Estimating the effects of project risks in software development projects

K. Jantzen, K+K Jantzen Software Services GmbH

klausj@jantzen-software.de

G. Adens, R. Armstrong, Tassc Limited

{gillian | robert}@tassc-solutions.com

Abstract

Every software project is exposed to adverse external influences, the so called project risks, that affect the cost and the duration of the project and, possibly, the quality of the products. With a risk analysis it can be determined for a specific project what the risks are. These risks then should be included in a systematic and formal manner in the project estimate in order to obtain a realistic and reliable project estimate and a realistic project plan. We will discuss the way that the project risks are accounted for in currently used estimation methods and we will show a method that is used by a modern estimation tool and which takes the two major properties of the project risks– namely probability of occurrence and impact on the project – into account when calculating a project estimate. Finally we will discuss how risk analysis and risk assessment fit into modern development processes and into CMMI.

Keywords

Project risks, estimation of effort, estimation of duration, product quality, contingency calculation, iterative development, CMMI

Zusammenfassung

Jedes Softwareprojekt ist negativen externen Einflüssen, den sogen. Projektrisiken, ausgesetzt, die den Aufwand und die Dauer des Projektes und, möglicherweise, die Qualität der Produkte beeinträchtigen. Mit einer Risikoanalyse kann man die Risiken, die für ein bestimmtes Projekt zutreffen, ermitteln. Diese Risiken sollten dann in einer formalen und systematischen Weise in die Projektschätzung aufgenommen werden, um eine realistische und zuverlässige Schätzung und einen realistischen Projektplan zu erhalten. Wir werden zeigen, wie Projektrisiken in den heute benutzten Schätzmethoden berücksichtigt werden und wir werden eine Methode zeigen, die von einem modernen Schätztool verwendet wird und die zwei Haupteigenschaften der Projektrisiken, nämlich deren Wahrscheinlichkeit des Eintretens *und deren Auswirkung auf das Projekt, bei der Projektschätzung berücksichtigt. Schließlich werden wir zeigen, wie Risikoanalyse und Risikobewertung in moderne Softwareentwicklungsprozesse und in CMMI eingebaut sind.*

Schlüsselbegriffe
Projektrisiken, Aufwandschätzung, Schätzung der Dauer, Produktqualität, Berechnung von Risikozuschlägen, iterative Entwicklung, CMMI

1 Introduction

No project, and especially no software project, is executed without adverse external influences. These influences constitute risks to a project in as much as they may affect the project in terms of delaying the timely completion, of increasing the cost and possibly of reducing the quality of the products of the project.

Surprisingly, risks and their effects on a project are rarely taken into account systematically in respect to their effect on a project. It is accepted that there are risks that threaten a project. But in reality risks are either not included in an estimate of cost and duration or a very simple method is used as a substitute for a detailed risk assessment.

In this paper we will discuss how currently used methods of estimation take the effect of project risks into account. Furthermore we will show how in a modern estimating tool risks and their threat to a project in respect to cost and duration are taken into account.

We will not discuss strategies on how to handle project risks, how the cost of mitigating the effects of project risks are determined or how project risks can affect the quality of the products. These topics are not central to the subject of cost and duration estimation.

2 The project risks

Project risks affect all aspects of a software project: the organization, the personnel, the technology etc. One can distinguish between two types of risk: *direct risks* – risk over which a project has a large degree of control – and *indirect risks* – risk over which a project has little or no control. Table 1 lists typical categories of possible risks [6].

Risks can be described by various characteristics. Two of them are the probability of occurrence (in the following just *probability*) and the cost of mitigating the problem in case the risk fires.

A detailed risk analysis reveals the risks that threaten a specific project, determines the strategies on how to mitigate the project risks in case they fire [11] and ranks their characteristics.

Management	Definition	Design
Team dynamics	Clarity of stated requirements	Formal process
Morale	Formal process	Rigor of the review
Project tracking	Customer involvement	Design reuse
Project planning	Experience levels	Costumer involvement
Automation	Business impact	Development staff experience
Management skills		Automation
Build	**Test**	**Environment**
Code reviews	Formal testing methods	Newness of technology
Source code tracking	Test plans	Automated process
Code reuse	Development staff experience	Adequate training
Data administration	Effectiveness of test tools	Organizational dynamics
Computer availability	Customer involvement	Certification
Staff experience		
Automation		

Table 1: Risks that influence the delivery of software

It is important to take risks into account when estimating project cost and duration in order to obtain realistic estimates. This is particularly crucial at the early stages of a project when risk is typically at its highest. However, risks are inherently unpredictable. Perceived risks may fire or may simply evaporate. Risks that were not even considered may suddenly emerge and have a serious impact.

The project managers' task is to determine how much contingency should be built into an estimate. They would be ill advised to take an overly optimistic view of the project and simply dismiss risks. Even the most experienced engineers cannot glide through a project, avoiding all risks. However, it might also be unwise to go to the other extreme and expect all risks to emerge. This would be a rather pessimistic view of the situation. Building in too much contingency can lead to an over-extended project schedule and to over-budgeting. This then may mean that the project no longer makes sense in a cost benefit analysis.

The level of contingency should reflect the level of risk exposure. The number of risks that can be identified during a risk analysis is one good indicator of risk exposure so the more risks the higher the contingency percentage. However, this would be a rather simplistic approach.

3 Current approaches in risk estimation

When discussing project risks with project managers they are convinced that they take them into account. In the following we will discuss how project risks are currently taken into account.

3.1 The simplistic approach

In many cases, independent of the method with which a project manager calculated cost and duration of a project, the project risks are taken into account by applying a single factor to the cost and/or the duration. The factor ranges from 1.0 to x depending on the gut feeling (sometimes called "experience") of the project manager.

Individual risks are not specified and not assessed and thus there is no way of determining the effect of a specific risk. One obtains two values: using factor 1 means no risk will fire (a very optimistic approach), using a factor x meaning that all risks fire (a very pessimistic approach).

3.2 Function Point Analysis

In straightforward Function Point Analysis (FPA) one must assume that the effect of the various project risks, together with other influences on the project, are reflected in the fourteen "General System Characteristics (GSC)" (Table 2 [6]). Each

General system characteristics	
Data communications	Online update
Distributed data processing	Complex processing
Performance	Reusability
Heavily used configuration	Installation ease
Transaction rate	Operational ease
Online data entry	Multiple sites
End user efficiency	Facilitate change

Table 2: General system characteristics (GSC)

of these fourteen characteristics is assigned a *degree of influence* (DI) between 0 (no influence) and 5 (strong influence). The overall contingency is expressed in the *Value Adjustment Factor* (VAF) which is calculated using the sum of all DIs.

$$VAF = 0.65 + 0.01 \sum_{n=1..14} DI_n$$

In case all characteristics have a DI of 5, the contingency is 35%, i.e. the number of unadjusted function points increases by 35% to obtain the adjusted function points.

Regardless of whether such a contingency is sufficient to take project characteristics (such as complexity) and project risks into account this approach does not allow us to determine the effect of a specific risk such as "Change of technology" as there is no known relationship between a specific project risk and the general system characteristics. Neither the impact nor the probability of the risks may be taken into account in any way.

As the VAF is clearly unsatisfactory for various reasons, some authors propose not to use the VAF at all [10].

3.3 COCOMO II

COCOMO II takes project risks into account by defining a risk factor characterizing each module to be developed [3]. The *total risk* (TR) of each module is the sum of the *risk levels* (RL) of six types of risk (see Table 3).

$$TR = \sum_{n=1..6} RL_n$$

The *risk factor* (R) of each module is determined by

Project risks
Schedule Risk
Product Risk
Platform Risk
Personnel Risk
Process Risk
Reuse Risk

Table 3: Project risks

$$R = \frac{TR}{373} * 100$$

This approach allows us to consider types of project risks at a module level. A risk like "Change of technology", however, would have to be allocated to more than one of these risk types which would make it difficult to adjust its threat. Probabilities are not taken into account.

"Expert COCOMO", an extension to COCOMO II, "aids in project planning by identifying, categorizing, quantifying, and prioritizing project risks"[3, page 284]. It is a heuristic method that uses rules to analyze risks on the basis of cost factor information. This means that the project risks are not addressed directly but through the cost factors specified for each module. This makes it even more difficult to recognize the influence of a specific project risk and its probability of occurrence as we need a relationship between the project risk and its effect on the cost of a module.

3.4 Other approaches

In a risk analysis Coombs [5] determines three characteristics of the project risks: the probability of occurrence, the difficulty of detecting whether the risk has occurred and the impact on the project if the risk occurs. In addition, for each risk the maximum person-days and the maximum cost to correct the damage if the risk fires are determined.

Each characteristic is assigned a *weight* (W_c) recorded as *Low*, *Medium*, or *High* corresponding to the values 1, 3 and 7. The sum of these three weights is the *OverallWeight*.

$$OverallWeight = \sum_{c=1..3} W_c$$

The maximum value of the overall weight, the $\text{OverallWeight}_{max}$, is 21, corresponding to a maximum contingency of 75%. The actual contingency is the proportion of the maximum contingency corresponding to the OverallWeight.

$$Contingency = \frac{OverallWeight}{OverallWeight_{max}} \times 75[\%]$$

The contingency then is applied to the maximum person-days and to the maximum cost of each risk to obtain the weighted maximum person-days and the weighted maximum cost in order to determine the project risk's effect on the project.

With this approach any number of project risks may be considered. Each project risk is taken into account separately and independently. The probability is only used to calculate a contingency. There is no analysis of the probabilities in terms of determining the most probable increase of the project duration.

Stutzke [11] defines the following characteristics of the project risks: the probability of occurrence (P_F), the cost of occurrence (C_F), the cost of correcting the damage (the cost of mitigation, C_M), the probability the risk continues to occur (P_R) and the cost of continued occurrence (C_R).

Two quantities are used to analyze the risks. The first quantity is the impact (I) of the risk which is the product of the cost (C) and the probability (P):

$$I = C \times P$$

With the rankings of the five characteristics, one calculates for each risk the *impact before mitigation* (I_B) and the *impact after mitigation* (I_A, also called the *residual impact*).

$$I_B = C_F \times P_F \quad and \quad I_A = C_R \times P_R$$

With these impacts one calculates a *risk reduction leverage* (RRL), the second quantity used to analyze the risks. It is used to prioritize the risk elimination actions.

$$RRL = \frac{I_B - I_A}{C_M}$$

Also this approach makes it possible to take any number of risks into account. One can rank each risk individually and thus can determine the effect of each risk separately and independently. The probability is used to calculate a factor which is used to prioritize mitigation actions. The cost contingency is determined by summing the impacts of all risks above a certain RRL. The effect of the project risks on the project schedule is not determined.

4 The Tassc:Estimator approach

The philosophy behind the Tassc:Estimator approach is that the effect of each risk on the project in respect to the cost and the duration must be considered separately.

This means that in order to obtain a reliable estimate of the contingency for a project a risk that "disappeared" must be excluded from all subsequent estimates and that new risks are included in estimates as soon as they are recognized.

4.1 Assessing the risks

For the estimation of cost and duration all project risks that were defined in a risk analysis are described by the two essential properties: *impact* and *probability* .

Here the impact is the amount of damage, i.e. the increase of the duration and of the cost of a project, as the result of a risk that fired. The impact of each risk can be recorded as *minor*, *low*, *high*, *severe* or *critical* [1]. These logical levels are mapped onto actual impact percentages ranging from e.g. 1% to 5%. Thus a risk with *severe* impact has a potential of increasing the project estimate by up to 4%.

The probability indicates a judgment on the likelihood of the risk firing and negatively affecting a project. It can be indicated by *remote*, *unlikely*, *50/50*, *possible*

[1] Theoretically the scale could have any number of levels. Having five levels has been found to be optimal. Three levels would be too few to deal with extremes. More than five or six levels can lead to confusion and to an endless discussion of nuances.

or *probable*. These logical levels are mapped onto actual probability percentages ranging from e.g. 15% to 85%. Consequently, a *remote* risk has a 15% probability of firing.

With the probability and the impact the *priority* of the risk is determined. The priority of the risk (1 being the highest priority, 9 being the lowest) indicates its level of threat to the project. The risks with the highest priority are the risks that one should intensively try to resolve [1].

Figure 1 shows an example of a risk assessment of a project. It shows different categories of risks and risks within some categories. All risk have a status. In the

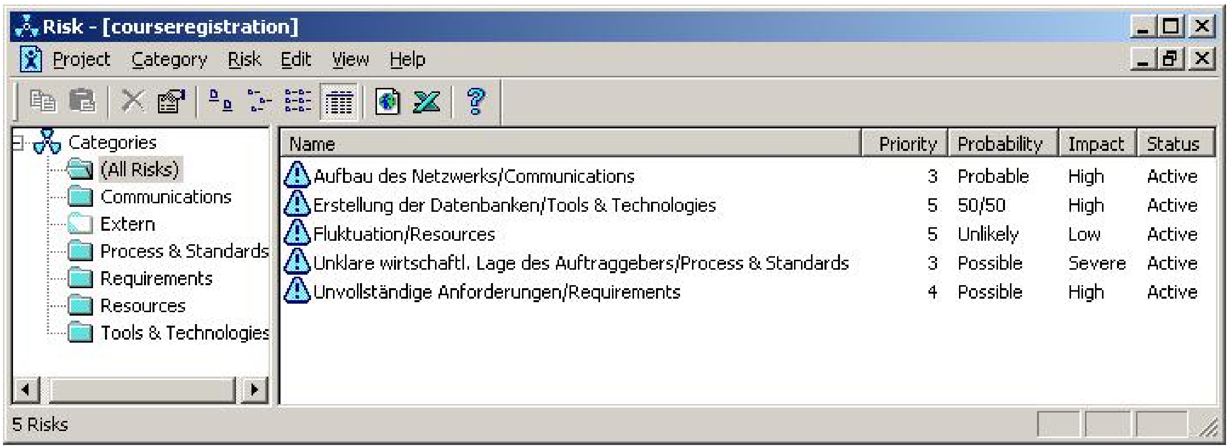


Figure 1: The result of a risk assessment

Figure 1 it is "Active". This means that the project manager considers that all risks have the potential of firing. When a specific risk occurs, its status is set to "Fired". This means that in all subsequent estimates of the project, the effort to deal with the risk is included in the calculation of cost and duration. Should a previously identified project risk "disappear", i.e. it will not be a threat to the project, it is set to "Inactive". This means that the risk was identified but will not affect the project. It is kept in the list for documentation purposes.

4.2 The result of the estimate

The combination of probability and impact defines the risk's level of threat to the project. This is the crucial factor in calculating an appropriate contingency for the project.

Considering a *severe* risk it has a potential impact of 4% on the project estimate. If this risk will definitely fire one would add a 4% contingency to the project estimate. During risk assessment, however, it is predicted that the probability of this risk to fire is *remote* (equivalent to a probability of 15%). Thus one can calculate a more appropriate contingency by taking 15% of the 4% resulting in a 0.6% contingency (see Table 4).

Probability		remote	unlikely	50/50	possible	probable
		15%	35%	50%	65%	85%
Impact						
minor	1%	0.15	0.35	0.5	0.65	0.85
low	2%	0.3	0.7	1	1.3	1.7
high	3%	0.45	1.05	1.5	1.95	2.55
severe	4%	0.6	1.4	2	2.6	3.4
critical	5%	0.75	1.75	2.5	3.25	4.25
				Contingency %		

Table 4: Calculating the contingency

The contingency calculated for a project is not just based on the impact of the project risks; it also takes account of their probability of occurrence.

The results of the above described calculations are shown in a risk graph (see Figure 2). Curve 1 shows the probability distribution of the durations using the

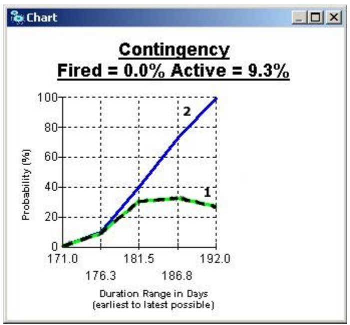


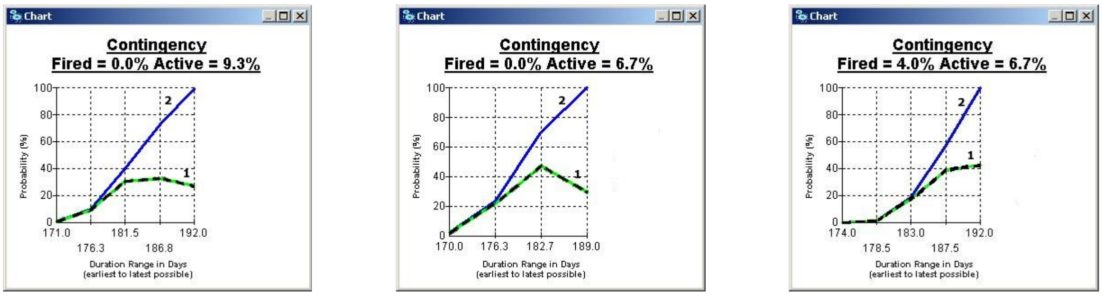
Figure 2: The risk graph

probabilities of all risks. This curve is the result of a stochastic model of random probability distributions such that the resulting range of durations can be analyzed statistically to predict the most likely duration.

Curve 2 shows the probability of project completion within a specific time using the combination of probabilities and impacts of all risks. The probability of completion within the shortest possible time is practically 0 as it is almost certain that one risk will fire. The probability of completion within the longest possible time is 100%: this means that all project risks fired and the duration is increased according to the assessment of each project risk.

4.3 The effect of risk status change

In the following we will show the effect of a change of risk status. For this purpose we take the risk no. 4 in the list in Figure 1. The impact of this risk is *severe*; its probability is *possible*. Figure 3 shows the effect of the change of its status. Risk



A **B** **C**

Figure 3: The influence of the risk status

graph A in Figure 3 is the result of the contingency calculation when the status of risk no. 4 is *active* (the status of the other risks is also *active*). This graph is identical to the one in Figure 2. The shortest and the longest duration is estimated to be 171 and 192 days, respectively. The most likely duration is 186.8 days.

In the assumption that risk no. 4 no longer exists, its status is set to *inactive*. The result of the contingency calculation is shown in graph B of Figure 3. The contingency decreases because the amount of possible additional work is reduced. As a consequence the longest possible duration is reduced to 189 days. The probability distribution of the durations changes such that based on the assessments of the remaining risks, the most likely duration decreases from 186.8 days to 182.7 days.

Now assuming that the risk did not disappear but occurred. In this case the status of the risk is set to *fired* (the status of all other risks remains *active*). The result is shown in graph C. The 4% contingency is added as required effort: the impact of the risk is *severe* equivalent to 4% according to Table 4; its probability, which was *possible* equivalent to 65% according to Table 4, is now 100%. Considering impact and probability of the remaining risks a new contingency of 6.7% is calculated. The shortest possible duration is increased to 174 days because the effort for solving the problems of risk no. 4 is added to the original project effort. The longest possible duration is still estimated to be 192 days (the same as in graph A): all other risks still have the potential to fire leading to the corresponding additional effort. The most likely duration is now 192 days.

The discussion above assumes that none of the work in the project has been done. If one of the above estimates would have been an estimate done during the work on the project in order to review the project plan, all work reported to be complete so far would have been taken into account accordingly. Similar risk charts would show durations and contingencies for the remainder of the project.

5 Risk assessment in the software development process

Today risk analysis is an important activity of modern development processes. It is fairly easy to determine the risks specific to a project as there exist extensive lists that describe what to look for [6, 11]. Possible mitigation actions are discussed in [11].

The assessment of the risks, i.e. the determination of the probability of occurrence, the cost of mitigation, the impact etc., however, requires a lot of knowledge and experience possibly supported by an appropriate database with the assessments of previous projects.

As the effect of risks on a project is not necessarily constant, the results of a risk assessment should continuously be revised in order to obtain a realistic estimate of cost and duration not only at the beginning of a project but also with intermediate estimates performed to control the project plan. During such a revision new risks and their assessment are included, risks that “disappeared” are excluded and the assessments of the individual risks are modified according to the latest information[2].

The Rational Unified Process (RUP) distributes the risk analysis and therefore also the risk assessment on the *Inception* phase and on the *Elaboration* phase. In the Inception phase only risks that endanger the feasibility of a project are considered [7, 9]. In the Elaboration phase the technical risks and their effect are taken into account.

The V-Modell XT process includes a risk management activity in the context of project planning and controlling. The guideline is more explicit in so far as it recommends to assess the probability and the cost of mitigation with which a value, that seems to be similar to what we referred to as impact, is calculated. It also recommends to continuously monitor these assessments [4].

The importance of the risk management within the software development process becomes evident by the fact that under CMM risk management was a practice inside “Software project planning” and “Software project controlling” whereas under CMMI it received a larger emphasis and became a separate process area on level 3 [8].

If an organization wants to improve its software processes under the CMMI model to achieve maturity level 3 it is required that a risk management process is established. As a consequence the results of the risk analysis should be included formally in project estimates in order to obtain reliable estimates of cost and duration and reliable project plans.

6 Outlook

A systematic and formal determination of the effects of project risks will significantly enhance the reliability of project estimates, i.e. the reliability of the estimated duration, of the estimated cost and of the project plans.

With a better understanding of the project risks and their effect on a project another approach for determining the content of the iterations in an iterative development can be taken. The content should not only be determined by the features to be implemented but also by the project risks. High risk elements are developed in the first iterations to reduce the overall risk for the following iterations.

References

1. ADENS, G., AND TUCKWELL, G. Risk and contingency calculations. Tech. rep., Tassc Ltd., 2004.
2. ARMSTRONG, R., AND ADENS, G. Managing Software Project Risks. Tech. rep., Tassc Limited, 2004.
3. BOEHM, B., ABTS, C., BROWN, A. W., CHULANI, S., CLARK, B. K., HOROWITZ, E., MADACHY, R., REIFER, D. J., AND STEECE, B. *Software Cost Estimation with Cocomo II*. Prentice-Hall, Inc., 2000.
4. BUNDESMINISTERIUM DES INNERN – KBST. Das neue V-Modell XT – Release 1.2, 2004.
5. COOMBS, P. *IT Project Estimation*. Cambridge University Press, 2003.
6. GARMUS, D., AND HERRON, D. *Function Point Analysis*. Addison-Wesley, 2001.
7. JACOBSON, I., BOOCH, G., AND RUMBAUGH, J. *The Unified Software Development Process*. Addison-Wesley, 1998.
8. KEUPER, R. *CMMI Verbesserung von Softwareprozessen mit Capability Maturity Model Integration*, 2 ed. dpunkt.verlag, 2006.
9. KRUCHTEN, P. *The Rational Unified Process*, 3 ed. Addison-Wesley, 2004.
10. POENSGEN, B., AND BOCK, B. *Function-Point-Analyse*. dpunkt.verlag, 2005.
11. STUTZKE, R. D. *Estimating Software-Intensive Systems*. Addison-Wesley, 2005.