available. • A homogeneous product data model cannot be developed.	330 days 220 days	1,33% - 4,61% 2,00% - 7,00%
Possible risks	• Financing of the project cannot be ensured. • Personnel resources are not available in a sufficient extent. • Required figures from parallel projects are not/ not in time available. • Design methods cannot be applied in a sufficient extent. • Aerodynamics cannot be determined in a sufficient quality.	780 days 780 days 780 days 330 days 170 days	1,11% - 5,28% 1,11% - 5,28% 1,11% - 5,28% 2,65% - 12,92% 5,21% - 26,61%
Frequent risks	• Operating life of the product cannot be determined. • Structural mechanics cannot be determined in a sufficient quality. • The optimization of the design cannot be executed in a sufficient quality.	190 days 150 days 280 days	23,50% - 47,64% 30,66% - 63,80% 20,41% - 30,26%

Table 5: Calculation of the Period Compliant Yields

Evaluation of the Benefit Yield of a Technology Project

Figure 6 now shows the evaluated benefit yields of a technology project with the BAPM®-method [Schabacker, 2001]: at first for the lower bound of the period compliant yield interval, then for the upper bound of the period compliant yield interval. The benefit yield of the technology project is between 17,74% and 43,30%. The shortfall risk of the technology project is between 5,39% and 10,36%, i.e. with a probability of nearly 90%-95% this project can be executed successfully. Finally, by using the respective dynamic investment methods, the economic efficiency of this investment can be determined.





Risk Classes	Costs according to the Risk Class	Benefit Yield of the Risk Class	Shortfall Risk of the Risk Class	Monetary Benefit of the Risk Class
Unlike Risks	0.00 €	0.00 %	0.00 %	0.00 €
Rare Risks	127382.72 €	5.71 %	0.60 %	7273.48 €
Possible Risks	667022.22 €	8.39 %	18.65 %	55981.82 €
Frequent Risks	143595.06 €	29.20 %	26.99 %	41927.35 €

Figure 6: Evaluation of the Lower and Upper Bound of the Benefit Yield of a Technology Project

LESSONS LEARNED OF THE EVALUATION OF TECHNOLOGY PROJECTS

Project management systems like e.g. MS Project have shown that a technology project can be modeled and project costs can be evaluated except of alternative or iterative loop processes, because project management systems have not these functionalities. Against it, technology projects contain dynamic processes where several process simulations are necessary with alternatives processes or different numbers of iterative loops. Of course, uncertainties with the estimation of throughput time and costs will stay. However, it has shown in accomplished projects that the throughput time and costs are more stable with the applied procedure model described in this contribution.

In addition, contemporary project management systems have no risk evaluation in this detailed way. Checklists are only available in MS Excel sheets or other procedures in finance mathematics like e.g. the Merton Option Pricing Formula [Merton, 1973] can be applied. This formula can calculate a "fair value" respectively a monetary value of the technology project risk. However, e.g. the value of one variable in this formula, the implied volatility for an underlying stock, is not available. So the formula is not applicable. Furthermore, a technology project has more than one risk, because it has shown in accomplished projects in product development that time and cost risks are not only the single aspects. There is a need to evaluate additional risks like e.g. the application of design methods. A technology project has many influences. Hence, risks from different aspects have to be classified. Finally, for the evaluation the risks are compared with capital investments with the help of risk experiences in the capital market. Therefore, they are understood as capital investments and methods of the portfolio theory which are stored in BAPM® can be applied.

Overall, in order to apply the described procedure model in this contribution there are to do some work. But it has shown in accomplished projects that these troubles are paying off for the project leader: he gets a more exact forecasting of throughput time, costs, and risks of the technology project as well as better reasons for the controlling department.

SUMMARY

In this paper a procedure model for the evaluation of technology projects has been introduced. The starting points are corporate and technical goals, from which risks can be derived. These risks are divided into risk classes according to their probability of occurrence. As usually, experience from former projects can hardly be used, capital market investments are assigned to the risk classes with the help of an analogy reflection from an investor´s willingness to risk. From the capital market, experience figures concerning the yield and the risk, exist. So now, the benefit yield of a technology project can be determined by using the BAPM®-method from [Schabacker, 2001]. At the same time, this procedure model allows statements about which technology projects are preferably carried out, due to the limited budget with the goals, costs and risks from the project description. In order to get the return on investment of a single technology project, the throughput time and the costs can be calculated in a process simulation.

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