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Time-varying risks of construction projects

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Abstract

Although risk management has become an integral part of project management generally insomuch that its application is required even by standards, 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. Known practices can still be developed in many parts, since in current approaches it is especially difficult to reflect on e.g. a phenomenon that individual risks typically decline and then disappear as construction progresses.
This article focuses on declining and disappearing risk changing with time, based on value-based risk monitoring. For providing the mathematical background of time-varying risks, it is important to detect and monitor risks related to the added value of the project. Consequently, if necessary, it is possible to start action plans to avoid losses. In a construction project, 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 building in its current state.
Our aim is twofold: to develop an evaluation method, which is able to determine the current market value of a project in the construction phase, and to provide a risk monitoring tool, which reflects the phenomenon of time-varying risks.

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Keywords: time-varying risks; project controlling; risk management; owner's value

1. Introduction

In the construction sector, there is an obvious need for an effective project risk-monitoring and controlling system conducive to the business success of the projects. Reviewing the relevant literature, approaches to risk management with emphasis on enhancing the number of risk criteria can be found, providing a fortified mathematical background and applicability in practice. However, these methods are usually static, and there are hardly any references to the fact that the individual risks in the risk classes may change as time passes. However, some of the risks inevitably get reduced, let us consider risks associated with the individual contractors, simply because the relevant subprocess has been finished. Although it would seem convenient to ignore this issue saying "less risk is better", and do nothing, in fact a reduction in one risk element can have numerous effects on other risks. A reduction in one risk element can

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extend the opportunities considering taking on other risks, but the opposite statement is also true: if a risk is increased, e.g. a contractor is late; it makes the risks of the deadlines of processes based on the work of that contractor higher.

The next problem arises when risks are interpreted in detail. Project management is basically deliverable-oriented, that is, the general goal is that an object to be finished according to the deadline at the defined quality and cost. When an element of risk is considered, we think of the extent the above goals are in danger. This, however is a multi-purpose optimization process, where in addition to the excessively complicated nature of the mathematical methods, sometimes not even the relative importance of the individual goals are clear.

In our study, we present a solution that considers the combined effects of time-varying risks along owner's interests, and puts the interpretation of risk in a context that can be easily handled mathematically. To develop the mathematical background for the project risk monitoring process, we use the value-based financial risk management approach defined by Toth and Sebestyen [15]. In this approach, critical values of the value-driver parameters are specified in the planning phase of the project and the occurrence of those values need to be collected continuously in the subsequent phases. In this article, we focus only on the development phase. The critical values of value-drivers are calculated based on the market value of the project just before its launch. The problem is that on the one hand, as time passes, the value of the project also changes and on the other hand, some plan data turn into fact data, and so the remaining possible deviations from expectations (in other words risks) become characteristically lower and lower. Our mathematical model, therefore, has to consider both the change in value and the change in risks at the same time. The key for a more sophisticated risk monitoring process is to update the project value and the critical value-driver values continuously.

The contribution of this research to the current body of knowledge is that it provides a mathematical background for understanding the time-varying project risks based on continuous monitoring process in an owner's value-based project risk-assessment framework for construction projects. This formalized, integrated risk management model describes the phenomenon of the decrease of risk as time passes, while the applicability of the process is maintained. Our aim is to exploit the developed model to further clarify the concept of value-based business project risks. The proposed model is presented through the planning phase, however it is valid for the development, and the operation and maintenance phases as well.

2. Continuous holistic risk evaluation

In the project management literature, risk is defined as a measure of the probability and consequence of not achieving project goals (see, e.g., [3, 9, 12, 13]), where project goals are typically related to the implementation of construction (time, cost, quality) as a deliverable. Construction project management literature tends to concentrate on specifying risk classes that jeopardize these project goals and focus on how to manage risks based on those classes. For example, Tserng, & al., (2009) recently presented an advanced ontology-based categorization of risk classes [16]. Risk has become increasingly understood conceptually as the likelihood of an event occurring within a project [4, 14], although an 'event' continued to cover a wide range of meanings. The principal methods of risk measurement have spread from other scientific fields to project management applications (for a summary see, e.g., [8]).

Although advanced risk management methods are highly supported by mathematical tools [1, 2, 5, 6, 10, 11], they do not develop the risk monitoring process and methods in detail. Although some of these works include sophisticated mathematical methods for risk management, the ownership approach is still missing from the criteria.

The challenge is not only to provide an integrated, holistic risk management method taking owner's value into consideration supported with proper mathematical models, but also to operate the project risk evaluation system continuously throughout the whole life cycle of the project. Continuous data collection and feedback are key issues for such a monitoring and controlling system. Although a combined evaluation method presented is able to determine the owner's value of a construction project in the planning phase, there are controlling issues left unanswered focusing on the need of relevant data to keep the project risk evaluation system updated constantly in the development phase [15].

An effective project monitoring and controlling system is fundamentally important in project-based organizations. A project monitoring and control system focuses on minimizing deviations from project plans, identifying and reporting the status of the project, comparing it with the plan, analyzing the deviations, and implementing the appropriate corrective actions (see, e.g., [7]). An effective system should clearly define the monitoring policy and the intervention and control policy (prevent, intervene and correct). In project management, mature monitoring techniques and analytical models are employed for earned value management, optimization tools, and decision support systems. In these areas of project management, continuous monitoring is well defined and widely used, however, without an owner's value approach. In the field of risk management, surprisingly, it does not even exist – at least not in the form of elaborated mathematical methods. We attempt to fill this gap because it would be beneficial to operate a project risk management system at a highly developed level, as well. In our opinion, an integrated project risk management system is able to evaluate risk enhanced with the concept of owner's value, provide a practical, easy-to-use model with a significant mathematical background, and continuously monitor and control the project in terms of its risks to start action plans.

3. Modelling approach for risk monitoring

The starting point to conduct this research is an integrated risk management framework defined by Toth and Sebestyen (2014) [15]. Fig 1 shows the value-based financial risk management process of a project.

The aim of risk monitoring is to check the occurrence of the critical values of parameters finalized in the planning phase in accordance with the financial model within the same contractual framework. The financial model is finished in the planning phase, and after fine-tuning, the value-driver parameters, which endanger value creation (or another selected parameter, such as liquidity, costs, and construction deadlines) can be derived. Construction, therefore, starts with the knowledge of these parameters and risks. If contractual conditions do not change, the task of risk monitoring is to follow risky value drivers and if necessary set the predefined action plans in motion to ward off harmful effects. Starting action plans usually result in shocking changes in the project, e.g. the suppliers, customers or the purpose of utilization of a building, etc. may change. This time the project moves into a new phase, the business model needs to be initialized again according to the current contracts and data, and the task of risk monitoring is again to watch critical value driver parameters.

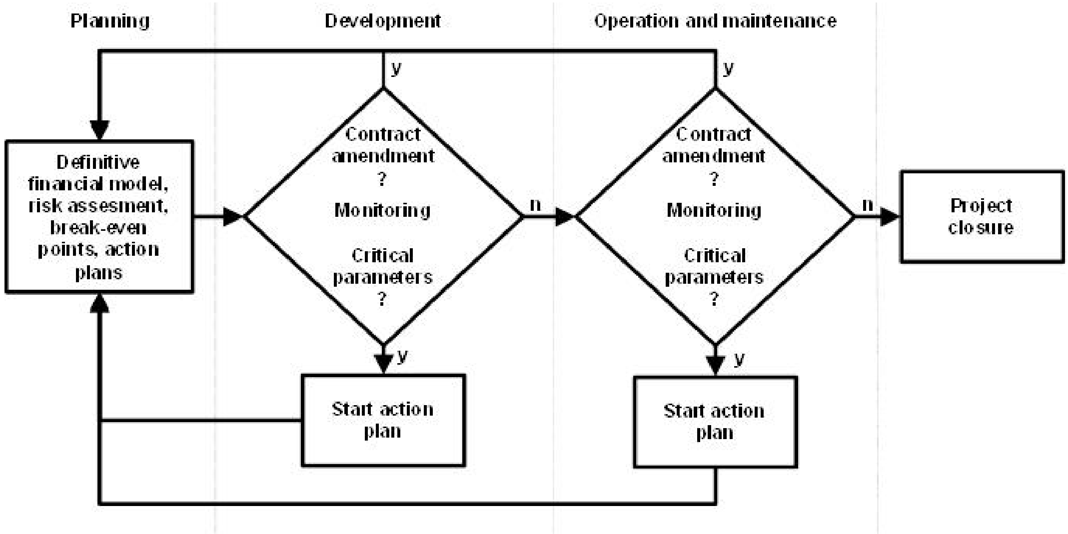

Fig. 1. risk monitoring in the value-based financial risk management process.

The new problem with the owner's value-based process is that while classical cost-quality-time objectives remain unchanged as the project develops, owner's value does not. Although the financial model is definite and permanent, even if there were no significant changes in the contracts since the launch of the project, the current value of the project is changing continuously because of the time value of money. To understand the problem, let us examine mathematically the owner's value of a construction project, and its change over time.

Let us define the value-driving parameter ($x_{n,t}$) as an arbitrary variable that can have any effect on the financial position of the owners of the construction project. $n = (1,\dots,N)$ refers to the nature of the parameter, and $t = (1,\dots,T)$ refers to the given time period in years. All value-driving parameters are expectations.

Based on these value-driving parameters, the expected annual cash flows to the owners ($CF_t = s(x_{1,t}, \dots x_{n,t}, \dots, x_{N,t})$) in year t can be calculated showing the expected change in the value of the owners' equity related to the business idea for that period. Fig 2 illustrates the cash flows of an office project with rental utilization against time.

In the planning phase, the costs incurred are usually related to the physical and financial foundation of the building. For example geological surveys, legal costs, costs of analysis and the wage cost of the preparation staff. At this time there is no decision on the start of construction, that is, the process may even be halted if; it cannot be shown that the project increases owner's value. After construction and financial plans have been finished, the development phase starts. In this period, cash flows are negative, while the value of the building is growing continuously. Finally, in the operation phase, cash flows are characteristically positive and in real terms can be characterized as annuity in the economic life span of the building.

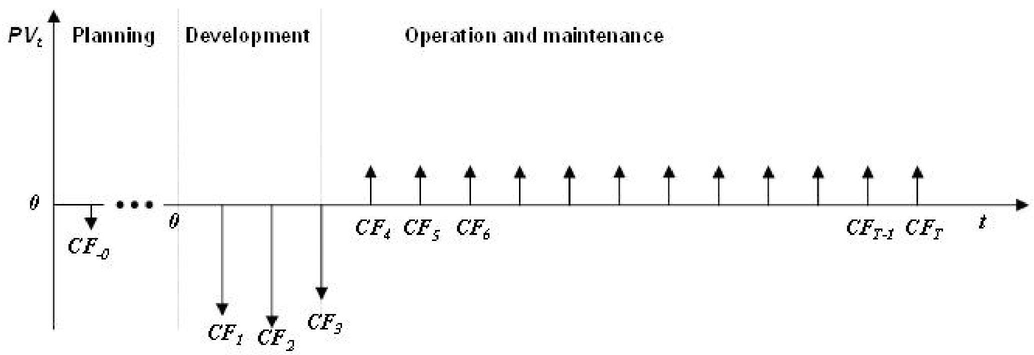

Fig. 2. cash-flows, present values, and net present values at the end of years.

In the value-based risk management process, we need the owner's value at the moment when the decision on starting the project is made.

Based on the theory of capital budgeting, the value of the project right before the first investment amount paid is the sum of the discounted cash flows, called net present value (*NPV*) (1).

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

The discount rate (r) refers to the minimum rate of return requirement on the capital invested by the owners. This rate mainly depends on the financial leverage of the project, the risk-free rate, and the risk premium. According to the theory of capital budgeting, the critical value of *NPV* is zero, therefore the harmful value of each value-driving parameter, called the economic break-even point ($B(x_n)$), can be expressed as follows (2).

$$NPV = \sum_{t=0}^{T} \frac{s(x_{1,t},...,x_{n,t}(1+B(x_n)),...,x_{N,t})}{(1+r)^t} = 0 \tag{2}$$

$B(x_n)$ 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 destructive.

Thereafter, the function of risk analysis is to determine the probability that changes in parameter x_n are larger than $B(x_n)$. If the probability density function of $f(x_n)$) is known, then by integrating over minus infinity to $B(x_n)$, the probability (P) that the value-driving variable is less than the break-even point can be determined (3).

$$P(-\infty < a_n \le B(x_n)) = \int_{-\infty}^{B(x_n)} f(x_n)dx_n \tag{3}$$

When there is discreet, measured data available of the given parameter, the probability of occurrence can be approximated with the quotient of the data measured in the harmful range and all the measured data. In trivial cases or if there is not enough data, usually an effect-probability of occurrence graph is usual, based on expert estimates (on a scale of low-medium-high).

This approach works well at time 0, both owner's value and risks can be determined, but in later years problems of interpretation regarding the potential of offsetting cash flows arise. The exact time when *NPV* is calculated is essential. Financial theory says that costs that we do not have any impact on at a given time become insignificant regarding the determination of value. These costs are called sunk costs by financial theory. (For example, the costs in the planning phase indicated with CF_{-0} in Fig 2 are required for the preparation of project appraisal and execution plans, but are usually excluded from all analyses, because by then they have sunk.) Thus, once investment starts, the current value of the project is determined by the present value (*PV*) of future cash flows. Fig 2 shows that at the end of the first year investment CF_1 becomes sunk. At that point, the following cash-flows can be earned for less investment, and *PV* increases with the sunken CF_1. To calculate NPV_1 we need the actual value of construction. The problem is that in the development phase it is usually very difficult to assign apparent market value to the investment, because there is no feedback on market price. In this phase, the project is usually unfinished and many contracts are still in force, so the project could only be sold at high transaction costs. Terminating contracts is time consuming and costly, and new measurements, status assessments, calculations, and deals are necessary for new contracts.

Note that the risk monitoring method presented in this article applies to a stable contractual environment. The possibility of automatic risk monitoring is examined in this environment, which is continuous from a contractual point of view. If there is a change in the structure of the project, a full revaluation is needed including the risk assessment processes.

In order to express how owner's value develops, it is important to reflect on the issue of sunk costs and the value of time. On the time range of the project let us set time 0, which indicates the investment decision. The actual year is designated with *t'*. To find the value of a construction project in year *t'*, it can be assumed that according to the plans (and contracts) other enterprises could produce the status of the building in the given year at similar costs as well. Following this, the current value is tied to the costs spent, the elapsed time, and the expected cash flows of subsequent phases. It is assumed, therefore, that the current value can be synthesized by the values of two phases: on the one hand, from the present value of realized cash flows $(\overline{CF}_t)$ calculated in time *t'*, and on the other hand, from the present value of the latter cash flow expectations (4).

$$PV_{t'} = \sum_{t=0-t'}^{0} \frac{\overline{CF}_t}{(1+\hat{r})^t} + \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t}$$
$$PV_{t'} = \sum_{t=0-t'}^{0} \frac{s(\hat{x}_{1,t},...,\hat{x}_{n,t},...,\hat{x}_{N,t})}{(1+\hat{r})^t} + \sum_{t=1}^{T} \frac{s(x_{1,t},...,x_{n,t},...,x_{N,t})}{(1+r)^t} \tag{4}$$

where $\hat{x}_{n,t}$ comes from factual data of events already occurred and $\hat{r}$ is the discount rate calculated from historical data. Technically, there is inverse discounting in the years that passed, since here the values of *t* are negative. This momentum that derives from the discounted cash flows framework reflects on the fact that as time passes the value of money invested earlier has to increase partly because the time value of money, and partly because of the risks taken.

On this basis, the calculation of the thresholds of risk analysis is to be reinterpreted, as the value-drivers of completed sections are no longer subject to change (5).

$$PV_{t'} = \sum_{t=0-t'}^{0} \frac{s(\hat{x}_{1,t},...,\hat{x}_{n,t},...,\hat{x}_{N,t})}{(1+\hat{r})^t} + \sum_{t=1}^{T} \frac{s(x_{1,t},...,x_{n,t}(1+B(x_n)),...,x_{N,t})}{(1+r)^t} = 0 \tag{5}$$

After that, the determination of the probability of harmful events can be calculated using formula (3), however, compared to the basic concept, the distance between $B(x_n)$ and x_n increases over time, and thus the probability of harmful event n decreases. This phenomenon reflects that getting closer to the end of construction the chance of the occurrence of any changes that would jeopardize shareholder value decreases.

The first part of formula (4) corresponds with the plan-fact analysis of controlling tasks, thus, this model does not mean extra responsibility for the management. Still, risk monitoring is much more sophisticated in this way than risk monitoring built on non-updated critical values set before the beginning of the project.

4. Discussion

The model presented shows that risk, defined as critical deviation form expectations, can be determined for all value-drivers and each year individually. In economic break-event point calculations uniform changes of a given value-driver parameter are usually examined in the given time, and this is also true for traditional project management, where risks in risk classes typically are not assigned with the time unit. For example, the change in electricity cost risk is usually judged uniformly for the whole development phase. In practice this means that when a traditional risk class or profit threshold is interpreted, judgment is made based on the combined yearly deviation of the given risk component. Side A of Fig 3 shows the deviations of individual years, whereas side B shows the combined deviation, based on which risk is usually determined.

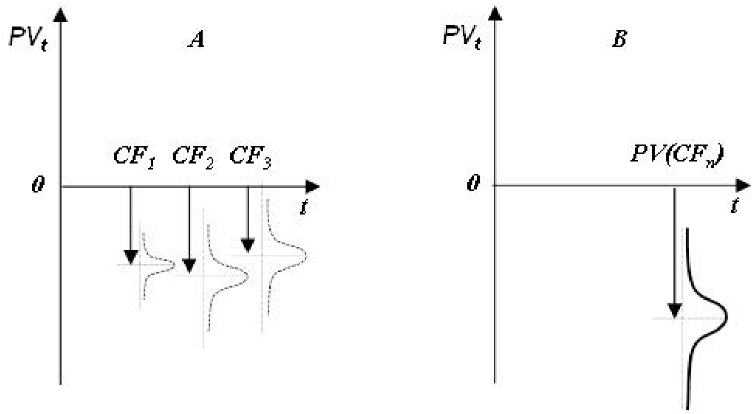

Fig. 3. (a) deviation of cash-flows in each year; (b) deviation of present value of cash flows.

After the first year, however, the cash flow of the first year is realized, that is, it no longer has deviation, e.g. the price of electricity in the above example becomes fact, and therefore combined deviation will also decrease. This is shown in Fig 4.

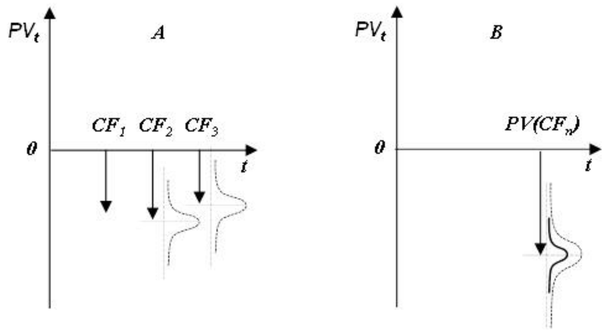

Fig. 4. (a) deviation of year 1 vanishes; (b) deviation of present value of cash flows decreases (plotted line: original, solid line: actual).

If combined deviation decreases, the probability of occurrence of the harmful event also decreases. Risk, such as the probability of occurrence of the harmful event, decreases as a result. This phenomenon highlights a significant shortcoming of the application of traditional risk classes and the calculation of economic break-event points: risk is not a static but a dynamic variable. Let us use the above example again: after the first year, the risk of changing electricity prices appears significantly less. Unlike traditional methods, the dynamic risk monitoring suggested by us takes this phenomenon into account.

Let us examine the causes and consequences of the continuous changes in value as well. Fig 5 shows the cash flows of the projects and the risk monitoring process suggested by us and the present value and the net present value of the project in each year.

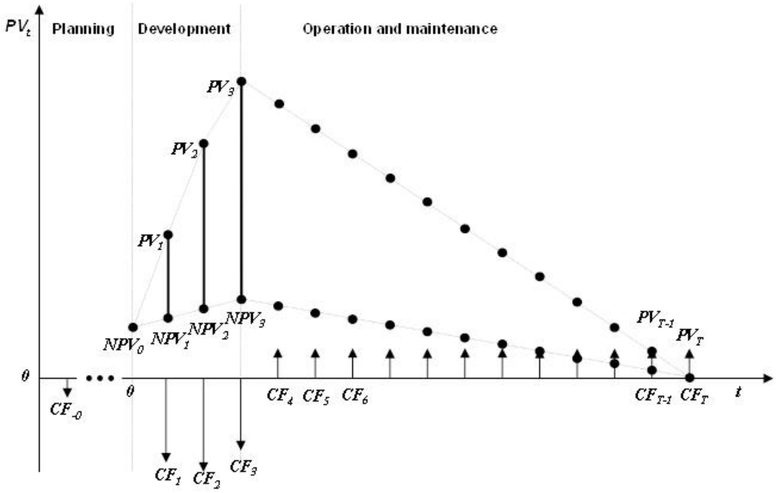

Fig. 5. in the development phase the PV of the project increases because of sunk costs, the NPV of the project increases because of time value of money.

The present value of the project (PV_n) increases continuously in the years of construction, since amounts paid earlier sink, and current net present value grows continuously indicating the time value of the investment. In the years of operation, current present value decreases, since the utilization time of the building decreases and as a result the same cash flow in the remainder of whole time period can be realized from the project, while current NPV also decreases, since as time passes the market value of the building also decreases.

Note that our model does not treat the development, and the operation and maintenance phases differently, therefore the method can be extended to the latter phases.

5. Conclusions

In project management sophisticated monitoring techniques and analytical models are employed for earned value management, optimization tools and decision support systems, but as our literature review showed, not for the continuous risk monitoring system. Although some of the employed risk management methods focus on advanced mathematical tools, they leave out either the ownership approach from the criteria, or the applicability of continuous usage. This article is based on a value-based risk management approach that includes the concept of owner's value and provides the mathematical background of the phenomenon of time-varying risks based on an algorithm to facilitate continuous risk monitoring. Our formalized, integrated risk management model describes the rather pragmatic phenomenon of the decrease of risk as time passes, while the applicability of the process that we proposed in Fig 1 is maintained. We believe that providing the mathematical context of time-varying application of our risk monitoring process will help further clarify the concept of business project risks.

Nomenclature

$x_{n,t}$ a value-driving parameter, where $n = (1,\ldots,N)$ refers to the nature of the parameter, and $t = (1,\ldots,T)$ refers to the given time period in years
CF_t expected annual cash flow in year t
r minimum rate of owners' return requirement.
$B(x_n)$ economic break-even point of an arbitrary value driving parameter
$\overline{CF}_t$ realized cash flow in year t.
$\hat{x}_{n,t}$ realized value of a value-driver parameter in year t.
$\hat{r}$ the discount rate calculated from historical data

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