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BENEFIT EVALUATION OF NEW TECHNOLOGIES

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ABSTRACT

In business theory there are no suitable benefit evaluation procedures for new technologies (e.g. CAD/CAM systems, EDM/PDM systems) in product development. Another problem is the missing process orientation as well as an inadmissible mix of quantifiable and qualitative benefits (if they are not be even neglected). Hence, the results are difficult to comprehend ([Schabacker, 2001], [Bauer, 1995]).

INTRODUCTION

Because the benefits of tools and their application in processes can be found in the whole product development, two views, the process view and the tool view, have to be regarded. The economic proof of the (optimised) processes can be measured rather easily using process throughput time, process costs, and process quality (the necessary formula and procedures are described in [Schabacker, 2001]). Compared to the process view, the economic proof of the application of tools is very difficult (and even worse e.g. for EDM/PDM systems). Hence, a method for benefits recording is necessary. There are two ways: the classical approach of costs, quality and time, and a Controlling approach.

RECORDING BENEFITS IN BENEFIT CATEGORIES

The drive to record benefits of tools is the classical requirements like less costs, quality improvement and reduced throughput time. However, these requirements have different meanings in context with processes, procedures, methods, and tools in product development, as well in co-operation with the customers. There are overlappings because e.g. time reduction can be transferred to cost reduction. Several interpretations are possible because e.g. quality can be product quality, service quality, or staff quality (to be achieved by qualification). Also it has to be regarded that companies are structured in projects for the implementations of temporary plans. Hence, six benefit categories were defined in [Schabacker, 2001]:

- staff environment
- tool application
- product quality
- service quality
- process performance
- and project performance.

Exemplary benefits are related to the single benefit categories in table 1.

Benefit Categories	Benefits
staff environment	• qualified people • human-adjusted working content • …
tool application	• better handling of information • better information quality • …
product quality	• low waste • higher product quality standard • …
service quality	• improvement of consulting quality • increasing of repeated businesses • …
process performance	• standardization of processes • improvement of processes with systematization of products • …
project performance	• reduction of project costs • keeping exact dates • …

Table 1: Exemplary benefits

An additional way to get the benefit categories was based on the resulting difficulties that appeared not only during benefit recording and evaluation but also mostly in classical Controlling [Schabacker, 2001]. Therefore, new controlling methods had to be found. One of these was the Balanced Scorecard [Kaplan, Norton, 1997], which was created originally for manufacturing. The Balanced Scorecard is able to give a financial value to product development, processes in the company, staff know how, staff motivation as well as staff flexibility, and customers loyalty, and new technologies, even then if these topics are not listed in a company balance. The Balanced Scorecard was the unique new controlling instrument that focusses on customers, staff, and processes. All other instruments focus only on one of these aspects like e.g. Total Quality Management on quality. Moreover, the Balanced Scorecard applied in product development, offers the same six benefit categories (**figure 1**) which can be derived by the interpretation of the original four Balanced Scorecard perspectives [Kaplan, Norton, 1997]:

- learning and development perspective
- staff perspective
- process perspective
- financial perspective.

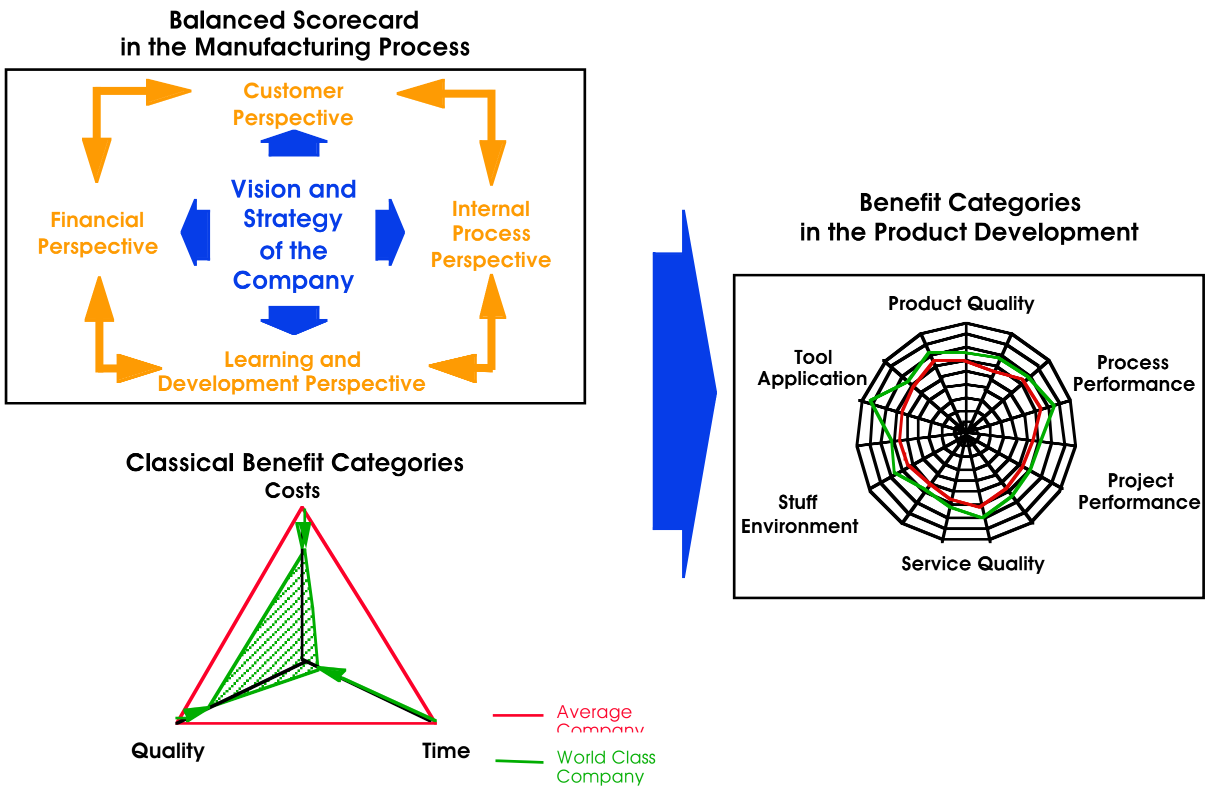


Figure 1: Derivation of the benefit categories in product development and Balanced Scorecard

EVALUATING BENEFITS IN BENEFIT CLASSES

In the single benefit categories for benefit evaluation, the benefits can be quantified completely by monetary means and benefits (where the quantification is possible but with difficulties). These benefits are classified in so-called benefit classes based on the [VDI guideline 2216]. The benefit class "synergy effects" extended the benefit classes, which covers company internal and external synergies. These five benefit classes can be arranged as a portfolio. This portfolio is called the *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. This portfolio consists of the single benefits, which are linked to the respective benefit categories.

In analogy to the benefit portfolio, an investor creates an investment portfolio of money market stocks. The quantitative evaluation of these investments results under yield 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. Indeed, an investor will have to decide himself for an efficient portfolio, which is the *optimal* portfolio for him. In dependence of the Portfolio Selection Model of Markowitz, the possibility of an investment into a riskless bond is assumed. Finally, the benefit[1] is maximized with the help of a benefit function [Auckenthaler, 1994].

This means for the benefits in the benefit portfolio, that

- the evaluation of the different benefits of an investment corresponds to the evaluation of the different yields of a money market investment,
- the risk is understood as "a danger for the benefit portfolio respectively for the investment portfolio to miss an expected yield" [Auckenthaler, 1994]. For the quantification of the benefits two views emerge for the term "risk". On the one hand, there is the risk, whether the indirect benefits of the new technologies will appear at the desired size at other areas of the product development or not. On the other hand, there is the uncertainity respectively the risk to evaluate the yield exactly. In both cases, there are two possibilities for calculating the risk on the money market: In the first case the shortfall risk [Leibowitz, Henrickson, 1988] with the approach of the shortfall probability, and in the second case the deviation of expected yields in form of entrance probabilities expressed by the so-called volatility [Steiner, Bruns, 1996],
- the liquidity of the different benefits is evaluated by the portfolio yield of the Portfolio Selection Model of Markowitz,
- quantifiable benefit classes correspond to cash or zerobonds at money market investments. They offer a secure source of income (e.g. interests, dividends), i.e. the yield can be calculated with the formulae from the investment theory in a simple way [Vajna, Schabacker, 1997],
- benefit classes which are quantifiable with difficulties correspond to stocks or bonds at money market investments. They offer a very uncertain source of income during their term, i.e. the yield is affected by elements of uncertainity and it is calculated with the help of the shortfall probability [Vajna, Schabacker, 1997].

[1] In the Modern Portfolio Management Theory the term benefit marks a compromise between yield aim and safety aim: The larger the realizable yield of the invested money is, the smaller is also the joined safety to get back the money without loss [Auckenthaler, 1994].

Further details and the result of the proof (table 2) are shown in [Schabacker, 2001] that this portfolio is similar to a portfolio in the money market containing stocks, bonds, cash, and zerobonds.

Benefit Classes	**Money Market Investments**
Directly quantifiable benefits	Cash
Directly quantifiable with difficulty benefits	Domestic Bonds
Indirectly quantifiable benefits	Zerobonds
Indirectly quantifiable with difficulty benefits	Domestic Stocks
Synergy effects	Foreign Bonds

Table 2: Benefit Classes vs. Money Market Investments

Hence the portfolio theory of Markowitz [Markowitz, 1952] as well as methods and procedures for yield and risk evaluation of money market investments can be applied on the benefit evaluation.

ALGORITHM FOR BAPM®

For the evaluation of benefits the following optimazation problem of the efficient portfolio has to be solved:

$$\min \sum_{i=1}^{n} w_i^2 * \sigma_i^2 \; + \; 2 * \sum_{j=1}^{n} \sum_{i=1}^{n} w_j * w_i * COV(R_i, R_j)$$

with the constraints

$$E\left(R_P\right) = \sum_{i=1}^{n} w_i * E\left(R_i\right), \; \sum_{i=1}^{n} w_i = 1, \; w_i \geq 0, \forall i = 1,...,n$$

,

whereby

$E\left(R_P\right)$ = expected portfolio yield,

$E\left(R_i\right)$ = expected yield of the ith benefit,

w_i = part of the benefit i within the portfolio,

n = number of the existing benefits in the portfolio.

Markowitz measures the expected portfolio risk with the help of the variance σ^2, which is known as the deviation measure from statistics. For the variance of the single yields emerges

$$\sigma_i^2 = \frac{1}{m} \sum_{k=1}^{m} \left(E\left(R_{i_k}\right) - \bar{\mu} \right)^2 \quad \forall i = 1,...,n$$

$$with \; \bar{\mu} = \frac{1}{m} \sum_{k=1}^{m} R_{i_k}$$

For the covariance emerges

$$\sigma_{ij}^2 = COV(R_i, R_j) = E\{[R_i - E(R_i)][R_j - E(R_j)]\}$$

$$\forall i, j = 1, \ldots, n \; with \; i \neq j$$

The yields for the single benefits can be evaluated by forecast procedures of the money market. These procedures are derivative finance products like e.g. options and futures which are used for the hedging of individual stocks. Hence, the herewith won knowledge can be transformed analogously to the benefit development of an investment. Finally, the portfolio yield can be calculated.

THE PILOT REVIEWER

For predicting and measuring costs and benefits of process improvements and tool application an evaluating tool called PILOT Reviewer was implemented. In a first step, this evaluating tool based on BAPM® [Schabacker, 2001] is intended to measure benefits of processes, projects, and tools (e.g. CAD/CAM, EDM/PDM), in a second step benefits of methods will be included. The PILOT Reviewer contains the benefits of the tools which were applied during processes and activities. Further information of costs and throughput time are also available. In order to apply the BAPM® in context with the PILOT Reviewer the following procedure is recommended:

The information of applied methods and tools, the used time and costs altogether are transferred into the PILOT Reviewer. In BAPM® benefits are classified in benefit categories and in benefit classes. To get the individual yield of each benefit class, each benefit in each class has to be evaluated (more details about this in the next chapter). The application of the portfolio theory of Markowitz results in the respective yield-and-risk-portfolio of each benefit class. Applied for the second time, the portfolio theory of Markowitz now delivers the yield-and-risk-portfolio of the whole benefit portfolio.

The output of the benefit evaluation is placed in an Internet Browser window (details shown in **figure 2**).

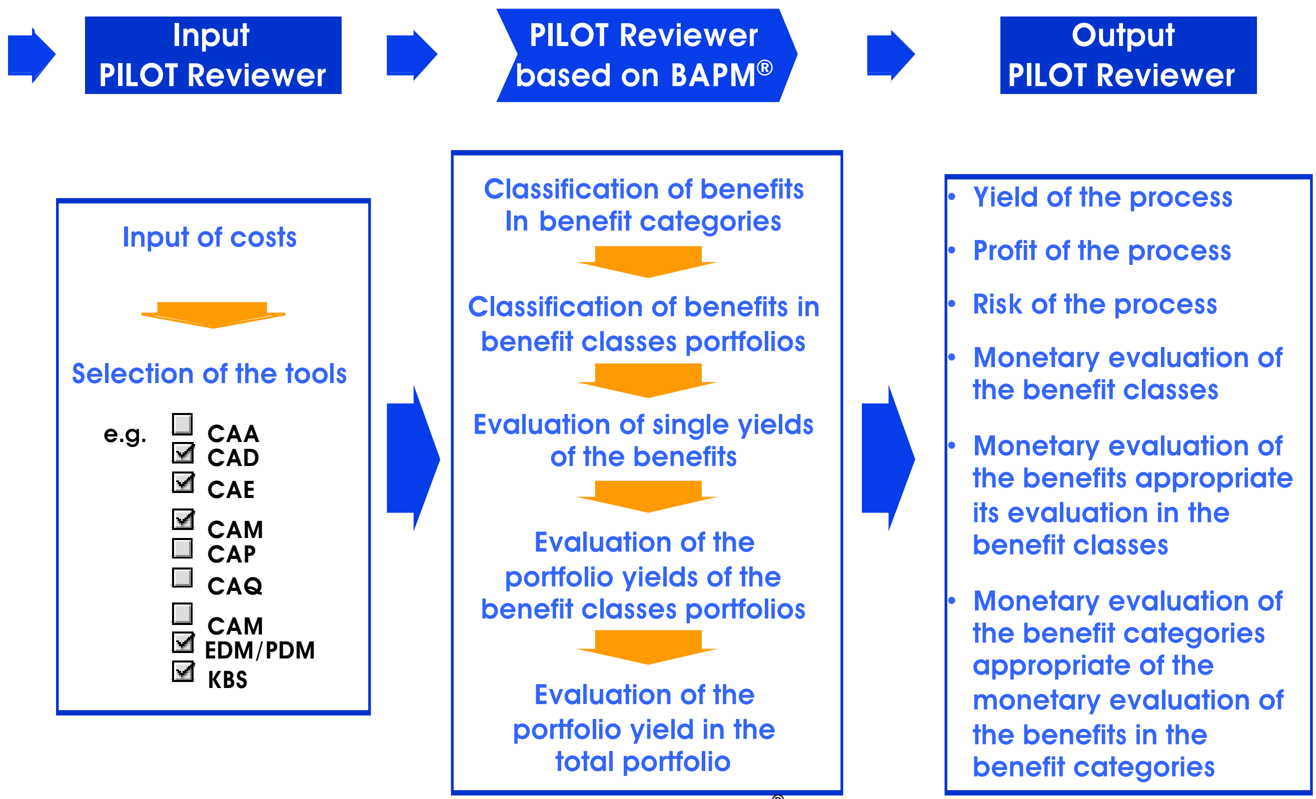


Figure 2: Software approach of BAPM® in PILOT Reviewer

TOOL EVALUATION EXEMPLARY SHOWED ON EDM/PDM SYSTEMS

Mostly it is not enough to regard only the benefits of an EDM/PDM system. In order to get better results of benefit evaluation it is necessary to look on the function level of these systems. This has the advantage that several EDM/PDM systems can be compared with each other. The first step is to do a benchmark to create a function list with different function categories, e.g. Geometry Management, Drafting Management, Change Management, Release Management (Input 1 in figure 3). After that all functions are linked with analytical curves and their expected maximal yield after 5 years. Finally, the PILOT Reviewer could be applied. This procedure is a quick method to compare several EDM/PDM systems but it says nothing about the strength and weakness of an EDM/PDM system in the whole product development process. Hence, it has to be regarded the process (Input 2 in figure 3).

A *process* is a set of process elements or subprocesses for solving a task. A subprocess is a subset of a process and is also a set of process elements or other subprocesses. A *process element* describes an activity respectively of one or several working steps. It is started by one or several events and ends in one or several events. The single process elements (activities) are self-contained in content, and they are in a logical context to each other. Their description is based on a defined structure so that they are suitable also for the application in a computer-aided system [Vajna, Freisleben, Schabacker, 2001].

After identified the process elements of applying an EDM/PDM system the process elements are linked with the belonging functions (Input 3 in **figure 3**). Finally, the PILOT Reviewer can be applied for each process element. The result of each process element is the yield and risk.

To summarise, the process model of EDM/PDM evaluation is shown in **figure 3**.

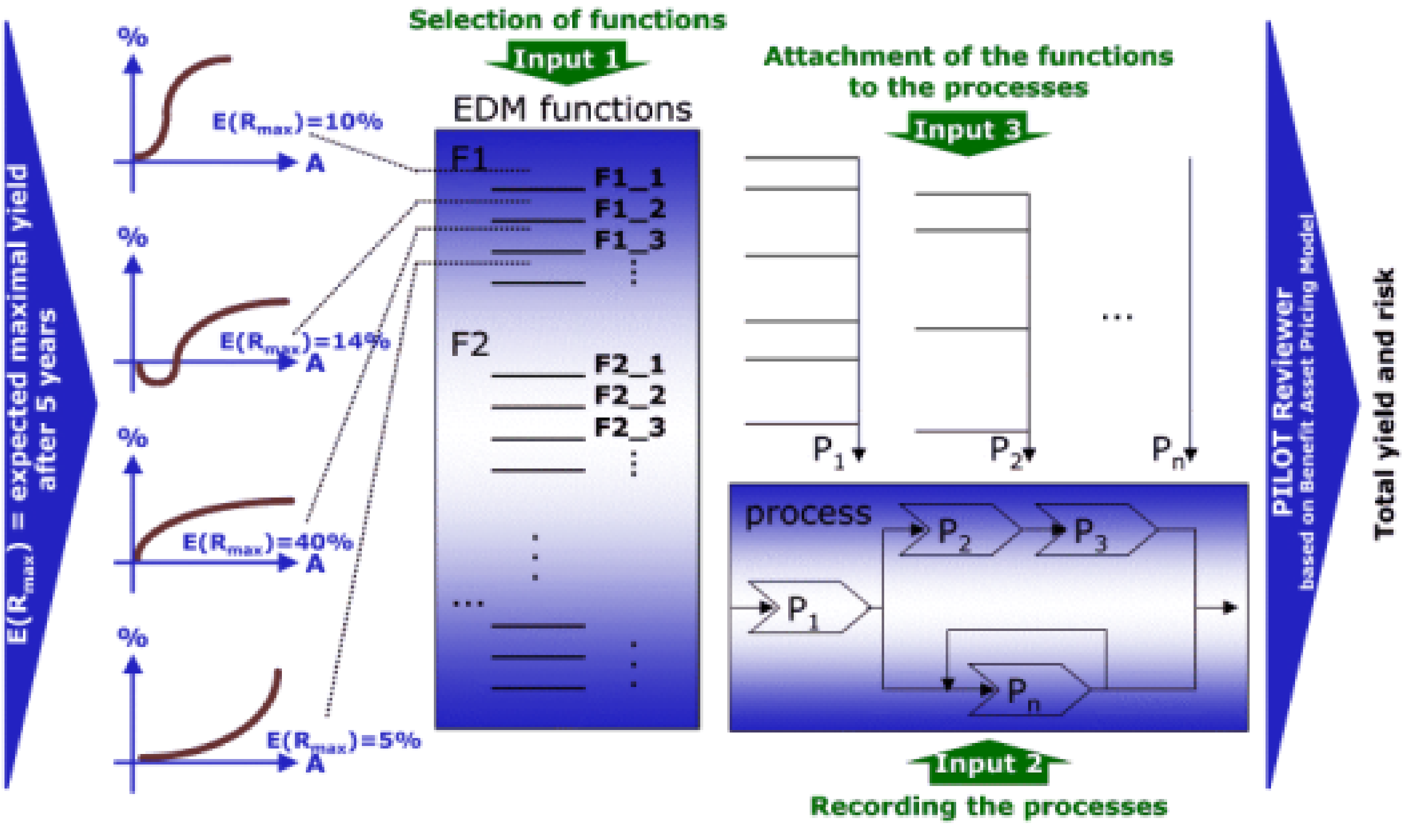


Figure 3: Process Model of EDM/PDM Evaluation

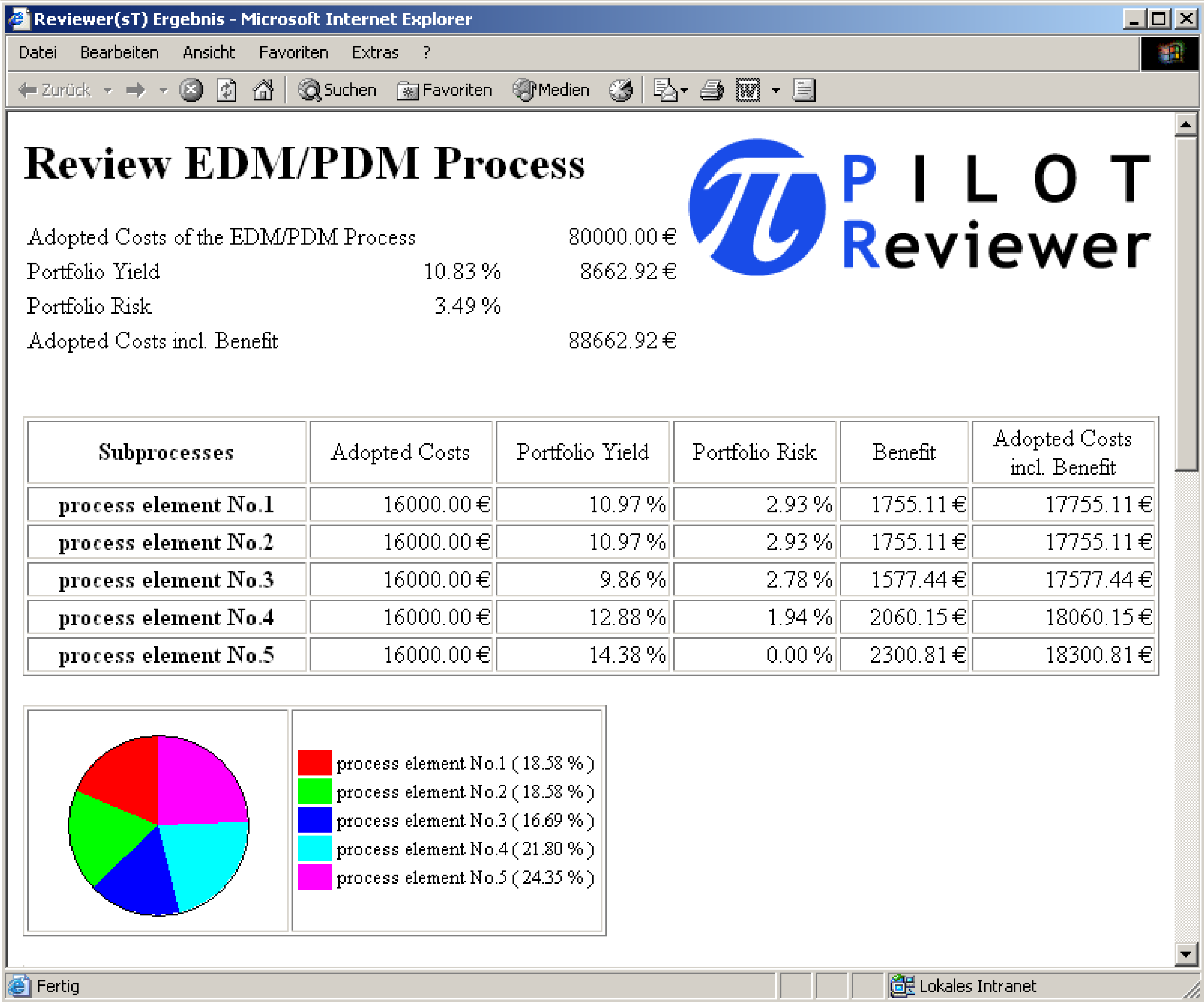
In **figure 4** a result of one process with 5 process elements is shown as an example in the PILOT Reviewer.

The first part of **figure 4** shows the adopted costs of applying EDM/PDM, the portfolio yield and risk of EDM/PDM functions in the whole product development process and the monetary value of the effect of the functions under the consideration that each function was regarded exactly one time.

The second part of **figure 4** shows the respective results for each process element. Functions are now regarded several times along the process.

The third part of **figure 4** shows the weighted parts of each process element in a circle graph.

Optionally, a detailed function list can be shown for each process element. The details can be the weighted part of the function within a process element and/or the monetary value of the effect of this function.



Reviewer(sT) Ergebnis - Microsoft Internet Explorer

Datei Bearbeiten Ansicht Favoriten Extras ?

Zurück Suchen Favoriten Medien

Review EDM/PDM Process

PILOT Reviewer

Adopted Costs of the EDM/PDM Process		80000.00 €
Portfolio Yield	10.83 %	8662.92 €
Portfolio Risk	3.49 %	
Adopted Costs incl. Benefit		88662.92 €

Subprocesses	Adopted Costs	Portfolio Yield	Portfolio Risk	Benefit	Adopted Costs incl. Benefit
process element No.1	16000.00 €	10.97 %	2.93 %	1755.11 €	17755.11 €
process element No.2	16000.00 €	10.97 %	2.93 %	1755.11 €	17755.11 €
process element No.3	16000.00 €	9.86 %	2.78 %	1577.44 €	17577.44 €
process element No.4	16000.00 €	12.88 %	1.94 %	2060.15 €	18060.15 €
process element No.5	16000.00 €	14.38 %	0.00 %	2300.81 €	18300.81 €

Figure 4: Review of Process Elements

In this evaluation a function was regarded exactly one time within a process element. Of course, it is often the case that a function will be applied several times within a process element. So it is useful to calculate so-called benefit multipliers for each process element as shown in **figure 5**. It is estimated the applying of functions within a process element. The benefit multiplier of a process element is evaluated as follows:

$$\textit{benefit multiplier}_{\textit{process element No.} j} = \frac{\sum_{i=1}^{n} a_{f_i}}{n}, j = 1, \ldots, m$$

with

n = number of different functions applied within in a process element

m = number of process elements

a_{f_i} = number how many times a certain function is used

f_i = applied function i within in a process element

After calculating the benefit multipliers these are multiplied with the portfolio yields of the process elements. The result can be seen in **figure 5** whereas it was supposed that the costs will **not** change.

This extended approach makes a better understanding in investments like EDM/PDM in product development process.

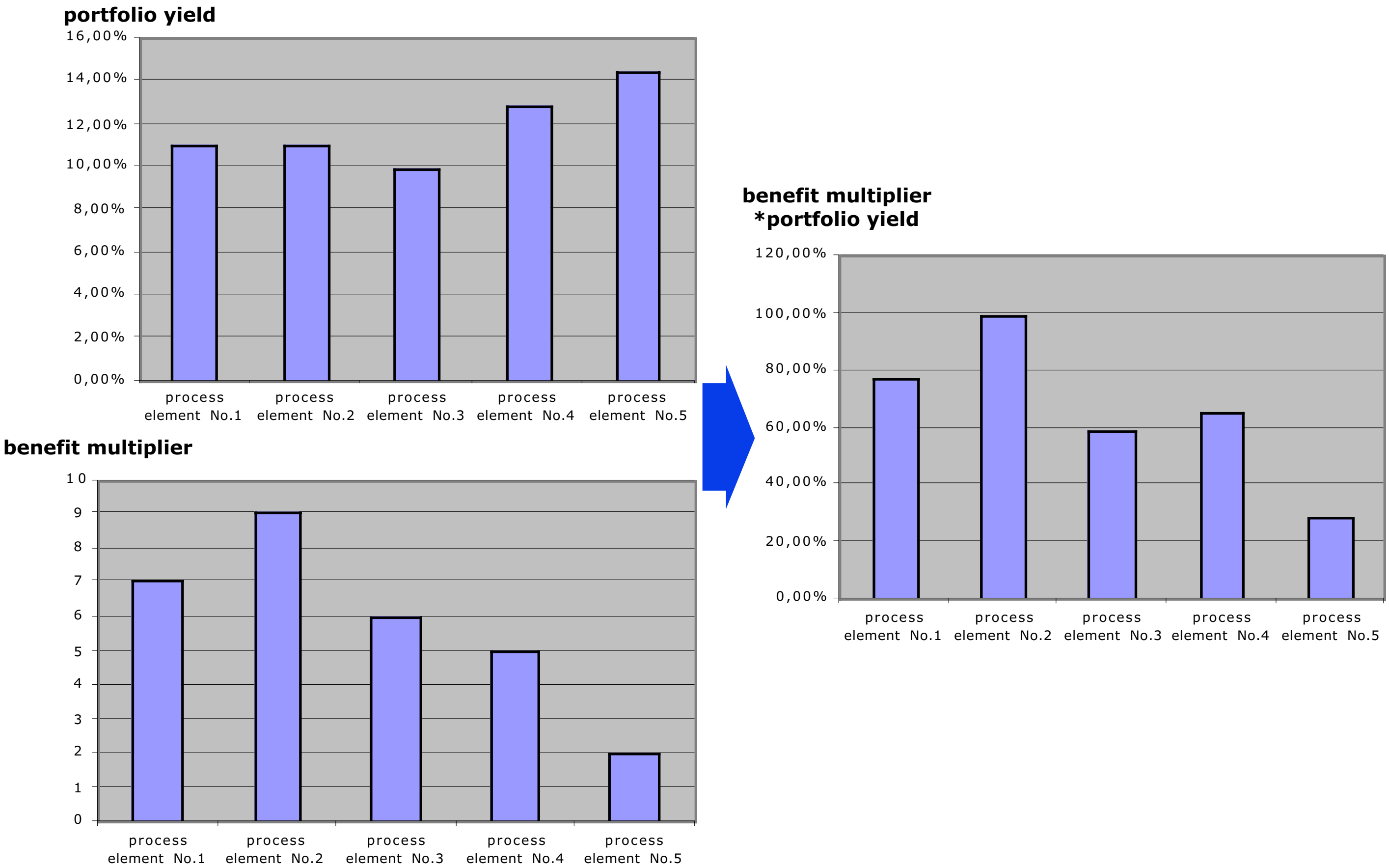


Figure 5: Review of Process Elements in Product Development

CONCLUSION AND OUTLOOK

Based on the evaluation of processes, projects, and their tools in product development, this contribution should motivate the discussion with other groups dealing with similar approaches and should increase the accumulated experience of forecasting the best application of new technologies in product development. The PILOT Reviewer is linked to a huge data base filled with functions for the most tools applied in product development. Also it is possible to compare tools in the same application area (e.g. EDM/PDM systems). So it makes sense to take the "best" values of functions in this area to create a reference system. Finally, the weightings of the functions to each other are known by the portfolio theory of Markowitz. That means in the future that BAPM® can be extended to a benefit evaluation index in analogy to a stock index (e.g. Standard & Poor's Index (S&P 500), Deutsche Aktienindex (DAX)).

The DAX is a German stock index and is evaluated newly every minute during the official stock exchange session. Moreover, the composition and the weighting of the DAX are adapted yearly new by adequate adaptation and correction factors. The DAX was designed as a so-called *performance index*. This concept implies a clean-up of the index in relation to payments of dividends and stock options at money increase, that is these earnings are again invested in the respective stock of the index portfolio. Therefore, this distribution has no effects on decrease of the index in opposite to a pure price index (e.g. Dow Jones Average).

In analogy to DAX a benefit evaluation index called BEI can be evaluated as follows [Eller, 1996]:

$$\mathrm{BEI}(t) = K(T) * \frac{\sum_{i=1}^{n} p(i,t) * q(i,T) * c(i,t)}{\sum_{i=1}^{n} p(i,0) * q(i,0)} * 1000$$

with

BEI (t) = value of the benefit evaluation index at time t
t = time of evaluation

K(T)	=	adaptation factor at time T
T	=	last adaptation date
i	=	benefit i (i = 1,...,n)
c(i,t)	=	correction factor at time t for the ith benefit
p(i,t)	=	”benefit price” of benefit i at time t
q(i,T)	=	number of money market investments of benefit i at time of the last adaptation T
p(i,0)	=	fixed initial value of the ”benefit price” of benefit i
q(i,0)	=	number of money market investments of benefit i at initial value

At the beginning of the benefit evaluation the "number of money market investments" is equal to 1 for each benefit. Because no adaptations have to be made in the ideal case at the benefit evaluation index BEI no clean-ups have to be made also at the index. That means that the adaptation factor *K(T)* is equal to 1. Furthermore, the portfolio theory of Markowitz provides the weighting *w(i)* for the correction factor *c(i,t)*. To summarise the following simplified formula of an adjusted benefit evaluation index called ABEI will be required:

$$\mathrm{ABEI}(t) = \frac{\sum_{i=1}^{n} p(i,t) * w(i)}{\sum_{i=1}^{n} p(i,0)} * 1000$$

with

ABEI (t)	=	value of the adjusted benefit evaluation index at time t
t	=	time of evaluation
i	=	benefit i (i = 1,...,n)
p(i,t)	=	”benefit price” of benefit i at time t
p(i,0)	=	fixed initial value of the ”benefit price” of benefit i
w(i)	=	weighting of benefit i

If this benefit evaluation index has proven successful in practice, performance measures for money market investments (e.g. the Sharpe measure, the so-called Reward-to-Variability-Ratio [Sharpe, 1966]) can be taken for the controlling of the investment success in new technologies in product development. As well further applications of the money market arouse curiousity on transfer in product development.

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