Available online at www.sciencedirect.com

SciVerse ScienceDirect

International Journal of Project Management 31 (2013) 126–135

International Journal of Project Management

www.elsevier.com/locate/ijproman

Optimum budget allocation method for projects with critical risks

Tomoichi Sato [a,*], Masahiko Hirao [b]

[a] JGC Corporation, Japan
[b] Dept. of Chemical System Engineering, The University of Tokyo, Japan

Received 11 March 2011; received in revised form 1 April 2012; accepted 5 April 2012

Abstract

In this paper, the authors analyze the trade-off problem between project budgets and critical risks. Project managers face the problem to balance cash flows and risks when preventive risk response plans require additional costs. Mathematical modeling approach is used with a metric called risk-based project value (RPV). RPV is an evaluation of projects calculated with cash flows and risk probabilities of activities that constitute the project network diagram. There exists an optimal solution for the budget allocation problem that maximizes the expected project value. There is a condition where additional budgets can improve the project value. The study result suggests that there should be an integrated process to optimize the budget plan with the risk management plan. Methods are developed to obtain optimum budget allocations for projects with various types of activity networks. Evaluation of the marginal cost sensitivity on the RPV supports project manager's decisions on reallocation of budgets.

Keywords: Project evaluation; Risk; Cash flow; Budget allocation; Parallel funding

1. Introduction

This paper aims to elucidate an optimum solution to the trade-off problem between project budget and risks. Risk mitigation strategies often require more budgets, which may push the project cash flows toward a negative side. Cost reduction efforts, on the other hand, are sometimes associated with higher risks. Project managers face the problem to balance cash flows and risks in the planning phase.

Risk is usually regarded as a possibility of events that may cause adverse effects on project objective/performance. There are positive risks, or, in other words, opportunities as well, that may cause positive impact on achieving project objectives. Although there are various ways and spans to define it (Chapman, 2006; Kino, 2005; Smith and Merritt, 2002), this manuscript refers to the risk in the most stringent meaning: the possibility of critical situation where an activity cannot deliver mandatory outcome(s) required for the project objective and no other immediate alternatives are available. Such critical risk events will bring a project to forced termination.

Purpose of this study is to present the existence of an optimal solution for the trade-off problem between the critical risks and budgets. A calculation method is provided for budget allocations that maximizes expected project value, using mathematical models and operations research (OR) techniques.

Normal process of project planning covers the work breakdown structure (WBS) definition, development of activity network, cost and time estimation of each activity, and risk analysis. Risk analysis includes: (1) identification of possible risk events and their drivers, (2) assessment of probability and impact of each risk, (3) risk classification and prioritization, and (4) development of a risk response plan. Then, the project budget is revisited and finalized. The trade-off problem arises on this step, especially with the preventive type of risk mitigation decisions.

Risk response plans can be categorized into two types: preventive and adaptive. They depend on the nature of risk drivers. Some risk drivers can be mitigated with additional costs paid

* Corresponding author at: JGC Corporation, 2-3-1 Minato-Mirai, Nishi-ku, Yokohama 220-6001, Japan. Tel.: +81 45 682 8256; fax: +81 45 682 8564.
E-mail addresses: sato.tomoichi@jgc.co.jp (T. Sato), hirao@chemsys.t.u-tokyo.ac.jp (M. Hirao).

0263-7863/$36.00 © 2012 Elsevier Ltd. APM and IPMA. All rights reserved.
doi:10.1016/j.ijproman.2012.04.002

upfront (or investing additional efforts with resources/time/scopes, which, in turn, mean costs). We call them 'cost-dependent' risk drivers. Preventive budget allocation is suitable for cost-dependent risk drivers, thus becoming a source of the trade-off problems. An example is to provide a stand-by machine for a critical service in a new production plant in order to prevent accidental breakdown.

On the contrary, some risk drivers are cost independent. An example is rejection by the government on applications for building a new plant or cancellation of orders due to a financial crisis. Such critical risks are not reducible with additional payment. Adaptive plans are required for cost-independent risk drivers with contingency reserves in budget.

Cost reduction efforts can be another source of the trade-off issue. Using lower cost materials or resources with poorer qualities may increase critical risks. Higher reliability materials/resources mean higher costs. Problems are similar to cases with preventive risk plans, although the intention would be opposite.

Solution to this problem is especially important for projects with large costs and high risks of termination. New product development is one of such project areas. The pharmaceutical industry is a good example where new product development projects require large budgets but only a small percentage can reach fruition (Danzon et al., 2005; Kuwashima, 2006). R&D projects in the chemical industry are also exposed to high risks, where more than 90% of them could be terminated due to technical difficulties (Fukawa, 2007). Resource exploration project is another area where balancing is crucial between costs of drilling and risks with poor production outcome.

Previous studies on cost optimization were mostly related to the time/resource scheduling problem for a project or within a project portfolio (Dillon et al., 2005; Golenko-Ginzburg et al., 2006; Laslo, 2010; Yang, 2007). Fan et al. (2008) analyzed an optimal combination of preventive and adaptive risk response strategies based on a probability-loss model, although their data source was limited to construction projects. Czuchra (1999) analyzed optimum budget spending, but the model was limited to the field of software projects.

The PMBOK Guide (PMI, 2008) suggests two methods for quantitative risk analysis: Monte-Carlo simulation and decision tree analysis. The Monte-Carlo simulation technique is widely used to forecast overall project cost with their associated achievable probability based on each activity's cost probability distribution (Cochrane, 1992). However, it is not designed to support preventive decisions on individual risks.

Decision tree analysis can handle individual decision problems (Matsubara, 2001). It enables analysis on expected values of a project at each event node to choose the case with the maximum value. It can also be enhanced with real option analysis (Copeland and Antikarov, 2001). However, it cannot handle continuous-type decision problems. When we try to apply it to a large number of activities, the branches of the tree will rapidly grow to an impractical degree of complexity.

The aim of this study is to establish a guiding principle to balance project costs and critical risks. Lack of metrics to evaluate/optimize the entire project cost with the critical risks has made this problem difficult to tackle. In this light, the risk-based project value (RPV), a new metric proposed by Sato (2009a, 2009b), seems useful. The authors apply the RPV analysis to solve the optimal budget problem in this paper.

Our research hypothesis is that an optimal budget allocation would exist for any project with cost-dependent risks. In order to prove this hypothesis, a general cost–risk relationship model is proposed in this paper. Next, optimization methods are developed using OR techniques. Then, a condition is clarified where additional budget allocation improves the expected project value. Finally, a tool is created to support practical decisions for PM.

The basic assumption in this study is that inputs and outcomes of a project can be measured by cash values. Projects primarily aiming at intangible values, such as scientific discovery or human resource building, are not considered here, since balancing intangible values against tangible costs imposes another level of complexity to the problem. The expected monetary value of a project is the primary measurement to be optimized.

2. Introduction of the risk-based project value concept

In this section, the authors introduce the RPV and its associated theoretical framework (Sato, 2009a, 2009b) for analysis. RPV is the evaluation of projects and is calculated on the basis of cash flows and risk probabilities of activities that are comprised in the project network diagram. The authors consider that the RPV analysis fits the study purpose for three reasons. First reason is that RPV represents the value of an entire project. RPV can be measured at any moment in the project life cycle and is equal to the expected monetary value of the project cash flow. Second, the definition of RPV explicitly includes the cost and the risk probability of each activity in its deterministic calculation process. Thus, it makes sense to examine the trade-off relationship theoretically. This does not require random number simulations and sensitivity analysis, which do not always give reproducible results. Third, the framework of RPV analysis can handle the activity network structure of a project.

Project risks in the RPV analysis are represented by the probabilities of termination of the activities involved in the project. RPV is defined as the summation of attained cash flows (sales incomes minus allocated costs) of past activities and expected cash flows of ongoing/future activities discounted by the probabilities of termination. At the planning stage, all activities are in the future. Please note that, like the DCF method, RPV analysis is designed for investment type of projects, and thus, it encompasses the whole lifecycle of a project covering not only investment phase but also operational phase. The term 'project' sometimes refers to efforts to deliver a product, service, or result in the investment phase only, but valuation of a project cannot complete without considering its outcome cash values.

Let us first illustrate the basic concept of the RPV using a project with a single activity (which we call a 'simple-type' project). The initial cost C must be spent on the activity, and income S will be gained after its successful completion. There is a risk probability r for unsuccessful termination during execution (Fig. 1).