Plan-fact analysis in risk management

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Abstract

Risk management is one of the most researched areas of project management, and also, its knowledge is more and more important in practice (e.g., appearance of PMI Risk Management Professional qualification). The research presented in the article focuses on integrating risk management and plan-fact analyses of controlling into a common risk management framework. Therefore, firstly, a new integrated risk management process that is easy to use in everyday practice is introduced, based on the results on previous conceptual research. Secondly, the hypothesis that it provides better results from some aspects is justified illustrated with a sample project.

Keywords: Project Risk Management, Risk Evaluation Framework

Introduction

Although risk management has become an integral part of project management insomuch that its application is required even by standards (e.g., PMI, 2009), yet it is usually left to project managers to define the required processes in detail and only little relevant methodological literature is available to provide further theoretical content. On the one hand, no study has been made on methodological details, and on the other hand, practicability has not been investigated comprehensively yet, while 83% of organizations are high performers in project management practice risk management frequently, and these perform very well in in reaching their goals, while at the same time only 49 percent of low performers do so, with far less success (see, Pulse of the Profession® report (ESI International, 2015)).

As a result, our current research focuses on integrating risk management and plan-fact analyses of controlling into a common risk management framework. A proposed risk management framework has three basic requirements: 1) In addition to operating management based on conventional project risk management categories, the suggested one should take into account the minimum requirements of the owner. 2) Conventional project risk management evaluation is typically performed in the definition phase. Since owner interest can change at any point in the whole life cycle of the project, the model has to be able to operate and perform evaluation. 3) Although project managers have to possess some financial knowledge, they cannot be expected to play the role of a financial professional; therefore it is important that the models are easy to use in everyday practice.

There is a rather significant presence of risk classification in risk management literature (e.g., Chapman, 2001; Purnus and Bodea, 2013). Fortunately, the apparent subjective side of risk management is a thoroughly researched (e.g., Alexopoulos et al., 2009), yet in the risk management literature a characteristic quantitative approach appeared. These papers are supported by mathematical models and developed based on the relevant current risk theories. Derived from the traditional risk classification concept, mathematical models, such as various probabilistic approaches (e.g., Hajdu and Bokor, 2016; Mulholland and Christian, 1999), the analytic hierarchy process (e.g., Nieto-Morote and Ruz-Vila, 2011) fuzzy approximation and composition (e.g., Hosseininezhad et al., 2014), artificial neural networks (e.g., Jin and Zhang, 2011), Bayesian networks (e.g., Khodakarami and Abdi, 2014), and Markov modelling (e.g., Espada Jr. et al., 2014) are developed and applied to risk assessment.

We use the value-based risk monitoring framework developed by Tóth and Sebestyén (2016), where the primary purpose is to detect and monitor risks jeopardizing the expected project return, and if necessary, to start action plans in order to avoid losses. A basic problem of controlling plan-fact analysis is that while it examines whether the cash flow predicted in a given business plan is realized, it cannot handle (cannot suggest a solution to) discrepancies it may detect.

There are many unclear questions of plan-fact analyses. The most remarkable issue is that it is not clear exactly how the realization of fact data affects the relevant risks of a project. As we earlier explained, risks are time-varying, that is, as time passes, the uncertainty of the occurrence of a given event endangering the aim – be it anything – changes. We developed a value-based framework, where risk factors are measured on a linear scale. However, the framework, more precisely, the process in which the plan data are substituted by fact data, raises some questions. In order to maintain a value-based risk management process, a continuous valuation method is necessary which is able to capture the value of the project in its current state. In finance, conventional approaches typically tie the current value to the market value based on the contracts in force, which are often not observable, especially in the early stages of the project. In contrast, plan-fact analyses are built on an inverse concept, as they address only realized payments and book value, while market value is ignored. Then, what mechanism can be used in the plan-fact analysis to evaluate plan data turned into fact data? The answer is complicated because we know that fact data are sunken in a financial valuation process, that is, those data become irrelevant. The question arises: is it the same in a risk management process? Also, eliminating the deviation of the fact data from the risk, can we recalculate risk with analytic methods or just with approximate solutions like a structured Monte Carlo simulation? If these questions are answered, they can lead to a new controlling tool that solves one of the most acute problems of current controlling methods: a complete lack of integration of risk management.

The structure of this article is twofold. Firstly, the new integrated risk management process is introduced based on the results on previous conceptual research. Since the new approach is not trivial, appeared sparsely in publications, and is not widespread in science so far, the most basic integrated risk management steps and the underlying theory are presented. Secondly, the hypothesis that it provides different, and from important points of view, better results, is justified illustrated with a sample project.

Integrated risk management process

The starting point of this research is the value-based financial risk management process firstly defined by Sebestyén and Tóth (2014). In this approach risk management is based on the financial valuation of the project, and the risks are measured by the probability of the occurrence of critical deviance of the value-driving parameters from their expected values calculated in the planning phase of the project. Value-driving parameters become critical, when their deviations cause zero or negative NPV to the owners. If contractual conditions do not change, risk monitoring is about to follow risky value-driving parameters and if necessary, set the predefined action plans that restore the value making process. If this happens, the business model needs to be initialized again according to the current contracts and data expectations, and the risk analysis needs to be made again, too.

In Tóth and Sebestyén (2016), the value-driving parameter ($x_{n,t}$) is an arbitrary variable that can have any effect on the financial position of the owners of the construction project. $n = (1,\ldots,N)$ refers to the nature of the parameter, and $t = (1,\ldots,T)$ refers to the given time period in years. Using this definition, the expected annual cash flow to the owners in year t (CF_t) is (1):

$$CF_t = s(x_{1,t}, \ldots x_{n,t}x, \ldots, x_{N,t}) \tag{1}$$

And the value to the owners of the project (NPV_0) is as follows, where r refers to the cost of invested capital (2):

$$NPV_0 = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t} \tag{2}$$

The critical value of each value-driving parameter, called the economic break-even point ($B(x_n)$), can be expressed (3) as follows:

$$NPV = \sum_{t=0}^{T} \frac{s\left(x_{1,t}, \ldots, x_{n,t}\left(1 + B(x_n)\right), \ldots, x_{N,t}\right)}{(1+r)^t} = 0 \tag{3}$$

$B(x_n)$ expresses the changes of parameter x_n that occurs evenly in every year, which makes the project's net present value equal zero. That is, a larger change in the value of x_n makes the project value destroying.

Finally, the probability that changes in parameter x_n are larger than $B(x_n)$ can be determined (4) as follows:

$$P\left(-\infty < a_n \leq B(x_n)\right) = \int_{-\infty}^{B(x_n)} f(x_n)dx_n \tag{4}$$

Illustration with a sample project

In order to shed light on the details and consequences of the integrated project risk management process, let us consider the value-driving parameter expectations and project cash-flows (Table 1).

Let all value-driving parameters be normally distributed, and let the cost of capital be 10%. Let us first make the standard financial evaluation, that is, determine the value of NPV_0 (5),(6).

Table 1 – Value-driving parameters and cash-flows of the project

Years (t)	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Investment	-50	-100	-100				
Revenues				300	300	300	300
Material costs				50	50	50	50
Labor costs				30	30	30	30
Depreciation				70	70	70	70
Tax (30%)				45	45	45	45
CF$_t$	**-50**	**-100**	**-100**	**105**	**105**	**105**	**105**

$$NPV_0 = \frac{-50}{(1+0.1)^0} + \frac{-100}{(1+0.1)^1} + \frac{-100}{(1+0.1)^2} + \frac{105}{(1+0.1)^3} + \frac{105}{(1+0.1)^4} + \frac{105}{(1+0.1)^5} + \frac{105}{(1+0.1)^6} \quad (5)$$

$$NPV_0 = 52 \quad (6)$$

Then let us examine how big a change the changes of value-driving parameters cause in NPV, that is, create a sensitivity analysis (Figure 1).

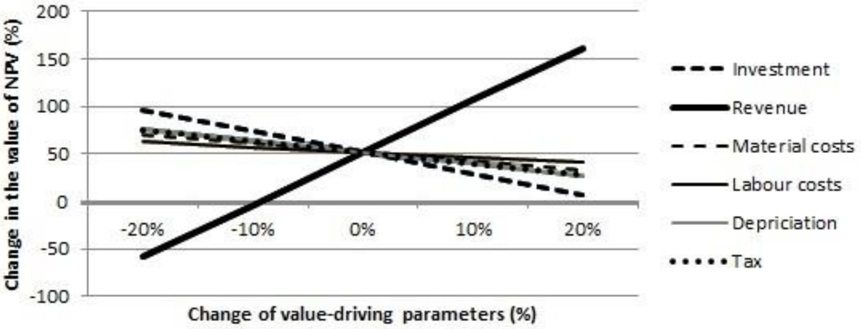

Figure 1 – Sensitivity analysis of the project

It can be seen that the value-driving parameters Investment and Revenues are the most sensitive parameters, that is, a 1% change in these causes the highest percentage change in the value of NPV. With (3) the break-even points of the individual parameters in percentage changes can be determined, then with (4), the probability that changes in value-driving parameters are larger than the related break-even points can be calculated.

Table 2 – Value-driving parameters and cash-flows of the project

	Sensitivity	Break-even point	Probability
Investment	-4%	123 %	1,07 %
Revenues	11%	91 %	18,40 %
Material costs	-2%	156 %	~0 %
Labor costs	-1%	194 %	~0 %
Depreciation	-2%	140 %	~0 %
Tax	-2%	44 %	~0 %

Based on these, Investment – although a sensitive parameter – still does not mean high risk since the probability of dangerous change is low (Table 2). The value-driving parameter Revenues, on the other hand, has a considerable effect on value creating ability and the probability of critical deviation is also high. On the risk map (Figure 2), the value-driving parameters are displayed as a function of sensitivity and probability.

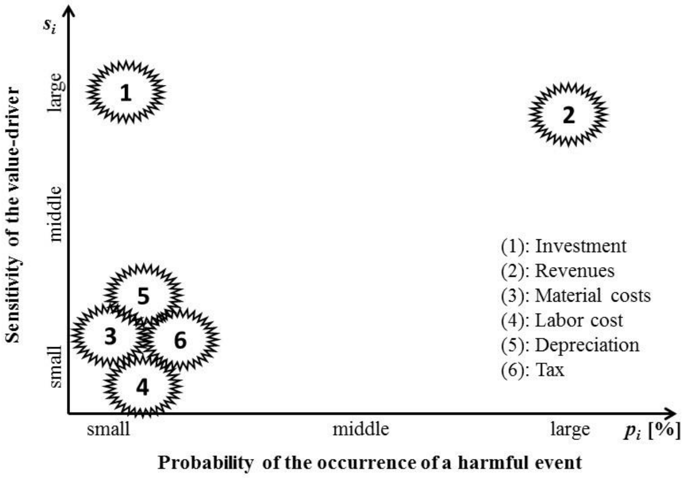

Figure 2 – Risk map of the project

The validity of the Cost-Time-Quality approach in the integrated process

Let us now go on to the methods of conventional project management risk analysis. How can the cost-quality-time approach be connected to the integrated model, which is built on the concepts of value-driving parameters and NPV, and time and quality only appear in it indirectly?

For this, the risks should be looked at in each year of the project, that is, the financial risk analysis above has to be made for every year. Here the new issue is that as time passes, the cash flows paid in earlier years sink, become irrelevant, and are not included in the risk analysis of the current year. Apart from this, the cash flows spent in the Investment phase represent a certain – albeit not easily measurable – value, as investments in progress. The question then is: how can a "half-finished investment" be evaluated in the investment phase?

Below we will use the solution to the valuation problem of the investment phase, presented in the article written by Tóth and Sebestyén (2016). Here, the method that introduced for the construction sector is generalized. If we designate the actual year with t' and the realized cash-flows by fact data with $(\overline{CF}_t)$, then the present and net present value of a project in year t' is (7),(8):

$$PV_{t'} = \sum_{t=t'+1}^{T} \frac{CF_t}{(1+r)^t} \tag{7}$$

$$NPV_{t'} = \sum_{t=0-t'}^{0} \frac{\overline{CF_t}}{(1+r)^t} + \sum_{t=t'+1}^{T} \frac{CF_t}{(1+r)^t} \tag{8}$$

Figure 3 shows how present value and owner's net present value develop year by year. In the development phase, the PV of the project increases because of sunk costs, the NPV of the project increases because of the time value of money.

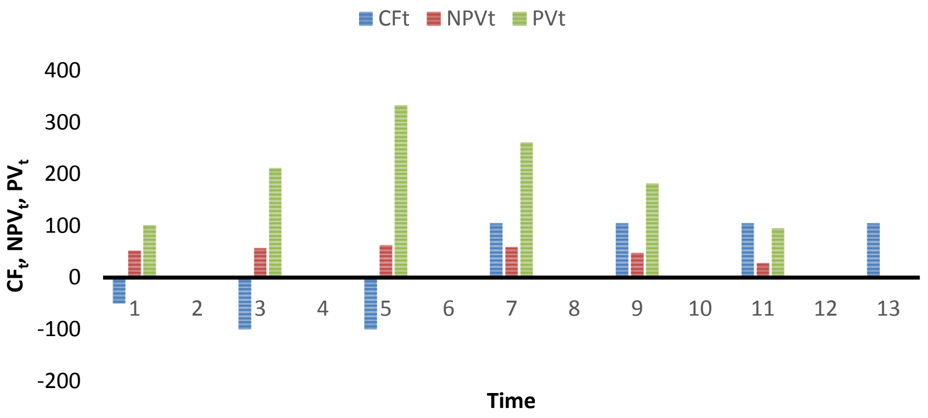

Figure 3 – Development phase

In year *t'* the break-even points can be recalculated as follows (9):

$$NPV_{t'} = \sum_{t=0-t'}^{0} \frac{\overline{CF_t}}{(1+r)^t} + \sum_{t=t'+1}^{T} \frac{s(x_{1,t}, \dots x_{n,t}(1+B(x_n)), \dots, x_{N,t})}{(1+r)^t} = 0 \tag{9}$$

However, if fact data are according to plans, doing the risk analysis of the investment phase each year, we get that risks remain unchanged, that is, in spite of the passing of time (and the increase of *NPV* by the cost of capital), break-even points and the risks are the same in this project phase.

This is an outstandingly important consequence of the integrated risk management process: if conditions are unchanged and fact data are according to plans, the risk characteristics remain the same in each year in the investment phase, thus in this phase it is enough to strive to finish the project with cost-quality-time parameters in the contract. This phenomenon makes the development and application of *CQT*-based (Cost-Quality-Time) special risk management methods especially justified, since in this case, the goal is to fulfil *CQT* without compromises. However, if the planned *CQT* is damaged in any way, risk changes to such an extent that it cannot be handled consistently within a *CQT* framework; we will show it in the following chapter.

Discussion

Concerning the above, two questions arise: 1) What happens to risks in the Operation phase and how are these affected by the change of the Investment phase? 2) What happens if the *CQT* framework cannot be adhered to in the Investment phase?

In the Operation phase, processes different from those in the Investment phase can be expected, since in this phase, the value of assets continuously decreases because they are used continuously. This decrease in value results in either the assets having a significant salvage value, or no value at the end of the project. Let us continue the example in the previous chapter in a way that the invested value accumulated in the third year linearly decreases to 0 in the following four years. Let us regard the depreciated investment calculated this way in the NPV_t calculations of the given year as CF_0 values.

In the table below we showed the sensitivities (S_t) of the individual value-driving parameters in the year of Investment and the years of Operation, in what direction the break-even points move (B_t) and what are the probabilities of occurrence (P_t) as a result.

Table 3 – Value-driving parameters, sensitivity, break-even points and risks

	S_0	B_0	P_0	…	S_3	B_3	P_3	S_4	B_4	P_4	S_5	B_5	P_5
Investment	-4%	123 %	1,07 %		-3%	29%	~0%	-3%	35%	~0%	-2%	41%	~0%
Revenue	11%	91 %	**18,40 %**		9%	-11%	**14%**	8%	-13%	**10%**	7%	-15%	**7%**
Material costs	-2%	156 %	~0 %		-1%	67%	~0%	-1%	77%	~0%	-1%	87%	~0%
Labor costs	-1%	194 %	~0 %		-1%	112%	~0%	-1%	129%	~0%	-1%	146%	~0%
Depreciation	-2%	140 %	~0 %		-2%	48%	~0%	-2%	55%	~0%	-2%	62%	~0%
Tax	-2%	44 %	~0 %		-2%	52%	~0%	-2%	60%	~0%	-1%	68%	~0%

Table 3 shows that the sensitivity of project value to value-driving parameters continuously decreases, therefore the distances of the break-even points increases, which results in a decrease of the probability of occurrence of a change greater than the break-even point. This is the phenomenon of time-varying risk, which comes from the reduction of the degrees of freedom of the individual risk elements (Figure 4).

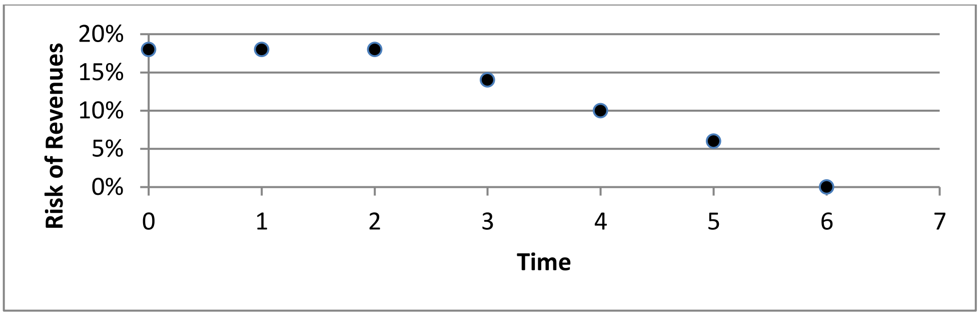

Figure 4 – The risk of Revenues is continuously decreasing, because the degree of freedom of risk elements decreases

If the project has a residual value, the reduction of risk as explained above remain the same, the only difference is that the residual value will also be a new value-driving parameter.

Plan-fact analysis becomes really important for answering the second question. Let us consider the following fact data (Table 4) in the case of our examined project.

Table 4 – Realized fact data of the cash-flow

Year	0	1	2	3	4	5	6
CF_t	-50	-150	-100	105	105	105	105

According to (9), substitute plan data with fact data. For the evaluation of the Investment phase, let us apply inverted discounting. Since in the second year, fact data were one and a half times what was expected, the risk evaluation process changes considerably (Table 5).

Table 5 – Since in the second year, fact data were one and a half times what was expected, the risk evaluation process changes considerably

	S_0	B_0	P_0	S_1	B_1	P_1	S_2	B_2	P_2	S_3	B_3	P_3	S_4	B_4	P_4	S_5	B_5	P_5
Investment	-4%	23%	1%	-14%	7%	24%	0%	n.a.	n.a.	0%	n.a.	n.a.	0%	n.a.	n.a.	0%	n.a.	n.a.
Revenues	11%	-9%	**18%**	91%	-1%	**46%**	91%	-1%	**46%**	31%	-3%	**38%**	19%	-5%	**31%**	14%	-8%	**21%**
Material cost	-2%	56%	**~0%**	-15%	7%	**24%**	-15%	7%	**24%**	-5%	20%	**2%**	-3%	32%	**~0%**	-2%	44%	**~0%**
Labor costs	-1%	94%	~0%	-9%	11%	**14%**	-9%	11%	**14%**	-3%	33%	**~0%**	-2%	53%	**~0%**	-1%	74%	**~0%**
Depreciation	-2%	40%	~0%	-21%	5%	**31%**	-21%	5%	**31%**	-7%	14%	**8%**	-4%	23%	**1%**	-3%	32%	**~0%**
Tax	-2%	-66%	~0%	-19%	5%	**31%**	-19%	5%	**31%**	-7%	15%	**7%**	-4%	25%	**1%**	-3%	34%	**~0%**

First of all, it is worth noting that the 50% increased fact data of the Investment of the second year considerably increased the risks of other value drivers in the following years. To show this, we present the sensitivity test carried out in the 1st and 2nd years (Figure 5). The increased Investment costs – although they fall within the acceptable range of the first year's risk analysis – considerably increases the risks of all value-driving parameters, since the break-even points are nearer to 0.

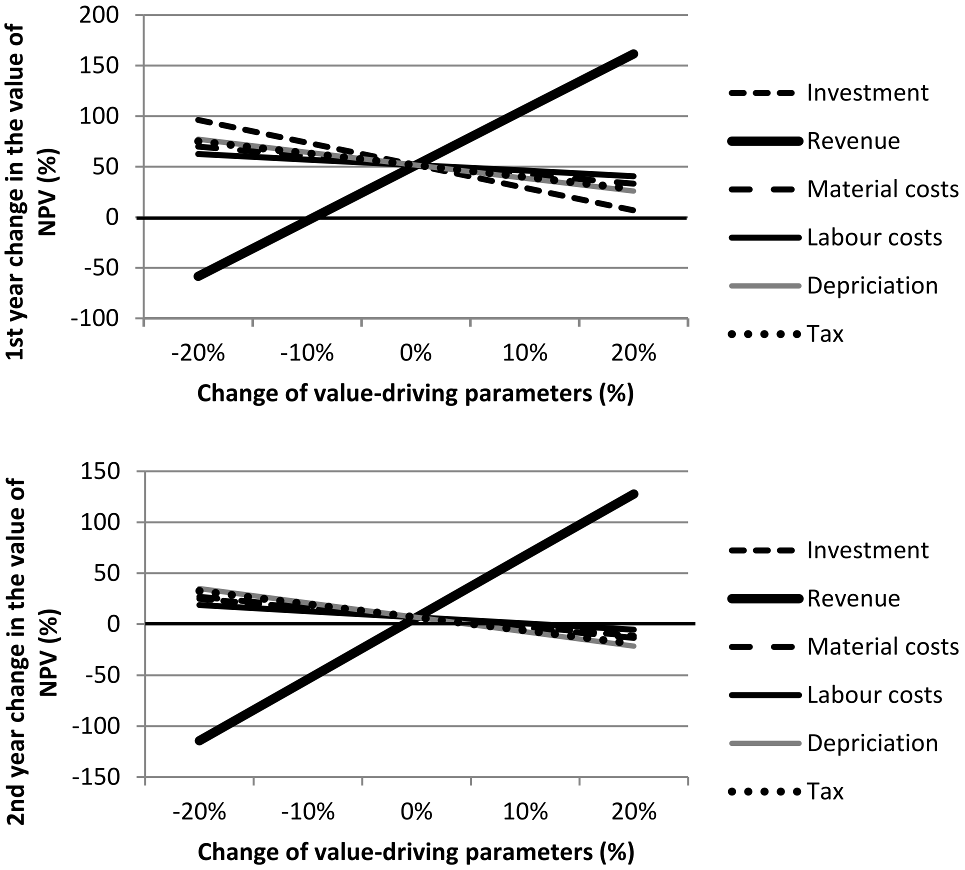

Figure 5 – The increased Investment costs

Based on the data of the 1st year, for example, the acceptable limit is 23% of the whole Investment amount, that is, the project tolerates about 58 units of increase in the investment phase. In the first year, the 150 units of investment instead of the 100 units are therefore under the acceptable limit, but the risk analyses made in the following years show a considerable increase of risk in the case of each value-driving parameter. Although the levels of sensitivities did not change considerably in the case of the individual value-driving parameters, break-even points still occur in the case of far smaller changes, that is, a considerable change of a value-driving parameter within its acceptable limit according to the original plans made otherwise non-risk parameters high-risk. The *CQT* framework of project management cannot handle this new, changed risk system, since owner's value measurement is not a part of it. The *CQT* dimensions remain the same on the following years, even though considerable risks can appear even in the investment phase.

However, the changed risks still can be shown and handled with the financial risk analysis part of the integrated risk management process.

Conclusion

The concepts of project management and financial risk management do not provide a universal and well usable solution for a continuous risk management of a project. The primary reason is that financial risk analysis is performed before the project starts, then due to the interpretation problems of plan-fact analyses (sunken costs) and the evaluation problems of a half-finished project, it is difficult to maintain a continuously recalculated system in practice. On the other hand, the risk management approach of project management cannot handle if there are changes in the fact data compared to the plan within the acceptable limit defined at the beginning of the project, that is, it cannot follow the changes of the whole risk system.

The integrated risk management process we suggest unites the methods of the two areas of science, and if the steps of the process are followed and the plan-fact data are properly taken into account, the issue of continuous evaluation, the issue of time-varying risks and the issue of interacting risks can be handled.

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