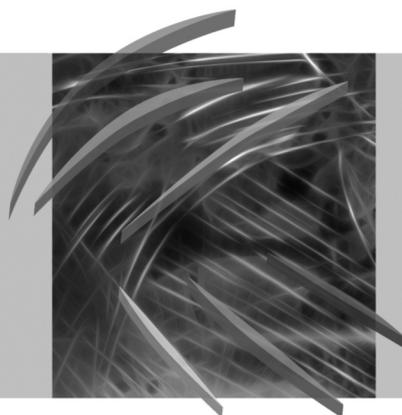


Advanced Information Technologies for Management – AITM 2011 Information Systems in Business



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ISSN 1899-3192

ISBN 978-83-7695-178-2

The original version: printed

Printing: Printing House TOTEM

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QUANTITATIVE RISK ANALYSIS OF IT PROJECTS

Abstract: Risk management is a very important and unfortunately often belittled process in IT project management. Meanwhile, risk identification and analysis, as well as other elements of this process are necessary for effective project management. The article points out the important role of quantitative risk analysis, and discusses the most commonly used methods: sensitivity analysis, EMV, Monte Carlo simulations, experts' survey, decision trees and PERT. It also discusses tools to help risk analysis.

Keywords: project risk management, risk analysis, it projects, quantitative risk analysis.

1. Introduction

IT projects are characterized by specific features. At the same time, there are different risks and their impact on the project, depending on whether we are dealing with the implementation projects, or with projects associated with development of information systems.

Among IT projects implemented in enterprises, the majority of the projects of this group are implementation projects. The difficulties associated with their implementation are due firstly to the need to tailor the system to specific customer requirements. Another source of potential risks are communication problems [Flasiński 2006, p. 29]. On the other hand the projects related to the construction of information systems are characterized by very high complexity. These are usually multi-stage projects which require cooperation of specialists experienced in many different aspects, not only IT professionals, but also representatives of the end user.

A particular source of risk in IT projects is project planning, because of their complexity and in many cases uniqueness. Besides, in IT projects it is often extremely difficult to estimate the duration of the project correctly. It is characteristic, especially regarding innovative projects, implemented in new technologies, etc.

Risk management is an essential aspect of IT project management and is inextricably connected with the effectiveness of the project [Dudycz, Dyczkowski 2006, p. 70]. This article aims to present the methods used in the process of quantitative risk analysis of IT project and an indication of how the IT tools could support the use of

these methods. The author also wants to point out the important role of risk management in project implementation. Likewise project managers increasingly recognize the importance of the problem, there are also trends to outsource the risk management [Jesionek 2007].

However, before proceeding to methods used in the risk analysis, we determine the evaluation place in the whole risk management process, and also the place of that process in the project implementation.

2. Stages of the risk management process

The risk management process consists of many stages. The place of risk management in the process of project realization is difficult to determine. Competent project management requires the repetition of phases of the risk management process, particularly when during the project realization there are identified and evaluated new risks. Depending on the concept of the risk management approaches, different phases of this process are mentioned. In each of these approaches there were other phases, which were separated, but it is important to focus on the fact that all approaches contain the steps associated with the identification and analysis of risks in projects (see e.g. [Bradley 2003; Chapman, Ward 1997; PMBOK 2008; PRINCE 2 2010]). These phases of the risk management process will be crucial for this study. No matter what names are assigned to individual phases, all of these concepts include some basic activities that have been assembled and presented in Figure 1 in the model adopted by the author. It will be used to discuss the risk management process in a software project, in particular the stage of risk analysis in section 3.

In the project risk management model adopted by the author, there are six distinguished steps:

1. Identification is the element of risk management process, which aims to identify relevant risks of the project [Pritchard 2002, p. 30]. These risks are potential ones, the occurrence of which will impact the cost of the project. The aim of the process of the risks identification is creating a list of all potential threats that are understood as an occurrence which would have a negative effect on the project. The most important is the detection of these risks that are crucial to the project. The list of potential risks is systematized due to the type of threats. Suitable systematization of all risks is essential for proper risk analysis of the project.

The literature lists several different classifications of risks in projects. And so Pritchard [2002, p. 10] identifies five main levels: technical, software, maintenance (service), cost, and schedules. The PMI defines four categories according to which potential risks are determined: technical, external, organizational, and related to project management [PMBOK 2008, p. 280]. For each of these categories there are several subcategories. In the PRINCE 2 methodology two fundamental groups of risk related to business and project aspects are distinguished. No matter what classification is adopted in a specific project, risk systematizing has several very impor-

tant functions in the risk management process. First of all, it makes it easier to determine the identification of potential risks. Secondly, in the evaluation phase, through systematization and then determining the risk influences related to particular categories and subcategories, there is a possibility to define the overall project risk.

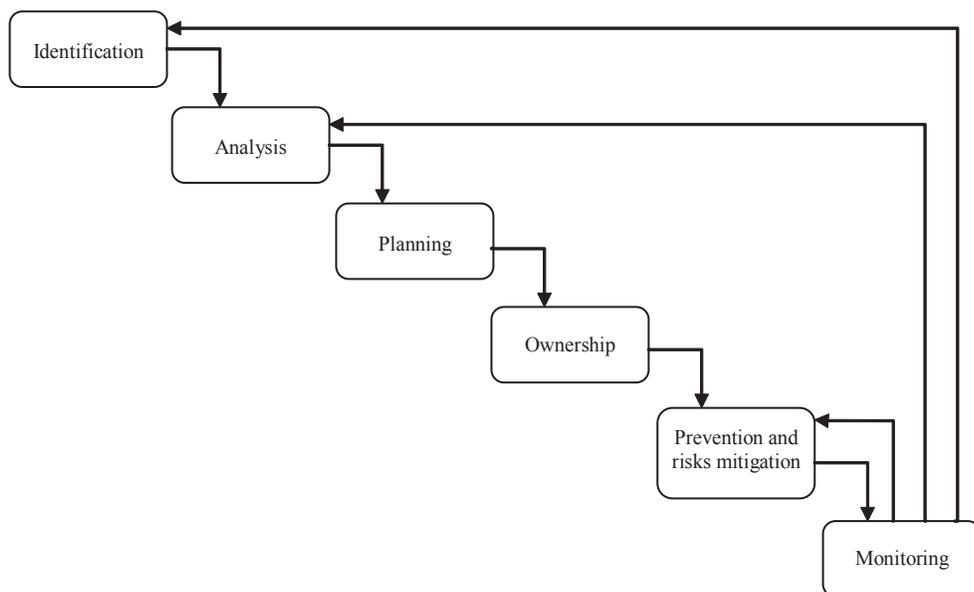


Figure 1. Phases of risk management

2. Analysis – rating is based on an analysis of unfavourable events, from the viewpoint of the project realization. Assessment should be done according to the probability of its occurrence, generating costs and also the impact on the risk concerned in the entire project. The result of the evaluation has to be a cumulative assessment of project risks. Qualitative analysis is to prioritize risks, then subsequent quantitative analysis determines the probability of risks and their impact on the project. The quantitative analysis carries out the ranking of each risks and it calculates the total impact of all risks in the project.

3. Planning – in this phase it determines actions that should be taken to prevent the occurrence of risks. It should also define what actions have to be implemented in case of an occurrence in an adverse incident. This applies to those particular risks that have an impact on the overall project risk that were assessed as high.

4. Ownership – the stage in which the responsibility is located by tracking risks.

5. Prevention and risks mitigation – performing the actions defined in the planning stage, that intend to eliminate or reduce the probability of incidents, if they occur – those that reduce their negative impact.

6. Monitoring involves tracking the existing risks or changes in the previously identified threats and detecting new ones. Continuous monitoring allows noticing early warning symptoms regarding risks. It can also bring the need of the revision related to the risk identification and, if it occurs – the need to implement the next phases of risk management in the project. And in the case of adverse incidents, previously identified and causing specific changes in the level of risk, the need to re-evaluate it could emerge. Repeating the process increases the security associated with IT project.

3. Methods of quantitative analysis of IT project risk

The literature mentions a number of quantitative methods of risk analysis, those that are recommended for project management methodologies, which will be discussed here. For example, according to PMI methodology [PMBOK, p. 298] in the risk analysis of the project, such methods as sensitivity analysis, EMV, Monte Carlo simulations can be used. However, in the literature other methods are mentioned: experts survey, decision trees, PERT.

Expert polls (used in expert survey) allow obtaining information about the risks in the project. Often the experts are required to determine the likelihood of occurrence of specified incidents and their impact on the project only in qualitative terms. Survey results are only the basis for the transformation of qualitative data into quantitative that made it possible to prepare risk analysis for the project [Pritchard 2002, p. 53]. Many of the techniques described in the literature are based on surveys of experts, a few of which will be discussed in the article.

According to the first technique, based on polls for each of the identified risks, its importance is determined in points in accordance with the occurrence likelihood and the impact that it may have on the project. The matrix according to each of the risks assigned to the risk points is in Table 1. After the points are added for each of the risks, the assessment is obtained for the whole project. The higher the score (number of points) is, the higher the risk connected with the project.

Table 1. Scoring of risk

Probability	Impact				
	minimum	low	average	big	extremely
Very high 80–100%	2.0	3.5	7.0	8.0	9.0
High 60–80%	1.5	2.0	5.0	7.0	8.0
Average 40–60%	1.2	1.8	4.0	5.0	7.0
Low 20–40%	1.0	1.5	3.0	4.0	5.0
Very low 0–20%	0.5	1.0	1.5	3.0	4.0

Source: [Pawlak 2006, p. 151].

The next technique is distinguished by risk categories, in which to each category a subjective importance is assigned (e.g. Table 2). In each of the categories there are defined threats, specified according to the risk value to the formula of Table 3.

Table 2. Categories of risk importance

Categories	Importance
Technical	3
Organizational	4
Financial	5
External	4

Source: [Frączkowski 2003, p. 105].

Table 3. Risk value

Value	Meaning
1	Negligible
2	Low
3	Average
4	High
5	Catastrophic

Source: [Frączkowski 2003, p. 105].

For each of the identified risks, previously catalogued, an example according to pattern placed in Table 3, we assign a quantitative measure of assessment in accordance with the Table 4. Then, for each category we calculate the level of risk according to the formula [Frączkowski 2003, p. 106]:

$$R_x = \frac{\sum_v + R_v}{n}.$$

Subsequently, in order to eliminate extreme and subjective assessments of the risks we normalize the risk category according to the formula:

$$R_{zn_x} = \frac{R_x + w_x}{w_{sr}}.$$

Based on the calculated risk levels for each category, it is possible to compute the normalized risk for the entire project:

$$R_{zn_calc} = \frac{\sum_x R_{zn_x}}{k},$$

where: n – number of tasks within a category,

R_v – risk value for the task in a given category,

k – number of categories,

w_x – risk category importance,

w_{sr} – average importance is calculated according to the formula: $w_{sr} = \frac{\sum_x w_x}{k}$.

Regardless of which method or technique of risk analysis we assume to evaluate a single task, to assess the risk of the entire project, it should be determined what impact on its level have different categories of risk. In previous studies the author suggested to calculate the importance of the different categories or subcategories, by using the method of AHP [Bryndza 2006, p. 395]. AHP method specifies the importance of elements affecting the goal, in this case – the impact of particular risk aspects on the overall level risk for the entire IT project.

Another method used in the risk analysis is a decision tree. The decision tree is a diagram that illustrates the relationship between decisions and opportunities for the occurrence of an incident. The diagram takes into account the probability of specific incidents in consequence with the specific results [Szyjewski 2004, p. 243]. The decision tree is used in the method of the expected monetary value, which will be discussed later in this article.

PERT (Program Evaluation and Review Technique) is another method useful in quantitative risk assessment that is often quoted in the literature. PERT makes it possible to calculate the expected duration for each task based on the previously estimated optimistic, pessimistic and most probable time. Three variants of the time for individual steps are indicated most often by a set of people carrying out the project. They are based on their own knowledge and experience [Trocki, Grucza, Ogonek 2003, p. 198]. The formula for expected duration of the task is:

$$t_{en} = \frac{a_n + 4m_n + b_n}{6},$$

where: t_n – expected duration of the task;

a_n – optimistic duration of the task;

m_n – the most probable duration of the task;

b_n – pessimistic duration of the task.

The result of the use of PERT are three deadlines for the project. On the basis of t_n value for all tasks, it calculates the duration of the project and determines the critical path.

A measure of the uncertainty estimate task duration is the standard deviation, the formula for it is:

$$S = \frac{b - a}{6}.$$

The standard deviation can be used as a measure of risk for each task [Frączkowski 2003, p. 113].

In the project level a critical path of PERT should be set (according to durations of tasks PERT). The duration of such a path is called the PERT average of the project [Pritchard 2002, p. 189]. For the critical path the standard deviation is determined, which is the square root of the sum of squared standard deviations of all tasks. The standard deviation and the PERT average (for example: plotted on the graph of curve of normal distribution) allow to determine what is the probability that the project fits

within a certain frame (e.g. within one or two standard deviations from the mean value).

The sensitivity analysis enables to determine which risks will potentially have the greatest impact on the project. The method is based on predicting the score by manipulating the variables having an effect on it. It makes it possible to compute the boundary values of individual factors that will enable achievement of specific result.

The next method – the method of the expected monetary value – EMV is an often used method of decision-making [PMBOK 2008, p. 298]. It requires estimations for each foreseen scenario to make it possible to select the option for which the expected monetary value is the highest [Pritchard 2002, p. 163]. The result of specific decisions and occurrence of a specific state of nature is known as a payoff value. Because of the fact that it can be implemented only in one of the scenarios, it has to be complied with two conditions:

$$P(s_j) \geq 0 \text{ for each of the states of nature,}$$

$$\sum_{j=1}^n P(s_j) = P(s_1) + P(s_2) + \dots + P(s_n),$$

where: $P(s_j)$ – probability of occurrence of state of nature s_j ,
 n – number of possible states of nature.

The formula for expected monetary value of “d” option is:

$$EMV(d_i) = \sum_{j=1}^n P(s_j)V(d_i, s_j),$$

where: $V(d_i, s_j)$ – payoff value associated with the d_i scenario and state of nature of s_j .

Reliability of calculations for this method depends only on the quality of the source data. Its major advantage is also the fact that the issue can be represented by a decision tree.

Among the methods currently used in quantitative analysis of project risk there is also a listed Monte Carlo simulation. Monte Carlo Simulation provides risk analysis, cost and schedule for the entire project [Pritchard 2002, p. 227]. The total cost of risk is expressed as the cumulative probability distribution of total costs of the project. Thus it is possible to determine with what probability the project will be implemented within the specified cost and schedule. The analysis requires the execution of calculations using numerous various values of attributes, therefore to this analysis the chosen probability distribution is applied.

Monte Carlo is based on generating random numbers, which should simulate the uncertainty regarding the implementation of each task. Simulations for each operation are aggregated, which allows to specify the total working time or overall costs. Such calculations are carried out repeatedly (many times) until the results of all calculations reflect the risk of the project.

Monte Carlo simulation gives the answer to the question: What is the probability of finishing the project within the budget and deadline?

Using some of mentioned methods requires the use of proper tools which will be discussed in the next section of the paper.

4. Tools supporting risk analysis in projects

On the market there are specialized tools that support risk management in projects. However, not always is it necessary to use them and the need of taking the advantage of them, as already mentioned, depends among others on the method used in the risk analysis.

In most cases, it is enough when the system used to project management assembles data of risk together with the plan. Each project management tool allows to add additional variables and to create a form that could be used in the risk management process. An example proposed by Pritchard is presented in Table 4.

Table 4. Risk analysis form

WBS	Task name	Risk	Probability	Consequences	Risk assessment	Importance

Source: [Pritchard 2002, p. 44].

Similarly, it is possible to store information associated with the methods of responding to risks. Such forms can be created e.g. in the Project Office, or in other popular tools that support project management.

Tools supporting project management can be also used with regard to the PERT method. Most of these tools have a built algorithm of PERT analysis. Although the use of this method is not difficult, it is not commonly used. Probably due to not having enough knowledge of this method and the erroneous assumption of applying, it is complicated and time consuming.

Using the PERT analysis in the Project Office, it is possible to set an optimistic, pessimistic and most likely time for each task. Project Office enables to determine the importance for each of those times, by default (in accordance with the assumptions of the PERT method) the most likely time has importance 4, and the optimistic and pessimistic times have importance 1. For each of the tasks, according to fixed values, there is an expected duration of task, which is calculated, but there is a possibility to modify the importance of each time. The standard deviation can be calculated by setting an additional variable, it is also possible to export the data into a spreadsheet to perform additional calculations and analysis.

However, in the case of Monte Carlo simulation it is necessary to use specialized tools to support risk management. Most of these tools allow to conduct analysis

regarding cost and schedules. Performing Monte Carlo simulations allows, for example, @ RISK and Risk +, affording the opportunity to identify the most important (because of the risk) tasks and focusing on management of these risks.

@ RISK allows one to enter data into the spreadsheet, however, requires, in contrast to the Risk+, detailed data for all tasks. The user determines the choice of decomposition, to choose among other decompositions: normal, uniform, or triangular [Palisade 2011].

The problem with using Monte Carlo simulation is to obtain estimates regarding the uncertainty of cost and schedules for each task. This is the hardest and most time consuming step, regardless which tools are used. All tasks must be analyzed separately, and for each of them the extent of risk and distribution of this range should be determined [Pritchard 2002, p. 231].

After entering the data for simulations the parameters of the calculation, including the number of repetitions, should be determined. The simulation results can be presented in a Gantt chart using Project Office. There is also an opportunity to present the results of the histograms, and create reports.

In @ RISK, you can also perform analysis of sensitivity and scenarios to determine which variables have the greatest impact on the model.

Risk+ also offers an analysis of risk in relation to costs and timetable. It also allows like @ RISK for sensitivity analysis, whereby, based on risk of tasks and schedule, it is possible to determine which activities will have the greatest impact on the deadlines of the project milestones. Risk +, as already mentioned, gives the possibility to quickly define and update the parameters for the whole project [Deltek 2011]. But there is possibility to change these initial settings to the selected activities from the schedule. This way of setting the parameters for analysis greatly speeds up the work, you can focus on selected tasks, without omitting the other.

Like other such tools, Risk+ is compatible with Project Office, after the installation becomes its integral part. All inputs and outputs of risk analysis are stored in your schedule. Integration with Excel gives, in turn, the possibility to generate additional reports and statements.

In practice, companies often make modifications in the software supporting the project management, such as the Project Office, adapting them to their needs and the methods used in risk management. This involves, inter alia, adding fields and creating the components that allow for example to create new data sheets or to integrate with other systems used in the enterprise. Sometimes companies for project management and risk project management use spreadsheets, in which the parameters of the Project are placed. In these sheets there is placed information about potential risks which are assessed according to rules accepted in the organization.

5. Conclusions

The risk management process is particularly important in its assessment. Some risks have a very serious impact on the project, but the probability of its occurrence is negligible, while others have a very high probability, but their impact on the project is small [Jones 2009, p. 168]. Assessment not only allows you to determine the importance of the risk of the entire project, but moreover which risks should be eliminated at first. Methods for quantitative risk analysis and tools supporting projects risk management allow to prioritize threats, designation of these tasks for which keeping deadline is fraught with the greatest risk in the context of the entire project.

The choice of methods, which implicates also the choice of tools that allow their usage, is not simple. Most often it is dependent on experience and qualifications of project managers. Tools using, for example, Monte Carlo simulation provide very reliable data, but only on condition that the source data is correct. Other methods are a little bit easier to use, such as PERT or expert surveys, which also allow you to determine the reliability of the experts. The importance of this issue is evidenced by results of the study, which indicate great difficulties encountered by project managers in the context of risk and its analysis. According to research conducted at the request of K2 Consulting Company among the heads of IT departments of best computerized Polish companies, nearly 60% of them were confident to entrust the management of the project and the risk of an external company [Jesionek 2007]. This is particularly true in large projects whose budgets exceed 5 million.

Risk management, including all of the above identification and analysis, is a complex process, requiring a lot of experience [Mamot 2008]. Not without reason, companies provide, in their structures of project, a risk manager, who assesses the risks in projects and the impact of risk on efficiency.

But risk management is effective when recognized practices and methods will be applied.

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ILOŚCIOWA OCENA RYZYKA PROJEKTU INFORMATYCZNEGO

Streszczenie: Zarządzanie ryzykiem jest bardzo istotnym i niestety często bagatelizowanym procesem w zarządzaniu projektem informatycznym. Tymczasem identyfikacja i analiza ryzyka, a także pozostałe elementy tego procesu, są konieczne do efektywnego zarządzania przedsięwzięciem. W artykule wskazano na istotną rolę ilościowej oceny ryzyka, a także omówiono najczęściej stosowane metody: analizę wrażliwości, EMV, symulacje Monte Carlo, ankiety eksperckie, drzewa decyzyjne oraz PERT omówiono również narzędzia wspomagające analizę ryzyka.