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Manage Your 'Blind Flight' – The Optimal Timing for IT Project Re-Evaluation

by

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Manage Your 'Blind Flight' – The Optimal Timing for IT Project Re-Evaluation

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Abstract. As the value of an IT project can change over time, management is in "blind flight" about the state of the project until the project has been re-evaluated. As each evaluation causes costs, continuous evaluation is economically unreasonable. Nevertheless, the "blind flight" should not take too long, because the project value can considerably deviate from its initial estimation and high losses can occur. To trade off costs of re-evaluation and potential loss of project value, this paper will elaborate upon an economic model that is able to determine the optimal time until re-evaluation considering the risky cash flows of a project. Based on a simulation, we find that it makes good economic sense to optimize the interval of re-evaluation. Therefore, companies are able to avoid financial loss caused by evaluating too early as well as hazarding project value caused by evaluating too late.

Keywords: IT project evaluation, risky cash flows, re-evaluation interval

1 Introduction

According to a study from the University of Oxford, one out of six IT projects turns out to exceed the planned cost by 200%, and the planned time by 70% [12]. The failure of IT projects with high initial investment and huge cost overrun usually do not only force top managers to resign, but can also cause devastating problems or even business failure to a company [12]. Management should therefore aim at avoiding project failure by devising capable project management means.

In today's management processes, usually IT projects are only evaluated monetarily before the project start in an effort to decide about investment alternatives. Possible changes affecting the project's cash flows are often not considered. As the project's cash flows are influenced by a dynamic environment, the cash flows are risky and the project value can change over time. If no re-evaluation is conducted later on, the initial evaluation is followed by a "blind flight", during which management does not know about the current state of the project [6]. During this "blind flight", possible changes within a project or in the project's environment can cause major problems without being recognized. Therefore, a high deviation of the project value from its planned value can occur, resulting in high losses. If the "blind flight" continues, the possible deviation of the initially estimated value increases, as does the potential loss. To consider the changing circumstances and requirements that influence the risky cash flows of a project, and

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thus to recognize changes and problems earlier, management should re-evaluate an IT project during its runtime from a risky cash flow-based point of view [24].

From this perspective, one might conclude that management should continuously evaluate an IT project without accepting any "blind flight". But as each re-evaluation consumes time and money, it is economically unreasonable to continuously evaluate a project. Management should accept a certain "blind flight" phase to conserve the financial resources of a company. But the "blind flight" phase should be limited. If it is not, the project value can deviate significantly from its initial estimation and the project's value gets out of control. Thus, management faces a trade-off between financial loss caused by evaluating too early and hazarded project value caused by evaluating too late.

Existing frameworks usually do not take into account the risky cash flow-based project value in order to determine the point in time for re-evaluation. Therefore, the monetary development of the project is not considered by these procedures, and the project cannot be evaluated according to value-oriented principles. Therefore, the optimal time until re-evaluation from an economic point of view should be determined. In this point in time, there is a balance between financial loss caused by evaluating too early and hazarded project value caused by evaluating too late.

To generate further insights, the aim of this contribution is to develop a formal-deductive economic model to provide an understanding of the importance of determining the optimal time until re-evaluation in IT project management. Therefore, we extend existing IT project management methods by considering risky cash flows for the optimization of the re-evaluation interval. To the best of our knowledge, there are no scientific papers addressing this question, yet.

Following a brief review of the essential literature, we develop an economic model that allows for a quantitative determination of the optimal time until re-evaluation subject to simplifying assumptions. Furthermore, we show that a better decision regarding the point in time of re-evaluation can be achieved by using the model. To conclude we summarize our results and address practical implications, and limitations, as well as possible areas of future research.

2 Literature Overview

An IT project should be managed as efficiently as possible [23]. For this purpose, it is monitored and controlled, and the value of the IT project is determined [28]. Willcocks [29] defines project evaluation as "establishing, by quantitative and/or qualitative means, the worth of IS to the organization". Generally, there are several main objectives of evaluation. First, if projects are evaluated before the project start, multiple projects can be compared, and the organization can choose the most beneficial one [15]. Second, evaluation enables controlling and management of an IT project. Performance and the deviation from the planned project value can be regularly observed, allowing management to consider corrective actions early on in the project [23]. Thus, the effective utilization of the organization's financial resources can be ensured, and good returns can be achieved. Third, by comparing ex post achieved results to ex ante planned values, the company is able to analyze mistakes as well as achievements, and can thus apply this information to future projects [6], [10], [11], [24].

To implement these objectives, literature offers a wide range of evaluation methods. According to Beer et al. [4] an integrated method for evaluation that considers costs, benefits, risks and interdependencies should be used. In order to consider those factors monetarily, Beer et al. [4] developed a practically applicable, integrated approach which focuses exclusively on point in time evaluation. However, Beer et al. [4] state that an integrated method for evaluation should comprise the entire lifecycle of an IT project. Thus, an IT project should be evaluated before it starts (ex ante), during its runtime (ex nunc) and after it ends (ex post) [16].

Ex ante and ex post evaluation alone might not be sufficient for successful IT project management because they do not consider possible changes during the course of a project [24]. As changes in a project's environment can unfavorably affect its successful completion [9], they should be managed [17]. Without proper controlling and management of those changes, an IT project can be subject to failure, or may have to be abandoned [9]. Since each re-evaluation provides additional information, re-evaluation during the course of a project is increasingly considered an opportunity to reduce causes of failure and might thus improve decision-making [8], [24]. Being aware of the current state of a project, a project manager has a chance to successfully turn around, or sensibly abandon an IT project [21]. Furthermore, early warning signs that indicate problems can be identified long before project failure. Thus, the deviation of the project value can be detected early, and management can then decide more quickly whether and which corrective actions they want to take [9], [17]. In contrast, if the project is not monitored over time, management is oblivious to the project's state. To prevent this, IT project evaluation over time is required [5], [16], [19], [24].

In practice, evaluation is usually conducted by a detailed cost valuation while risks, interdependencies and benefits are oftentimes neglected [6]. Furthermore, formal evaluation methods are rarely used by practitioners. One of the major reasons is that the practical application of formal methods is difficult. The identification and quantification of relevant costs and benefits of an IT project are especially challenging tasks [1], [4], [26]. Thus, organizations may consider such evaluations to be difficult and costly, and may thus refrain from implementation [20]. Another reason may be that managers do not understand the importance and economic potential of the evaluation [25]. Furthermore, lack of time, management support and organizational structure can hinder formal evaluation [3]. Another problem might be that formal evaluation methods oftentimes focus solely on ex ante situations and do not make a statement about at what point in time management should re-evaluate an IT project. A missing understanding about when to evaluate an IT project appears to be a central issue for managers [16], [24]. In literature few statements about the point in time of re-evaluation can be found. If addressed at all, predetermined review intervals are suggested [9], [18].

Most procedures like for example PRINCE2 do not regard the cash flow-based value of an IT project. Thus, the risk that the initial project value changes over time and that losses due to too early or too late re-evaluation may occur is not addressed. The longer a project is not re-evaluated the higher the probability that the project value will deviate substantially from its initial value. This deviation influences the project performance as costs and low returns might occur. To take these consequences into account, risky cash flows should be considered.

The procedures of literature and practice mentioned above might not be in line with value-oriented principles, because they do not monitor the value contribution of a project. They deliver a point in time for re-evaluation that does not regard the development and the risk exposure of the project during its runtime. Thus, the project might either be re-evaluated too early, when the project value did not essentially deviate from its initial value, or too late, when the project value already strongly deviated from the initial estimation. On the one hand, the project might be re-evaluated at a point in time where the probability that the project value considerably changed is low. Thus, re-evaluation might not have been necessary from a cash flow-based perspective. Since re-evaluation utilizes money and time, each re-evaluation consumes value. If the project is re-evaluated too early, the company's resources are unnecessarily spent. Thus, it is economically reasonable to accept a certain "blind flight" phase to hold down the costs of re-evaluation. On the other hand, if the IT project is re-evaluated too late, the "blind flight" phase may continue too long and major issues that might appear during the "blind flight" may be discovered too late. Thus, the project value can considerably deviate from its initial estimation without being recognized, and management cannot take corrective actions. In this case, management hazards project value and high losses may occur. Since both too early and too late re-evaluation could potentially consume value, we admit that the establishment of a predetermined review interval that does not regard the risky cash flows of an IT project might not be a reasonable approach. Therefore, we want to extend project evaluation by considering the risky cash flows that picture the deviation of the project value from its initial estimation. Thus, we determine the optimal time until re-evaluation that ensures that the project is neither re-evaluated too early nor too late. For this purpose the following research question is discussed in this article:

Research Question: *What is the optimal time until re-evaluation for an IT project based on risky cash flows?*

3 Determination of the Optimal Time until Re-Evaluation

As a first step to answer this research question, we provide an economic model that is able to determine the optimal time until re-evaluation of an IT project for one period, considering risky cash flows. It enables the determination of how long the "blind flight" is acceptable until the next re-evaluation is necessary.

3.1 Setting

IT projects are executed in a dynamic environment. Thus, their value can change over time. On the one hand, anticipated changes of an IT project's circumstances occur during its runtime. Thus, the company knows that the project value can deviate from its initial estimation. However, the company does neither know how circumstances vary, nor which impact the changing circumstances might have on the IT project. On the other hand, highly unlikely and completely unexpected events with a possible impact on the IT project can arise, such as natural or economic disasters. The company is not able to anticipate these kinds of events. As completely unexpected events require different treatment than anticipated changes, we only consider anticipated changes, while very unlikely and completely unexpected events are excluded from contemplation. If an unforeseen event occurs, a non-scheduled re-evaluation becomes necessary.

In the following section, we focus on a situation in which a company wishes to determine the optimal time until re-evaluation for a given IT project, considering anticipated changes. Therefore, we determine the time interval during which the project value is unlikely to undercut a threshold that is defined by management.
To determine the monetary project value, different approaches like Earned Value Management Method [2], Net Present Value (NPV) [14], [30] or the Real Options Theory [27] can be taken into account. As the NPV is oftentimes used in practice and literature, in the following we use the expected NPV.
By considering cash flows, the project's NPV discounted to project start can be calculated. They contain estimated payouts and incomes that can occur during the entire course of the IT project. As all past and future cash flows are taken into account, the NPV refers to the entire project progression, and the deviation of the actual project value from the planned value can be observed. By using the NPV, the project value stays comparable during its entire runtime, and thus performance can be measured monetarily. As the project value especially of very long and complicated projects is influenced by a variety of different factors, the cash flows are uncertain. Figure 1 illustrates four possible sample paths of the project's NPV. Starting from the NPV at a certain point in time, the value can follow any of the given, or any other sample path.

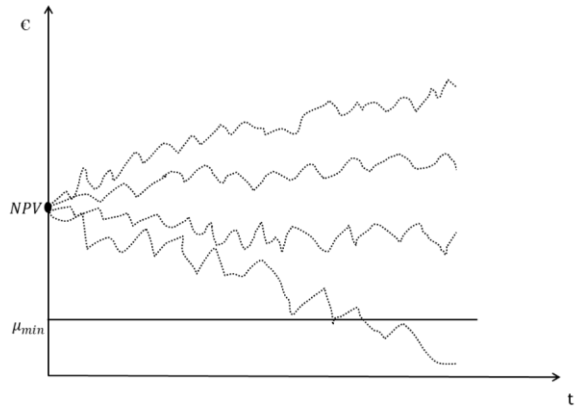

Fig. 1. Development of the Project Value over Time

Risk is depicted by the standard deviation. As positive and negative deviations do not meet the expected project value this two-sided risk measure is able to reflect reality. While the negative deviation obviously results in less project value for the company, a positive deviation is not desired as well. As resources are supposed to be deployed efficiently freed up resources can be allocated to other projects and improve the efficiency of the overall project portfolio. One sided risk measures like the expected shortfall or the Value at Risk do not reflect this characteristic.

Furthermore, figure 1 shows the threshold for the project μ_{min}. In order to manage the project in a good way, a threshold that is not supposed to be undercut should be defined before the project starts. Thus, management claims that the project value has to exceed a pre-defined project value. If this value is undercut, the project can be regarded as failed. In this model, the threshold is represented by a certain NPV μ_{min}. On the basis of investment theory, the smallest acceptable NPV for an investment is zero. A project with a NPV that is greater than zero can cause a positive value contribution, and thus it is aspired by the company. In contrast to that, μ_{min} here represents the expectations of the management towards the IT project, and thus can attain any value.

μ_{min} can also be used for damage control. If the project has to be implemented for example for regulatory reasons, the project might be accepted even though it has a negative NPV. In this case, μ_{min} represents the bottom line above which damage caused by the IT project is tolerated. Thus, μ_{min} can also be negative. Generally, management wants to be informed if μ_{min} is undercut so that corrective actions can be taken in an effort to avoid higher losses.

3.2 Assumptions

Since the NPV of an IT project is comprised of uncertain cash flows, the NPV is uncertain. Because circumstances and requirements of the project change with time, the project's NPV might change as demonstrated in figure 1. Thus, the changing project value can be depicted by a stochastic process.

Assumption 1: *The IT project's NPV follows an arithmetic Brownian motion.*

An arithmetic Brownian motion is a special kind of stochastic process. Especially long term projects with a large and complicated scope can be depicted this way as they are influenced by many different factors that might behave like they change randomly. This behavior is depicted by an arithmetic Brownian motion. To assume an arithmetic Brownian motion, however, three requirements have to be fulfilled [7].

First, the probability distribution of the future values of the stochastic process only depends on its current value, and is not influenced by the past, or by any other information. As all available information about the state of the IT project is considered when determining the actual project value, no other factors influence this value. Thus, the probability distribution for the future value of the IT project can be determined, if the current project value is known.

Second, independent increments exist in the arithmetic Brownian motion. "This means that the probability distribution for the change in the process over any time interval is independent of any other (nonoverlapping) time interval" [7]. Due to the variety of factors influencing the development of an IT project, for reasons of simplification, we assume that the probability for the changes in the project value is independent of past and future changes.

Third, changes in the stochastic process are (a) normally distributed and (b) the variance increases linearly over time.

(a) requires the change of an IT project's NPV to be normally distributed. As this change is a linear transformation of the NPV itself, the IT project's NPV also has to be normally distributed. As project cash flows are influenced by normally distributed market risks as well as other factors, we assume that the cash flows and therewith the NPV of the project value is normally distributed. It can be represented by a normally distributed random variable NPV $\sim N(\mu, \sigma)$ [14], [30]. The expected value at the point in time of the n-th re-evaluation ($n = 0, 1, 2, \dots, N$) is given by $E(NPV) = \mu_n$. Risk is conceived as symmetric positive or negative deviation from the given expected value per day, and is quantified by the standard deviation $\sigma(NPV) = \sigma_n$.

(b) implies that the variance of the project value is multiplied by the duration of the "blind flight". To model a linear increase, the risk exposure of the project value should stay constant over time. Since varying cash flows during and after the end of the project occur [6] we state the simplifying assumption that the possible deviation for each time interval of the same length remains constant between the points in time of evaluation and re-evaluation. The resulting deviation of the project value from its initial estimation increases with the length of the "blind flight", and is therefore multiplied by the duration thereof.

As the model exclusively enables one-at-a-time evaluation, the requirements for an arithmetic Brownian motion only have to remain valid until the end of an evaluation interval. Since an iterative determination of the optimal time until re-evaluation might be enabled in a re-evaluation cycle, a re-assessment of the project parameters enables an approximately realistic depiction of the real world. Thus, all requirements for an arithmetic Brownian motion are met by a one-at-a-time re-evaluation of an IT project.

To specify the project value, the project's expected NPV μ_n and the associated risk σ_n have to be determined. As this is very difficult in reality, Beer et al. [4] tried to develop a pragmatic method to determine μ_n and σ_n for an IT project. Those parameters can be determined at any time in the project. Nevertheless, as previously mentioned, the changing environment and circumstances continuously modify the project's requirements, and thus influence the project parameters. Since evaluation takes time, the input parameters for the model are usually outdated. Furthermore, the process of deciding which corrective actions should be taken also requires time. Thus, a time lag occurs. However, for reasons of simplification, we state the following assumption.

Assumption 2: *Re-evaluation can be conducted at any time during the project. After each re-evaluation, subsequent actions can be taken. Neither re-evaluations nor subsequent actions require time for accomplishment.*

As the subsequent actions are individual and can differ significantly for each project we do not focus on this topic in the following.

3.3 Model

After having determined the initial project value, its development during the course of the IT project is uncertain and the "blind flight" begins. Since the NPV follows an arithmetic Brownian motion, a cone that illustrates the deviation of the project value over time can be determined. By determining the cone, management knows the value range within which the NPV probably deviates during the project and can thus get an initial appraisement of its development.

For each single point in time, a $(1-p)$-confidence interval for the NPV that indicates in which range the NPV lies with a probability of $(1-p)$ can be compiled. $p \in]0;1[$ represents the probability that the project's NPV at a certain point in time does not lie within the confidence interval. Thus $(1-p)$ is the probability that the NPV lies within the confidence interval. The width of the confidence interval p, is defined by management.

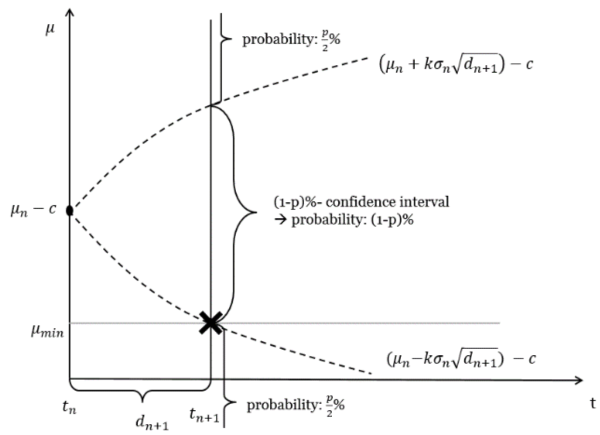

Fig. 2. Determination of the Optimal Time until Re-Evaluation $d^*_{\boldsymbol{n+1}}$

Figure 2 illustrates the $(1-p)$-confidence interval at the point in time of the $n+1$-st re-evaluation t_{n+1}. The part within the interval limits reveals where the expected NPV of the IT project lies with a probability of $(1-p)$. Consequently, the IT project's expected NPV is smaller than the lower limit of the confidence interval with a probability of $\frac{p}{2}$. By determining the lower limit of the confidence interval, management knows that in t_{n+1} the NPV does lie above this value with a probability of $\left(1-\frac{p}{2}\right)$. If management chooses that μ_{min} is not supposed to be undercut with a probability of 10% ($\frac{p}{2}=10\%$), the project value lies within the confidence interval with a probability of 80%. Furthermore, the value lies above the upper limit and below the lower limit of the confidence interval with a probability of 10% each ($p=20\%$).

The value of the interval limits depends on two parameters. On the one hand, the interval limits are influenced by the value that management chooses for the probability p. On the other hand, the limits diverge over time, because the standard deviation changes with time. Since the variance ${\sigma_n}^2$ grows in proportion to time, the standard deviation σ_n increases in proportion to the square root of time $\sqrt{d_{n+1}}$ [7]. d_{n+1} is the duration of the "blind flight", and therefore the time interval from the n-th until the $n+1$-st re-evaluation. Thus, the standard deviation in t_{n+1} is $\sigma_n\sqrt{d_{n+1}}$, for example the standard deviation of a project increases by the factor 3 in 9 days.

Because the value of the interval limits also depends on the probability p, a typical measure to determine the value for one point in time is the $k\sigma$-range of the normally distributed NPV. k measures the deviation from the expected NPV in multiples of σ_n. Thus, the lower (upper) limit of the confidence interval corresponds to the negative (positive) deviation of the expected NPV. The wider the confidence interval, the smaller is the probability that the expected NPV falls short of the lower limit. The value of k can be deduced from the distribution function for the standard-normal distribution. With $\Phi(x)$ denoting the standardized normal distribution function, we know for the distribution of μ_{n+1} that

$$P\left(\mu_n - k\sigma_n\sqrt{d_{n+1}} \leq \mu_{n+1} \leq \mu_n + k\sigma_n\sqrt{d_{n+1}}\right) = 2\,\Phi(k) - 1 = (1-p) \qquad (1)$$

Thus, we can deduce, for example, that for a 66%-confidence interval k=1 and for an 80%-confidence interval k=1.28. By choosing different confidence intervals, management can decide with which probability the project value can fall short of or exceed its limits. To retain generality, we consider the variable k.

Furthermore, the costs of each re-evaluation c should be considered for the determination of the interval limits, as each evaluation utilizes the company's resources and thus decreases the project value. Therefore, we define the costs of re-evaluation of an IT project to be greater than zero ($c > 0$). To depict the development of the interval limits over time, figure 2 illustrates the resulting cone. The limits of the cone can be calculated [7]. The lower limit of the cone is defined as

$$LL(d) = \left(\mu_n - k\sigma_n\sqrt{d_{n+1}}\right) - c \qquad (2)$$

As previously outlined, management does not want the IT project's NPV to fall short of μ_{min}. Therefore, the point of intersection between the lower limit of the cone and μ_{min} is calculated. At this point in time the IT project's expected NPV does not fall short of μ_{min} with a probability of $(1 - \frac{p}{2})$.

$$\left(\mu_n - k\sigma_n\sqrt{d_{n+1}}\right) - c = \mu_{min} \qquad (3)$$

By solving equation (3), we receive a possible solution.

$$\hat{d}_{n+1} = \left(\frac{\mu_n - \mu_{min} - c}{k\sigma_n}\right)^2 \qquad (4)$$

This possible solution should be checked for validity by verifying whether or not $\hat{d}_{n+1}$ is smaller than the remaining project term. If $\hat{d}_{n+1}$ is smaller than the remaining project term, ${d^*}_{n+1} = \hat{d}_{n+1}$ becomes the permitted solution and the answer to the research question. If $\hat{d}_{n+1}$ is larger than the remaining project term, the project is completed without further re-evaluation. If the calculated point in time of re-evaluation cannot be realized, management should find the next possible point in time of re-evaluation before and after. Those two points should be evaluated, compared and the economically preferred point in time should be used. The project should be re-evaluated when the optimal time until re-evaluation ${d^*}_{n+1}$ according to the risk exposure of a project's cash flows has passed, and corrective actions have potentially become necessary. By adhering to this process, management can recognize problems early enough to avoid large losses due to project failure without spending too much money on unnecessarily frequent re-evaluation.

So far the model enables the determination of the time until re-evaluation of an IT project for one-at-a-time re-evaluation. To enable the application to multiple periods the model should be integrated into a re-evaluation cycle. Thus, management can apply corrective actions after each evaluation period. As corrective actions differ for each project we refrain from specific recommendations to project managers. The application of a re-evaluation cycle for evaluating an IT project over time enables project management according to value oriented principles.

4 Model Evaluation

In the following chapter we want to show that project re-evaluation after the optimal time until re-evaluation that regards the risky cash flows of an IT project is economically more reasonable than re-evaluating a project after a predetermined evaluation interval. Therefore, the following chapter outlines the considerable advantages, which can be realized by applying the model presented above based upon simulated data.

Since a sufficient amount of IT project data for a formal evaluation is hard to acquire, we conduct a Monte Carlo simulation to create real world settings by varying the input parameters. To show the advantages that can be utilized by applying the developed model, we compare the optimal time until re-evaluation ($d^*{}_{n+1}$) to non-optimized re-evaluation intervals (d_{reg}).

In the following, we distinguish how and why the optimal time until re-evaluation delivers superior results for two settings. On the one hand, if the optimal time until re-evaluation is undercut, financial loss caused by evaluating too early can occur. On the other hand, the company does additionally hazard project value caused by evaluating too late.

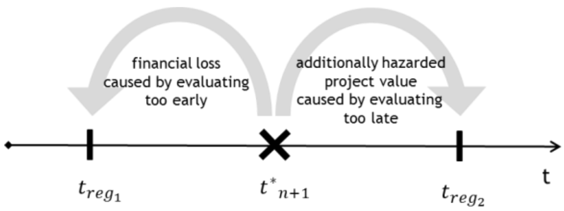

Fig. 3. Consequences of Non-Optimized Re-Evaluation

As figure 3 shows, if the point in time for the regular re-evaluation t_{reg_1} lies before the point in time for the optimal re-evaluation $t^*{}_{n+1}$, the IT project is re-evaluated too early. Thus, the company's resources are unnecessarily spent. The project is re-evaluated even though the "blind flight" did not take long and it is not likely that the project value significantly deviates from its initial expectation. The money spent for this early evaluation can be described as financial loss. It can be calculated by considering the difference between the optimal time until re-evaluation $d^*{}_{n+1}$, and the regular evaluation interval d_{reg} in proportion to d_{reg}. As a result of these calculations, the proportional premature evaluation can be identified. To capture the premature evaluation in monetary units, we multiply it by the costs of one re-evaluation. Thus, we calculate the financial loss caused by evaluating too early with the formula $\left(c\,\frac{d^*{}_{n+1}-d_{reg}}{d_{reg}}\right)$. To enable a comparison, the financial loss is related to the initial project value.

If the point in time for the regular re-evaluation t_{reg_2} lies after the point in time for the optimal re-evaluation $t^*{}_{n+1}$, the IT project is re-evaluated too late (see figure 3) as problems that cause a deviation of the project value from its initial expectation might be discovered too late. If management does not recognize the deviation, they hazard losing project value, and high losses due to project failure can occur.

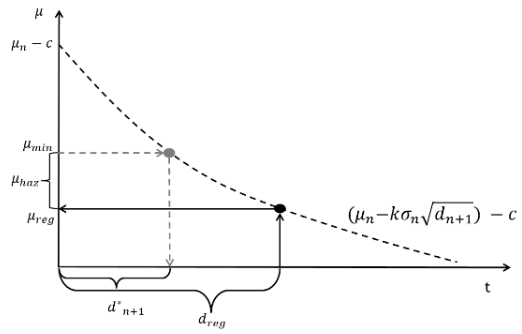

Fig. 4. Additionally Hazarded Project Value caused by Evaluating too Late

If μ_{min} is used as a threshold for the project, the model delivers d^*_{n+1} as the optimal time until re-evaluation. If a regular re-evaluation interval d_{reg} that is longer than d^*_{n+1} is used, the introduced model delivers μ_{reg} as the lower limit of the confidence interval in t_{reg}, which is not undercut with a probability of 10%. Since μ_{reg} is smaller than μ_{min}, the threshold set by the company is undercut (see figure 4). The difference between μ_{min} and μ_{reg} determines the monetary project value that is additionally hazarded μ_{haz}. This value is not definitely lost, but the risk that μ_{min} is undercut increases. To enable a comparison of several IT projects with a different project value, the additionally hazarded project value also is related to the initial project value.

To derive conclusions we examine the consequences of non-optimized evaluation by means of a Monte Carlo simulation. Thus, we outline two exemplary scenarios (re-evaluation after 30 and 180 days [24]) that represent regular re-evaluation. During our evaluation we used more scenarios which lead to the same conclusion.

Following the simulation approach of IT projects in Fridgen and Müller [13], we simulate 10.000 IT projects with an expected net present value and the associated risk (μ_n, σ_n). The model parameters can be found in table 1.

For each simulated IT project, the optimal time until re-evaluation d^*_{n+1} is calculated. We then calculate the financial loss caused by evaluating too early, and the additionally hazarded project value caused by evaluating too late for each scenario.

Table 1. Input Parameters

Input parameter	*Value*	*Distribution*
μ_n	[10; 10,000] (in thousand €)	equal
σ_n	[0.05%; 5%] of μ_n	equal

We set μ_{min} to 75% of μ_n. $\frac{p}{2}$ is supposed to be 10%. c is assumed to be 1% of μ_n.

Table 2 shows, the fraction of the simulated projects that are evaluated too early, as well as the average and the highest financial loss caused by evaluating too early as a fraction of the initial project value. In general, it can be stated that the shorter the regular re-evaluation interval is, the higher the financial loss caused by evaluating too early will be. Additionally, table 2 illustrates, as expected, that the shorter the evaluation interval, the more simulated projects are evaluated too early.

Table 2. Financial Loss caused by Evaluating too Early

Regular interval	*Fraction of projects evaluated too early*	*Average financial loss*	*Highest financial loss*
30 days	62%	6.6%	45.9%
180 days	19%	2.2%	6.8%

Table 3 shows the fraction of the simulated projects that are evaluated too late, as well as the average and the highest additionally hazarded project value caused by evaluating too late as a fraction of the initial project value. It can thus be stated that the greater the regular re-evaluation interval is, the more project value is hazarded. Furthermore, as expected, the greater the evaluation interval is, the more likely it is that the simulated IT projects will be evaluated too late.

Table 2. Additionally Hazarded Project Value caused by Evaluating too Late

Regular interval	*Fraction of projects evaluated too late*	*Average ad. hazarded project value*	*Highest ad. hazarded project value*
30 days	35%	5.8%	11.1%
180 days	80%	31.2%	61.9%

As we can see from the model, an optimal point in time for project re-evaluation can be identified according to the risk exposure of a project's cash flows. At this point corrective actions have potentially become necessary. By conducting this procedure, management can recognize problems early enough to avoid large losses due to project failure without spending too much money on unnecessarily frequent re-evaluation. Therefore, the model determines the optimal time until re-evaluation, and thus enhances existing evaluation methods by a risky cash flow-oriented view. As we derive from the model's evaluation, a company hazards more project value or spends more money than necessary if a regular evaluation interval is applied. Thus, we can conclude that the determination of the optimal time until re-evaluation considering risky cash flows can improve IT project management and therefore preserves financial resources.

5 Practical Implications, Limitations and Outlook

When an IT project fails, high losses can occur. Through the progressional evaluation of a project, transparency regarding risky cash flows could help to avoid high losses, given that appropriate corrective actions are taken. Best practices already provide methods to solve some of the application problems, but do not regard the risky cash flows, and therewith also disregard the potential change in project value. This paper provides a guideline for management regarding at what point in time an IT project should be re-evaluated. By integrating risky cash flows to determine the optimal time until re-evaluation, existing project management approaches can be enhanced by an economic aspect.

The introduced model shows that the development of the project value over time should be assessed, and thus issues influencing the project value can be recognized early. The evaluation of the introduced model shows that if the predetermined evaluation interval is shorter than the optimal result of the model, the company loses financial resources because a re-evaluation is executed even though the risk of high losses for the company is low. In this case, the company might lose 7% of the initial project value on average for the sole reason that the IT project was re-evaluated too early. If the regular evaluation interval is longer than the calculated optimum, the deviation of the project value might not be discovered in time, because the "blind flight" takes too long. As a result the company additionally hazards project value. If a project is re-evaluated after 180 days instead of the optimal time until re-evaluation on average more than 31% of the project value is additionally hazarded. By determining the optimal time until re-evaluation, both effects can be avoided and management can save project value. Thus, an economically reasonable model for IT project re-evaluation is provided.

With regard to the limitations of our findings, we have to mention that the IT project's NPV in the model is regarded as a normally distributed random variable, and therefore we use an arithmetic Brownian motion to picture the project progression. Nevertheless, an arithmetic Brownian motion might not be able to depict every kind of IT project. Other stochastic processes might better be able to depict project progression. Moreover, it might be hard to determine the input variables in practice. Since the model only enables one-at-a-time determination of the time until re-evaluation, the influence of the model on multiple periods cannot be considered.

As this is a first approach in the direction to determine an optimal time until re-evaluation future research should extend the model to other stochastic processes in an effort to represent e. g. skewed distributions, fat tails, and trends. Furthermore, a Bayesian formulation that considers the foreground knowledge of a manager and newly arriving information might be used to depict the expectations towards the development of the project in future research. As the developed model has not yet been exhaustively tested with empirical data a computation of the coherences and relationships within the model based on real world data should be provided. Furthermore, a sensitivity analysis to measure the effect of estimation errors on the model parameters is subject to further research. Since the model only enables one-at-a-time determination of the time until re-evaluation, the influence of the model on multiple periods cannot be considered. A re-evaluation cycle that enables the repetitive utilization of the introduced model might state a first step for the application of the model to multiple periods. Furthermore, future research should provide a categorization for the project value and consider corrective actions and their consequences.

Although the model pictures reality in a constrained way, it provides a basis for firms to improve their re-evaluation strategies in IT projects by economically considering the risky cash flows of an IT project. The model evaluation shows that companies should not stick to fixed evaluation intervals but consider individual ones for their projects. Thus, companies might be able to re-evaluate their IT projects more efficiently and project management can be improved. Even though it is still difficult to determine the relevant input parameter in practice, the model can be used as a guidance for project management. The paper furthermore contributes to the scientific knowledge base by creating awareness for a practically relevant topic that has not yet been deeply discussed in project management literature. Moreover, the model is a theoretically sound economical approach, which allows for further development, and delivers insights to IT project re-evaluation. Thus, IS researchers should further be concerned with the examination of model intrinsic correlations and derive further hypotheses for empirical testing.

References

1. Alshawi, S., Irani, Z., Baldwin, L.: Benchmarking information technology investment and benefits extraction. Benchmarking: An International Journal, 10, pp. 414-423 (2003)
2. Anbari, F. T.: Earned value project management method and extensions. IEEE Eng. Manage. Rev., 32, pp. 97-110 (2004)
3. Ballantine, J. A., Galliers, R. D., Stray, S. J.: Information systems/technology evaluation practices: evidence from UK organizations. Journal of Information Technology, 11, pp. 129-141 (1996)
4. Beer, M., Fridgen, G., Müller, H., Wolf, T.: Benefits Quantification in IT Projects. In: Proceedings of the 11th Conference on Wirtschaftsinformatik (WI 2013), Vol. 1, pp. 707-720. Leipzig, Germany (2013)
5. Beynon-Davies, P., Owens, I., Williams, M. D.: Information systems evaluation and the information systems development process. Journal of Enterprise Information Management, 17, pp. 276-282 (2004)
6. Buhl, H. U.: The Contribution of Business and Information Systems Engineering to the Early Recognition and Avoidance of “Black Swans” in IT Projects. Business & Information Systems Engineering, 2012, pp. 55-59 (2012)
7. Dixit, A. K., Pindyck, R. S.: Investment under uncertainty. Princeton university press, Princeton (1994)
8. Eveleens, J. L., Verhoef, C.: Quantifying IT forecast quality. Science of Computer Programming, 74, pp. 934-988 (2009)
9. Ewusi-Mensah, K., Przasnyski, Z. H.: On information systems project abandonment: an exploratory study of organizational practices. MIS Quarterly, 15, pp. 67-86 (1991)
10. Farbey, B., Land, F., Targett, D.: Evaluating investments in IT. Journal of Information Technology, 7, pp. 109-122 (1992)
11. Farbey, B., Land, F., Targett, D.: Moving IS evaluation forward: learning themes and research issues. The Journal of Strategic Information Systems, 8, pp. 189-207 (1999)
12. Flyvbjerg, B., Budzier, A.: Why Your IT Project May Be Riskier Than You Think. Harvard Business Review, 89, pp. 23-25 (2011)

13. Fridgen, G., Müller, H.: An Approach for Portfolio Selection in Multi-Vendor IT Outsourcing. In: Proceedings of the 32nd International Conference on Information Systems (ICIS), Shanghai, China (2011)
14. Fridgen, G., Müller, H.: Risk/Cost Valuation of Fixed Price IT Outsourcing in a Portfolio Context. In: Proceedings of the 30th International Conference on Information Systems (ICIS), Phoenix, Arizona (2009)
15. Gunasekaran, A., Ngai, E., McGaughey, R. E.: Information technology and systems justification: A review for research and applications. European Journal of Operational Research, 173, pp. 957-983 (2006)
16. Irani, Z.: Investment evaluation within project management: an information systems perspective. Journal of the Operational Research Society, 61, pp. 917-928 (2010)
17. Kappelman, L. A., McKeeman, R., Zhang, L.: Early warning signs of IT project failure: The dominant dozen. Information Systems Management, 23, pp. 31-36 (2006)
18. Keil, M.: Pulling the plug: software project management and the problem of project escalation. MIS Quarterly, 19, pp. 421-448 (1995)
19. Krcmar, H., Lanzinner, S., Leimeister, J. M.: Toward IT Value Mapping: An Approach to Value-Based IT Management. In: Proceedings of the 14th Americas Conference on Information Systems (AMCIS 2008), Toronto, Ontario (2008)
20. Lin, C., McDermid, D., Pervan, G.: IS/IT investment evaluation and benefits realization issues in Australia. Journal of research and practice in information technology, 37, pp. 235-251 (2005)
21. Montealegre, R., Keil, M.: De-escalating information technology projects: lessons from the Denver International Airport. MIS Quarterly, 24, pp. 417-447 (2000)
22. Project Management Institute: A Guide to the Project Management Body of Knowledge, vol. 4. Project Management Institute, Newton Square (2008)
23. Remenyi, D., Sherwood-Smith, M.: Maximise information systems value by continuous participative evaluation. Logistics Information Management, 12, pp. 14-31 (1999)
24. Remenyi, D., Bannister, F., Money, A.: The effective measurement and management of ICT costs and benefits. Elsevier, Oxford (2007)
25. Seddon, P. B., Graeser, V., Willcocks, L.: Measuring organizational IS effectiveness: An overview and update of senior management perspectives. ACM SIGMIS Database, 33, pp. 11-28 (2002)
26. Ullrich, C.: Valuation of IT Investments Using Real Options Theory. BISE, 5, pp. 331-341 (2013)
27. Walter, S. G., Spitta, T.: Approaches to the ex-ante evaluation of investments into information systems. WIRTSCHAFTSINFORMATIK, 46, pp. 171-180 (2004)
28. Willcocks, L.: Information Management: The evaluation of information systems investments. 1. ed. Chapman & Hall, London u.a (1994)
29. Zimmermann, S., Katzmarzik, A., Kundisch, D.: IT Sourcing Portfolio Management for IT Service Providers - A Risk/Cost Perspective. In: Proceedings of 29th International Conference on Information Systems (ICIS), Paris, France (2008)