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Improving Project Budget Estimation Accuracy and Precision by Analyzing Reserves for Both Identified and Unidentified Risks

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Abstract

Project risk is a critical factor in estimating project budget. Previous studies on this topic have only addressed estimation methods that consider project budget reserves against identified risks. As a result, project managers still face the challenge of completing projects within given budgets but without the relevant tools to deal with unidentified risks. This study proposes an approach for estimating reserves for both identified and unidentified risks separately. The study also suggests using the three-point estimation technique and R-value determination for estimating risk costs, which can improve budget accuracy and precision. The construction of residential building projects in South Korea demonstrates the advantages of the proposed approach compared with previous methods.

Keywords

contingency reserve, management reserve, risk cost, budget estimation

Introduction

Cost is the most critical parameter (Becker, Jaselkis, & El-gafy, 2014; Ke, Ling, & Ning, 2013; Sweis, Sweis, Rumman, Hussein, & Dahiyat, 2013) within the standard success criteria of cost, schedule, and performance targets—often called the "iron triangle" (Pfleeger & Atlee, 2006; Williams, 2016)—when it comes to managing projects. However, in reality, project cost overruns and scope creep are normal phenomena in infrastructure and construction projects carried out in both developed and developing countries (Bhargava, Anastrasopoulous, Labi, Shiha, & Mannering, 2010; Doloi, 2013; Enshassi, Al-Najjar, & Kumaraswamy, 2009; Frimpong, Oluwoye, & Crawford, 2003; Sambasivan & Soon, 2007; Smith, 2014). Flyvbjerg, Holm, and Buhl (2002) found that 90% of construction projects underestimated costs, which resulted in cost overruns of between 50% and 100%.

Project cost overruns are significant problems in government project management as well. In government project management, projects are complex and larger. Thus, many large-scale, complex systems development projects also experience persistent cost and schedule overruns (U.S. Government Accountability Office [GAO], 2013). In 1983, the Nunn-McCurdy Act was passed into law by the U.S. Congress to prevent overruns. The law requires Department of Defense (DoD) acquisition programs and other large-scale federal government projects to report to Congress when they exceed certain established cost overrun thresholds (Schwartz, 2010). This law has been amended many times over the years to reflect evolving federal project management and reporting practices (Adoko, Mazzuchi, & Sarkani, 2016).

While project managers have been managing projects to meet budget, time, and performance targets, researchers have been trying to identify the root causes of cost overruns and develop accurate budget estimation methods to solve these problems. According to previous researchers, risks are one of the major reasons for cost overruns; thus, various budget estimation methods, including estimating project reserves against risks, have been developed. However, previously developed project reserve estimation methods were presented to estimate reserves against identified risks only, even though budgets against unidentified risks are also included in project reserves, which is a deficiency of the budget estimation methods previously studied. Thus, projects still may suffer from cost overruns.

Project budgets are funds estimated during the planning phase based on what the project is expected to cost at

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completion. It is very difficult to estimate project budgets accurately before executing the projects due to lack of information and risks. Thus, a project management plan including cost estimation are developed at an early stage before projects are constructed. So, it is very difficult to accurately estimate the project budget due to lack of information or data (Creedy, Skitmore, & Wong, 2010; Koushki, Al-Rashid, & Kartam, 2005; Oberlender & Trost, 2001), and is needed for justification of projects on economic grounds and for efficient capital planning and financing (Baccarini, 2006; Caron, Ruggen, & Merli, 2013).

The purpose of this article is to develop an innovative budget estimation method that includes estimating project budget reserves against both identified and unidentified risks. This article will discuss the advantages of the method presented herein, along with recommendations for a simplified treatment of correlations between past performance and future performance. Application of this methodology in example projects will also be presented. Twenty residential building construction projects in South Korea were selected, and the variances between budgets and actual costs were analyzed.

Literature Review

Researchers have investigated the root causes of cost overruns and developed solutions to prevent them in different countries and various ways. According to previous research, inaccurate cost estimation and uncertainties are the major reasons for cost overruns. Various estimation methods have been developed to mitigate the additional costs resulting from uncertainties. However, the existing models have estimated project reserves for identified risks only so that cost variances cannot be predicted and controlled; thus, cost overruns are still a common occurrence in project management. The main drawback of the existing estimate reserve methods is their lack of consideration of unidentified risks. Therefore, an innovative budget estimation method that responds to unidentified risks as accurately and precisely as possible is required in order to avoid cost overruns.

The Root Causes of Cost Overruns

Nawaz, Shareef, and Ikram's (2013) work on cost performance in Pakistan listed factors that are responsible for cost overruns. These factors include corruption and bribery, political interests, poor site management, delays in site mobilization, rigid attitudes among consultants, extra work without approvals, and frequent changes during execution. In Ghana, 75% of groundwater construction projects exceeded the original project schedule and budget. The main causes of the delays and cost overruns were financial difficulties, poor resource management, and unexpected natural events (Frimpong et al., 2003). Sweis et al. (2013) analyzed different types of public construction projects in Jordan and found that 65% of them were not finished on budget. The major factors that caused the cost overruns were governmental delays, followed by severe weather conditions, and design changes. These three factors account for 73% of cost overrun causes. A survey of 104 public projects in Singapore indicated that nearly two-thirds suffered from cost overruns and more than half were delayed due to risks (Hwang, Zhao, See, & Zhong, 2015; Ke et al., 2013). According to Koushki et al. (2005), delays and cost overruns increased in the construction of a private residential project in Kuwait due to three main causes: contractor-related problems, material-related problems, and owners' financial constraints. In the Nigerian construction industry, one of the causes of cost overruns was inadequate contingency allowance, where a 5% to 10% contingency allowance was a common practice. However, the actual 17.34% contingency allowance estimated falls within the 15% to 20% allowance recommended by the U.S. Department of Energy (DOE) for budget estimates of new buildings (Aibinu & Jagboro, 2002). Aziz (2013) presented improper bidding/tendering methods, inaccurate cost estimations, and unexpected risks as the major factors causing cost variations for constructing wastewater projects in Egypt. Economic factors such as interest rate, unit price for material and labor, rental rate for equipment, and changes in planned works were risk factors for building construction in South Korea (Cha & Shin, 2011). More recently, other studies have shown somewhat similar results. Major factors affecting cost overruns in public construction projects included: materials price fluctuations, lack of experience among contractors, incomplete drawings, government delays, incompetence, inaccurate estimates, improper planning, and poor labor productivity (Doloi, Sawhney, & Rentala, 2012; Kasimu, 2012; Memon, Rahman, & Azi, 2012; Tabish & Jha, 2011). Researchers have indicated that these significant cost overruns are caused by uncertainties arising from risk events and inaccurate budget estimates (Bannerman, 2008; Creedy et al., 2010; Elkjaer, 2000; Hullet, 2012; Lai, Wang, & Wang, 2008). Uncertainty of cost items is an important aspect in complex projects, and cost uncertainty analysis aims to help decision makers understand and model different factors that affect funding exposure and ultimately estimate the cost of projects (Khodakarami & Abdi, 2014). As a result of this research, two main causes of cost overruns have been identified: One is managerial factors not related to risks, such as regulations, contract methods, and political issues, and so forth, which are beyond the scope of this article because they could be improved by education, project team member experience, and historical data. The other cause is inaccurate cost estimation resulting from uncertainties—especially unrecognized or unexpected events—which are within the scope of this research to help improve. The main objective of this article is to present an innovative budget reserve estimation method used to mitigate the impacts against both identified and unidentified risks in order to minimize the cost variances.

Cost Estimation Methods

Estimating an accurate project budget is challenging for project managers, because of the unpredictable risks concerning how big the impacts on construction project results are and when they will occur. Furthermore, budget estimation is conducted during the planning phase (Caron et al., 2013; Koushki et al., 2005; Sato & Hirao, 2013; Xenidis & Stavrakas, 2013), which is an early stage of the project life cycle, when there is a lack of data and information. Project managers need a budget estimation method to respond to risks as accurately and precisely as possible in order to prevent cost overruns. In response to uncertainties and risks, Project Management Institute (PMI) (2013) defined reserves that are composed of a contingency reserve for identified risks (known-unknowns) and a management reserve for unidentified risks (unknown-unknowns). Previous researchers have presented several methods to estimate cost reserves but those are not sufficient to cover all types of risks. One method is the traditional percentage model (Moselhi, 1997), which is arbitrary and difficult to justify or defend (Thomson & Perry, 1992); the other method is Monte Carlo simulations (Barraza & Bueno, 2007; Clark, 2001; Eldosouky, Ibrahim, & Mohammed, 2014); and a third method is the regression model (Adoko et al., 2016; Kim, Kang, & An, 2004). These models are used for estimating total project costs and are powerful statistical tools used for analytical and predictive purposes in forecasting the total final cost of the project. These methods lack consideration of estimating risk costs because they are used to estimate the total project budget without risk analysis. If a single project is executed many times, the probability density function (p.d.f.) can be obtained. The probability of the project cost can be calculated by the probability density function, so that the probability that actual cost can exceed the established target cost can be obtained on the probability density function during project execution (Garvey, 2008; Zhu, Zhang, & Wang, 2011). Thus, any types of risk can be estimated to a monetary value, which can be involved in project cash flow as well (Halawa, Adbelalim, & Elrashed, 2013). For example, gamma distribution (Uzzafer, 2013) and a scenario-based method without statistical concepts (Book, 2007; Garvey, 2008) have been presented for estimating cost risk provided by cumulative probability distribution with limited predefined values of risk impacts for all risks, regardless of whether they are identified or unidentified. Other models using the fuzzy expert system (Carr & Tah, 2001; Dikmen, Birgonul, & Han, 2007; Idrus, Nuruddin, & Rohman, 2011) and artificial neural networks (Chenyun, 2012; Zhu et al., 2011) have been used for the development of a project cost contingency estimation model. These models are suitable for the nonlinear modeling of data, which contrasts with linear approaches using regression (Baccarini, 2006), and may be used effectively in the risk assessment for identified risks, but they are less effective for estimating cost contingency.

The results of previous research do not clearly estimate reserves for unidentified risks, because unknown-unknown risks were excluded from the research due to assumption by the author (Baccarini, 2006) or unmanageable (Chapman, 2000). Furthermore, contingency resources estimated to handle unknown risk events cannot be justified because these could not be identified and estimated (Kitchenham & Linkman, 1997). In addition, these are events not known to the project team before they occurred or viewed as impossible in a specific project situation. By definition, unknown-unknowns are not foreseeable and thus cannot be dealt with proactively (Smith & Merritt, 2002; Thamhain, 2013). Although risk cost estimation methods for identified risks have been presented by previous researchers, the reserves for unidentified risks have not been sufficiently examined. The rare studies on estimating reserves against unidentified risks cause large cost variances and difficulty for sponsors or project managers in making decisions properly in order to provide benefits from the project results.

The Basic Terminologies of Budget Compositions

Net cost, allowance, and point estimate (PE)

Project managers create a work breakdown structure (WBS) and identify the applicable cost factors associated with project work packages in order to develop the project budget. The budget of each work package consists of the labor, materials, and overhead costs. In this article, however, the overhead costs are not included because they represent another cost factor that can be variable depending on the organization's management level. The costs of work packages can be calculated by multiplying the quantity of material and/or labor by the unit cost of material and/or labor. The net cost is the sum of the monetary value of the resources for a fixed scope of work without any tolerances or margins. Generally, the resources for a fixed scope are described in the design or on drawings. The quantity of materials and labor contains net quantity and any tolerance or margin against mistakes and/or miscalculation, such as human error. Additional funds for any margins or tolerances is an allowance intended for specific subjects that have not or cannot be fully specified (e.g., technical allowance, purchase allowance, and weather allowance) (Bedarida & Conti, 2012). The allowance can be changed depending on the project members' experience, educational level, knowledge, historical data of the project, expert judgment, and lessons learned. The sum of net cost and allowance becomes the PE of the element costs across the project's WBS without any adjustments for uncertainty but including any allowances (Garvey, 2008). The sums of each work package's point estimate become the total point estimate of the project without any risks.

Reserves and Budget Baseline

Once the PE has been reviewed and approved the next step is to estimate reserves as a budget against risks. In addition to all the work identified, projects will have some other unplanned work that is the result of risks. The project budget consists of PE and reserves. Although a PE not related to risks can be made as accurately as possible based on education and experience, reserves as risk cost related to risks can be estimated with probabilities and impact amounts. There are two categories of reserves: the contingency reserve for identified risks and the management reserve for unidentified risks. The former is the budget for response actions taken against identified risks, and the latter is the budget to cover other risks, such as unidentified risks that include residual and secondary risks beyond identified risks. The project budget baseline can be described as the sum of the PE from the project cost management process and the contingency reserve for identified risks from the project risk management process. The management reserve is not included in the budget baseline, but it is included in the total project budget (PMI, 2013). The relationship between the project risk management process and the project cost management process should, therefore, be considered in the estimate of the total project budget.

Confidence Level

Historical data and experiences are aggregated to review and determine an appropriate level of confidence. The confidence level covers all of the actual costs, including PE and additional costs from identified risks, unidentified risks, residual risks, and secondary risks (Book, 2007; NASA, 2008). The additional dollar amount beyond the budget baseline is considered and executable within the level of confidence. Software programs such as Crystal Ball and @Risk are used to determine the confidence level. The confidence level is subject to change depending on the projects' features and categories, including IT, construction, and R&D projects.

Analysis of Previous Project Cost Performance

Project selection and analysis. For the research presented in this article, 20 residential building construction projects were selected for performance analysis to verify the insufficiency of the existing estimation methods to cover risks. The purpose of performance analysis on past projects is to develop the confidence level and examine trends in the variances between budgets and actual costs for future projects. All work packages are assumed to be independent of each other so that there are no positive and/or negative correlations between work packages, because correlation is a very important aspect of combining cost distribution. For example, if the cost of one work package increases because of risks, then the cost of other work packages neither increases nor decreases.

Data collection was conducted through interviews and consulting with project managers and/or directors between the years 2014 and 2015. The residential building projects analyzed were constructed between the years 2008 and 2015. These projects were selected to maintain continuity and consistency and to avoid the bias in data analysis caused by differentiation of work breakdown structure, risk register, and maturity level of project management. All the selected projects were from one company. The company's policy for the case study to estimate reserves was to use a hybrid method with traditional percentage and risk analysis to develop response plans. Reserves for risks were determined to represent approximately 10% of the total budget. The sum of the total budget of 20 projects are overrun by 37,693, whereas the point estimate was 5,541 overruns, which were not caused by risks. Overruns of reserves were 32,152, which were caused by inaccurate risk budget estimation and unidentified risks. The 5,541 overruns of the point estimate are caused by estimation errors or miscalculations. However, the 32,152 overruns of the reserves are caused by the errors of the risk analysis, including risk identification and estimation risks. The details of cost overruns and risk costs are analyzed in Table 1. The type of currency was not identified for the purpose of company confidentiality.

Findings

Only the identified risks were recorded on the risk register. Response plans were developed in response to those risks, but the unidentified risks could not be recorded and calculated. It was very difficult to determine accurate reserves, because project managers or experts could not precisely forecast the number of probabilities and the impact in the early stage, even though some risks could be identified. In this article, the variances between budgets and actual costs by each budget composition—such as PE, actual costs for identified risks, and for unidentified risks—were analyzed to develop a new budget estimation process. As a result of the above analysis, there must be three cases regarding the relationship between risk costs and actual costs. The first case is that there are budgets and actual costs for risks; the second case is that there are budgets but there are no actual costs; and the third case is that there are no budgets, but actual costs are disbursed. The last case describes a situation in which the costs are incurred by unexpected events. As in the first case, the cost overruns of reserves for identified risks were 17,542 between the budgets of 146,838 and actual costs of 164,380. In the second case, risk budgets for exchange rate were estimated at 463, but there were no actual costs. In the third case, there were actual costs of 15,073 without risk budgets in some of the risk items such as cash flow impact, delays due to excessive approval procedures, lack of coordination among project participants, capability of the owner's group, and others. The first and second cases are described for the contingency reserves against identified risks, whereas the third case was for management reserves against unidentified risks. In terms of project cost management, cost variances between budgets and actual costs are inevitable. Thus, calculating the contingency reserve and management reserve separately is necessary to control project costs by collecting data as lessons learned for future projects in order to minimize cost variances even when the total variances between risk budgets and actual costs are underrun or zero. In this article, an innovative estimation method for project risk budget—including contingency reserves for identified and management reserves

Table 1. Risk Register and Risk Budgets versus Actual Costs

Category	Risks	Probabilities (%)	Overrun Costs of PE	Risk Reserves Budget (A)	Risk Reserves Actual (B)	Risk Reserves A − B
Natural and Environmental	Weather impacts	60		54,230	68,240	−14,010
Political	Regulation changes against constructors	40		320	45	275
Financial	Exchange rate change	30		463	–	463
	Capital funding impacts	40	255	–	–	–
	Cash flow impacts	40		–	473	−473
	High costs due to improper bidding parties	30		522	457	65
	Poor estimating	30	4,530	4,133	5,802	−1,669
	Increased labor costs	40		2,506	1,240	1,266
	Increased material and equipment costs	40		90	2,236	−2,146
Technical	Design changes	50	540	212	3,415	−3,203
	New risks due to new technologies	40		727	1,250	−523
	Failures in production equipment	30		4,221	5,413	−1,192
	Scope change	70		24,450	23,984	466
	Technology selection	30		373	438	−65
	Implementation methodology	30		481	527	−46
	Delay due to excessive approval procedures	30		–	746	−746
Managerial	Quality management risk	40		32,548	21,498	11,050
	Strikes of subcontractors	30		2,110	1,091	1,019
	Poor communications	30		5,438	9,972	−4,534
	Assigning unqualified project participants	40	57	–	–	–
	Late making decisions	30	31	–	–	–
	Lack of coordination between project participants	30		–	6,250	−6,250
	Lack of professional pre-planning studies	30		5,632	6,814	−1,182
	Capability of owner's project group	40		–	6,890	−6,890
	Contractor capability	30		478	528	−50
	Vendor's capability	30		8,367	11,430	−3,063
	Others	30	128	–	714	−714
	Total		5,541	147,301	179,453	−32,152

for unidentified risks—have been developed separately to improve project cost management.

Proposed Method for Estimating Project Budget

Accuracy and precision are important factors to consider when determining project budget to minimize cost variances by cost overrun or underrun. The proposed project budget estimation method is an innovative one that improves budget accuracy using the probabilistic estimate (Book, 2007; Garvey, 2008), and budget precision using the three-point estimation technique and R-value determination.

Probabilistic Estimation

It is assumed that the actual cost of a project is random variable X_i with probability density function f_i. Each project presents a p.d.f. of the forecasted project cost if the total project cost is a lump sum of many cost components, such as work packages. When the number of WBS elements increases, the distribution of the total cost of the WBS elements approximates the normal distribution with mean μ and variance σ^2 based on the Central Limit Theorem (Barraza & Bueno, 2007; Book, 2007; Eldosouky et al., 2014). A three-point estimation technique for each work package on the WBS is used to obtain this p.d.f. for project budgeting from the Monte Carlo simulation (Clark, 2001). This is an improved method over single-point activity cost estimates because it considers uncertainty and risk better (Book, 2007; PMI, 2013). The three-point estimation technique, which is assumed to follow triangular distribution (Xenidis & Stavrakas, 2013), is adopted to develop a p.d.f. with a cumulative S-curve. The main focus of this research is to determine project budgets with a low probability of overrun or underrun (accuracy) and small cost variances (precision). The cumulative distribution function (c.d.f.) for project i is also defined by the mean value (μ_i) and variance $(\sigma^2{}_i)$.

$$F_i\ (x_i) = \int_0^{x_i} f_i(t)d \tag{1}$$

$$= \ (\mathrm{PE} \pm\ \alpha) + (RC \pm \varepsilon) = (PE + RC) \pm (\alpha + \varepsilon) \tag{2}$$

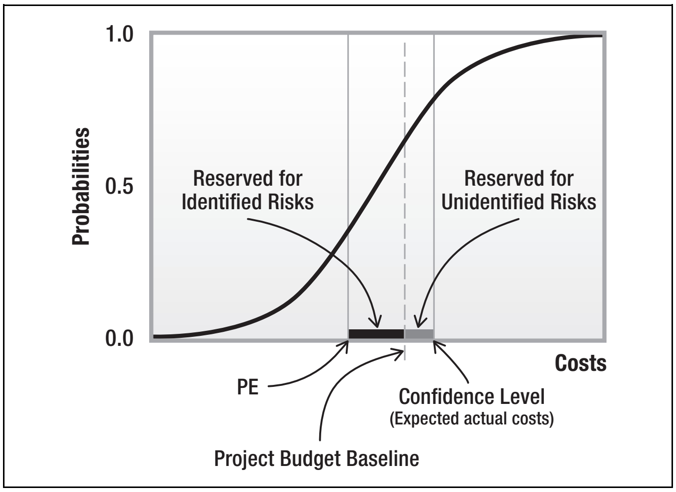

Figure 1. Confidence level on cumulative probability distribution.

α Costs of unplanned works by errors for PE
ε Costs of unplanned works by risks for risk cost

$$0 \leq \alpha, \varepsilon$$

Unplanned work α and ε are also assumed to be independently and normally distributed random variables with mean zero and variance σ_{α}^{2} and σ_{ε}^{2}, respectively. The value of α, which is the cost of unplanned works by errors or mistakes for estimating PE including allowance, is reducible by the project members' experience, educational level, knowledge, historical data, expert judgment, and lessons learned. On the other hand, the value of ε, which is the cost of unplanned works by unidentified risks, is unmanageable. Project managers have often made efforts to calculate accurate risk costs for project budgets by minimizing ε. In reality, it is very difficult to make α and ε value zero perfectly, so one technique to minimize ε and α is to develop a confidence level that can be obtained from the c.d.f. of triangular distribution by using a three-point estimation technique. The probability of the actual costs, which come from analyzing previous project performance results, becomes the confidence level of the firm, as described in Figure 1.

Difference (R Value) Between the High and Low Values in the Three-Point Estimation Technique to Estimate Risk Costs

In this article, the three-point estimation technique has been used to calculate the PE of work packages for estimating the total project budget. Using a three-point estimation technique not only for estimating the PE of work packages, but also for each risk response plan to estimate risk costs, is an innovative application. Low, most likely, and high values of the impact amounts are estimated in order to calculate the expected monetary value (EMV) by multiplying probabilities and each impact value together, respectively. The most likely value is the cost of the activity based on a realistic effort assessment for the required works and any predicted expenses. The optimistic value (low value) is based on the best-case scenario for the activity, and the pessimistic value (high value) is based on the worst-case scenario for the activity. Most project budgets are substantial, so two critical factors are needed to control the project budget. One factor is the accuracy to meet that project budget; the other factor is precision to minimize the cost variance between the budget and actual cost. The difference (R) between the high and low values can measure the precision for cost variation between budgets and actual costs and is described as follows:

$$R = (High\ \ value - Low\ \ value) \tag{3}$$

The smaller the R value, the higher the confidence to meet the budget with only small cost variances. Through the three-point estimation technique, PE and risk cost can be determined by selecting the most likely value or the higher value between the mean value and the most likely value, depending on the project management maturity level, previous experiences, and historical data. In this article, higher values were selected because of the low maturity level of the company under evaluation. In addition, the project risk probability and R value matrix should be specified in the project risk management plan shown in Figure 2. The dark gray area represents the high-risk response plans that are required to analyze and develop preventive plans. The light gray area represents moderate risk that may be required for preventive plans, and the white area does not require any analysis or additional actions.

The actual costs of the project can fall within the interval as shown below:

$$(\mathrm{PE} - \alpha) + (\mathrm{RC} - \varepsilon) \leq \text{ Actual costs } \leq (\mathrm{PE} + \alpha) + (\mathrm{RC} + \varepsilon) \tag{4}$$

However, PE and an α value can be minimized and estimated as accurately as possible by developing a WBS and using a three-point estimation technique. Therefore, the cost variances between the budget and actual cost of PE are assumed not to be critical if the scope of work has not changed; however, the risk cost is changeable depending on risk occurrence. It is a very challenging task to determine the point estimate for risks. Probabilities and impact amounts of risks can be estimated by expert judgment, historical data, and experience. Therefore, cost variances can be expected as follows:

$$\mathrm{Min.RC} \leq \text{ Cost variance } \leq \mathrm{Max.RC} \tag{5}$$

Cost variances between the total project budget and actual cost can be affected by risks; thus, making the gaps between Min. RC and Max. RC smaller is a critical success factor in determining the optimum budget with greater precision.

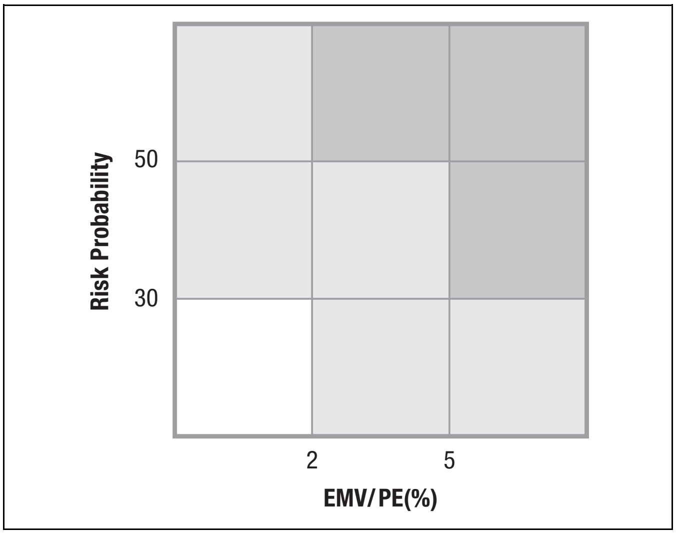

Figure 2. Project risk probabilities and EMV/PE matrix.

Determine the Confidence Level

To determine the confidence level, the budget of each of the selected 20 projects was re-estimated using a three-point estimation method. According to the results of these re-estimates, a cumulative S-curve of each project was obtained. The probabilities of PE and the actual costs of each project can be calculated on the cumulative S-curve and assumed to follow normal distribution with means and variances after confirming a normality test. As with the results of the previous 20 projects' performance, the mean probability of PE is 48.93% with a variance of 12.0281, while the mean probability of actual cost is 74.71% with a variance on 7.4237 on S-curve, as shown in Table 2. Thus, the probability of actual cost (74.71%) is determined as the confidence level on the cumulative S-curve derived from the triangular distribution of each project performance. The 90% confidence interval of the firm for the residential projects falls between 70.2% and 79.19%, which determined that the confidence level (74.71%) could cover the whole cost, including identified and unidentified risks as well as secondary and residual risks. However, the confidence level can be adjusted by updating the cumulative results of the project performance regularly.

Applying the Proposed Method to a Live Project

Calculation of the Budget

Live projects from the company were selected to demonstrate the budget estimating processes using this proposed method for five ongoing projects, applied by this proposed method. The comparison between the budget estimated by the traditional methods that have been used to date and the re-budget by the method proposed in this article are described to verify the improvement of the new budget estimation process.

The Basic Terminologies of Budget Compositions

Net cost, allowance, and point estimate (PE). The net cost of each work package from the WBS can be calculated as precisely as possible by referring to the design drawings, and the allowance can be determined based on the technical and management levels. Thus, point estimate can be estimated accurately if there is enough time to plan project management; however, the project budget may not be estimated accurately due to lack of information and uncertainties within limited time. The three-point estimation technique for the point estimate is typically used to cover the unplanned works of α in a new method, because budget estimation is required in the early planning phase before executing the project. All work packages are assumed to be independent of each other in terms of cost, but some work packages are assumed to be interdependent in terms of schedule. The estimated data of each work package are shown in Table 3.

According to Equation (2), Planned PE $=$ Actual PE $\pm$ α. The value α can be reduced by improving the project management maturity level. Project managers should develop a guideline or policy to determine PE considering the α value. The guideline or policy indicates which value is selected as the PE among the mean, most likely, or a certain point on the S-curve, because the confidence level depends on the company's maturity level. In this article, the larger value between mean value and the most likely value can be determined as the PE for each work package, because the project maturity level is low for this company.

$$\mathrm{PE} = \mathrm{Max}\,(\text{mean, most likely value}) \tag{6}$$

The S-curve is obtained using the three-point estimation technique, and 6,172 becomes the PE in this case project according to the above assumption. The obtained S-curve is assumed to follow a triangular distribution. Therefore, PE $=$ Most likely value $+\ \alpha = 6{,}121 + 51 = 6{,}172$ at 52.12% on an S-curve was obtained using the @Risk version 6.0.0 with 1,000 trials. When the α value is included in the PE, the ε value only becomes the management reserve. Therefore, the minimum project budget of 6,908 can be calculated by applying the confidence level (74.71%) on the cumulative S-curve, as shown in Figure 1. The gap of 736 between CL (6,908) and PE (6,172) becomes the risk costs including contingency and management reserves.

Risk cost assessment. The project budget consists of two parts: One is the PE not related to risks, and the other is risk cost (RC) related to risks. Project risk cost has probabilities where actual cost exceeds the established target cost during the project execution caused by project risks (Zhu et al., 2011). The identified risks are recorded in the risk register in as much detail as reasonable. The main purpose of risk management is to develop risk response plans. These plans, which are additional processes with cost and time, are variable depending on the probability of a risk's occurrence and the risk's amount of impact

Table 2. Three-Point Estimate and Confidence Level

	Preliminary Project Budget			Re-estimate PE				Actual Costs			Cumulative S-curve (Probabilities)	
Project Number	PE	RC	Total	L	M	H	Mean	PE	RC	Total	PE	CL
1001	60,214	5,955	66,169	21,256	60,214	93,328	58,266	60,034	7,892	67,926	54.05	72.96
1002	39,309	4,271	43,580	16,578	39,309	65,236	40,374	39,586	6,534	46,120	46.72	71.03
1003	26,143	2,492	28,635	9,784	26,143	45,265	27,064	27,678	4,756	32,434	46.11	75.73
1004	37,566	3,806	41,372	15,608	37,566	57,347	36,840	36,950	5,340	42,290	52.61	72.54
1005	12,357	1,236	13,593	3,346	12,357	21,882	12,528	12,128	2,790	14,918	48.61	72.53
1006	106,759	10,420	117,179	59,862	106,759	153,294	106,638	107,586	12,950	120,536	50.19	75.32
1007	60,006	6,079	66,085	42,677	60,006	83,270	61,984	60,023	8,378	68,401	42.69	76.59
1008	73,751	7,034	80,785	44,234	73,751	101,244	73,076	73,950	9,356	83,306	51.78	79.47
1009	49,453	4,783	54,236	33,890	49,453	70,619	51,321	48,941	6,823	55,764	42.37	71.61
1010	163,146	16,927	180,073	93,620	163,146	238,062	164,943	164,505	19,345	183,850	48.13	72.84
1011	48,124	4,935	53,059	31,702	48,124	68,899	49,575	48,234	8,376	56,610	44.15	80.46
1012	41,682	4,022	45,704	20,264	41,682	61,256	41,067	41,371	5,210	46,581	52.25	73.16
1013	148,585	15,055	163,640	107,053	148,585	199,983	151,874	148,120	17,239	165,359	44.69	74.90
1014	98,390	10,023	108,413	52,350	98,390	140,789	97,176	98,820	9,836	108,656	52.06	72.46
1015	167,892	18,912	186,804	102,985	167,892	236,894	169,257	168,495	19,127	187,622	48.47	73.73
1016	78,390	9,732	88,122	51,953	78,390	104,264	78,202	77,943	9,320	87,263	50.56	78.65
1017	76,551	7,295	83,846	40,392	76,551	114,453	77,132	78,254	8,137	86,391	48.82	71.95
1018	27,764	3,027	30,791	18,913	27,764	36,219	27,632	27,234	3,234	30,468	51.14	77.40
1019	49,764	4,948	54,712	24,814	49,764	75,635	50,071	49,990	7,460	57,450	51.93	76.25
1020	64,813	6,349	71,162	31,489	64,813	96,584	64,295	66,358	7,350	73,708	51.19	74.70
Total	**1,430,659**	**147,301**	**1,577,960**	822,770	**1,430,659**	2,064,523	1,439,317	**1,436,200**	**179,453**	**1,615,653**	**48.93**	**74.71**

Note. PE(Point Estimate), RC(Risk Cost), L(Low), M(Most Likely), H(High), CL(Confidence Level).

Table 3. Three-Point Estimate for PE

WBS Level 1	Level 2	L	M	H	Mean	PE
Design	Design definition	29	42	54	42	42
	Conceptual design	138	273	408	273	273
	Preliminary design	226	360	521	369	369
	Final design	195	394	588	392	394
Civil work	Foundation	409	624	897	643	643
	Roads	120	250	380	250	250
	Landscape	113	220	350	228	228
Architecture work	Steel fabrication	382	654	910	649	654
	Steel erection	275	525	764	521	525
	Pouring concrete	160	277	378	272	277
	Internal finishing	151	236	342	243	243
	External finishing	85	185	282	184	185
Mechanical work	System	128	251	373	251	251
	Facilities	160	260	355	258	260
	Machines	165	259	376	267	267
Electrical work	Rough in	188	382	545	372	382
	Equipment	189	357	510	352	357
	Installment	232	572	832	545	572
Sum		3,345	6,121	8,865	6,110	6,172

Table 4. Risk Response Plan and EMV

Response Plan	Probabilities (%)	Impacts L	M	H	Mean	EMV*	R* (H-L)
Improper estimate	30	78	129	174	127	39	29
Increased material and equipment costs	40	149	218	294	220	88	58
Scope changes	70	185	258	346	263	184	113
Design changes	50	121	192	238	184	96	58
Poor communication	30	181	243	298	241	73	35
Vendor's capability	30	360	442	495	432	132	41

amounts; thus, the response plan should be added to the preliminary project management plan. When general risks occurred, project managers conducted risk response plans.

There are two steps in developing risk response plans: First, project managers develop alternatives to respond to risks, if possible, with impact amounts and probabilities of risk occurrence; then they select the best alternative among them. A three-point estimate of the impact amounts should be estimated the same as the method for the PE of work packages. Second, the larger value between the mean and most likely value of the impact amount among the estimated values using the three-point estimate technique is determined to calculate EMV by multiplying by probability and construct confidence level to cover ε as same method as PE. The lowest EMV of the alternatives is selected as the response plan. Budgets for each risk response plan can be estimated by calculating EMV, as shown in Table 4.

The project budget baseline, excluding management reserve, becomes 6,784 by adding 612 of contingency reserves to 6,172 (PE), so that management reserves become 124, which is described in Figure 3.

The second step is to analyze selected response plans for improving budget precision. Risk response plans are categorized into two types: preventive and adaptive plans (Sato & Hirao, 2013). Preventive response plans should be contained within the preliminary WBS, so that their additional costs are included in the PE to mitigate the risks in advance. However, the additional costs of the adaptive response plans are used as contingency reserves when risks occur.

Generally, the prevention costs rather than the correction costs save the total cost of quality; thus, the greater the preventive costs, the more the save costs and the adaptive costs become lower and with greater precision, as shown in Figure 4. However, project managers should consider that the sum of preventive and adaptive costs cannot be higher than the preliminary risk cost. The criteria of reassessment of the risk response plan are developed in Figure 2.

$$EMV = (Probability \times Impact\ \ amounts) + Preventive\ \ costs\ \ (PC) \tag{7}$$

Several independent risks can be prevented by one risk response plan that can cover some work packages that will

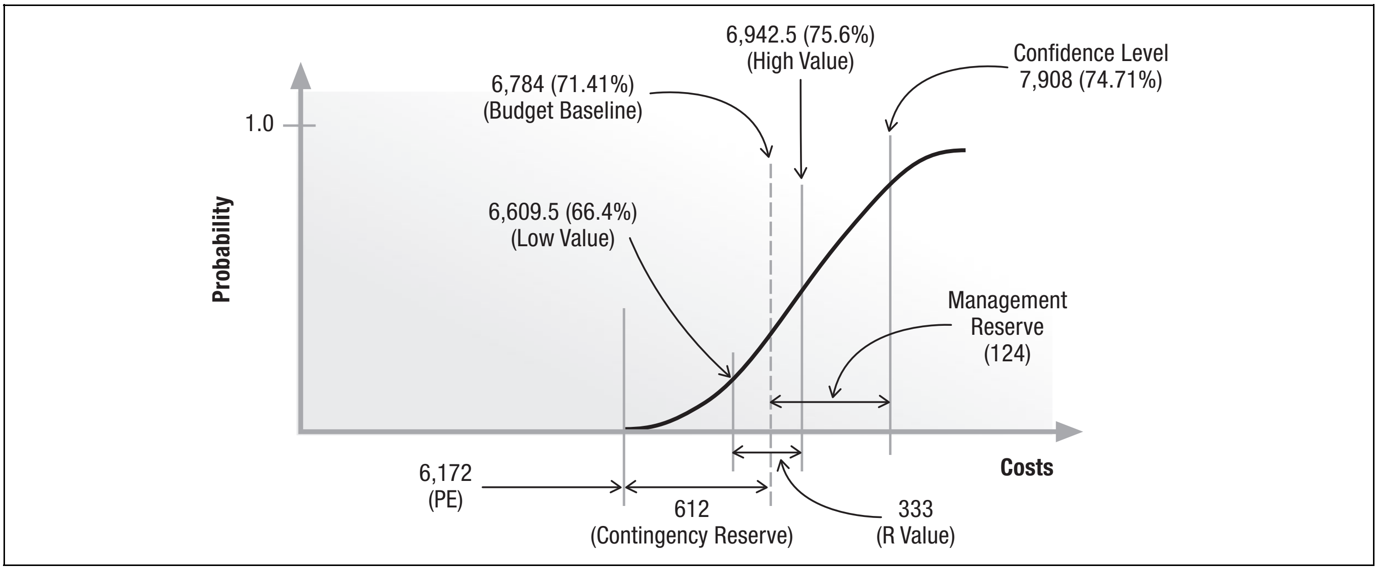

Figure 3. Preliminary budgets with risk cumulative distribution curve.

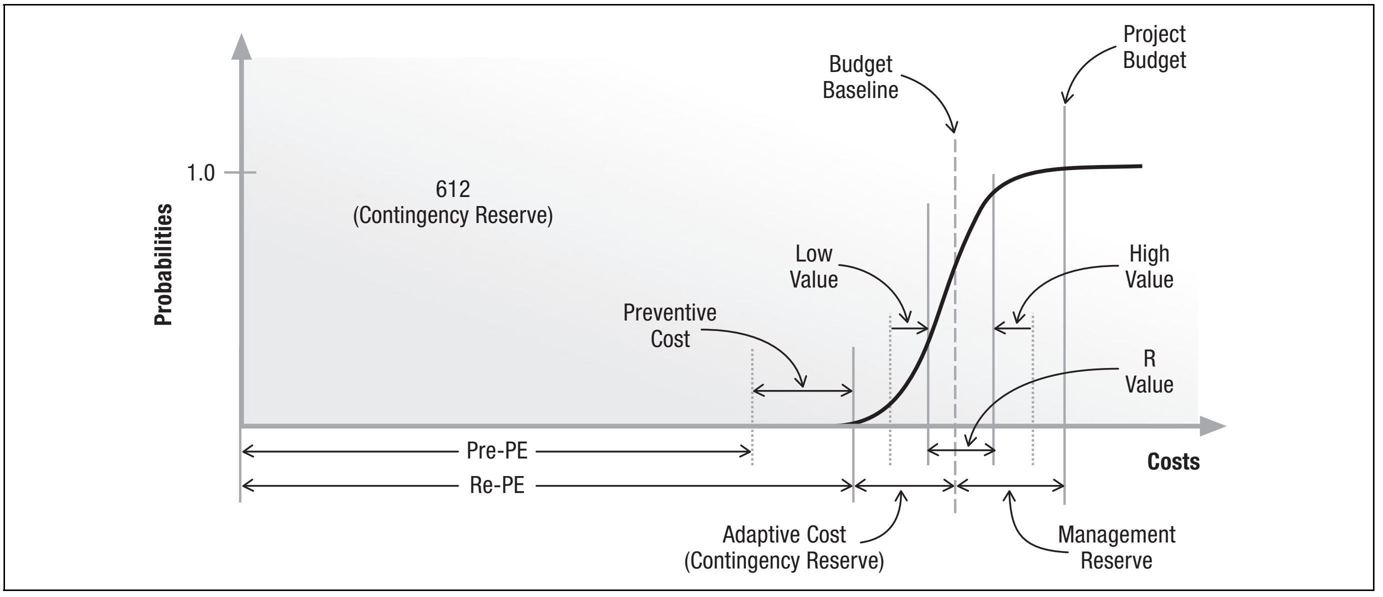

Figure 4. Project budget with re-estimated risk response plan.

be impacted by risks when they occur. The results of analyzing and re-estimating risk response plans are shown in Table 5.

Re-estimating the project budget. The final total project budget becomes 6,819, which is reduced from the preliminary budget of 6,908 with higher precision by decreasing the *R* value of risk from 333 to 220. The PE increases from 6,172 to 6,262 by adding preventive costs of 90. On the other hand, risk costs—including both contingency and management reserves—decreased from 736 to 557 because the contingency reserve was reduced from 612 to 433, but the management reserve 124 remains unchanged.

Applying the New Method to Ongoing Projects

This method was applied to five ongoing projects to verify the improvements of the budget estimation method between preliminary budgets using traditional methods and the re-estimated budget using the proposed method with the estimate at completion (EAC). A comparison table of cost variance percentage is shown in Table 6. One project was completed with the new estimation method and the other four projects are

Table 5. Analyzed and Re-estimated Response Plans

Response Plan	Preventive Cost	Probability (%)	L	M	H	Mean	Adaptive Cost	R (H-L)	EMV
Improper estimate	0	30	78	**129**	174	127	39	29	39
Increasing material and equipment costs	10	40	95	**135**	175	135	54	32	64
Scope changes	40	70	135	168	215	**173**	121	56	161
Design changes	15	50	95	**143**	184	141	72	45	87
Poor communication	10	30	105	**165**	195	155	50	27	60
Vendor's capability	15	30	280	320	385	**328**	99	32	114
Sum	**90**		788	1,060	1,328	1,059	**433**	**220**	**523**

Note. Higher values as bold entries are selected because of the low maturity level of the company.

Table 6. Results of Application to Ongoing Projects

	A			B		
Project Number	PE	RC	Total	PE	RC	Total
201	0.62	19.19	2.60	2.04	–7.36	1.28
202	–1.82	20.18	0.29	–0.29	3.39	0.00
203	–2.19	25.70	0.18	0.00	0.57	0.03
204	–2.83	26.53	–0.05	–0.19	1.34	–0.08
205	–2.40	30.12	0.86	–0.33	3.26	–0.07
Mean	–1.72	24.34	0.78	0.25	0.24	0.23
Var (σ^2)	1.85	20.97	1.15	1.02	19.53	0.35
SD	1.36	4.58	1.07	1.01	4.41	0.59

still in progress. The completion percentage technique was applied to estimate the EAC. These selected five projects are very similar to the previous 20 projects so that the results of the re-assessments could be consistent and comparable.

$$A = \frac{(\text{Preliminary budget} - \text{EAC})}{\text{Preliminary budget}} \times 100,$$
$$B = \frac{(\text{Re} - \text{estimated budget} - \text{EAC})}{\text{Re} - \text{estimated budget}} \times 100$$

Discussion and Conclusions

Application of the proposed method to real projects was carried out to demonstrate improvements in project budget accuracy and precision. Dual budgeting was conducted for the comparisons between budgets using the traditional and proposed methods. One project was completed with the new estimation method and the other four projects are still in progress. The completion percentage technique was applied to forecast the EAC. While the budget accuracy can be calculated by dividing the differences between the budget and actual costs, precision can be calculated by the variances or the standard deviation of the differences. The accuracy of PE, RC, and the total preliminary budget against EAC is –1.72, 24.34, and 0.78, with variance (precision) 1.85, 20.97, and 1.15, respectively, whereas the re-budgets are 0.25, 0.24, and 0.23, with variance (precision) 1.02, 19.53, and 0.35, respectively. The results show that budget accuracy and precision on risk cost improved by 24.10 and 1.44, while improving by 0.55 and 0.48 percentage points in total, respectively.

The project budget has two types of reserves against risks: One is the contingency reserve for identified risks as an event, and the other is the management reserve for unidentified risks as a variability. However, previous researchers have presented various methods for estimating reserves to cover the risk as an event that can only be identified as an expected uncertainty. Thus, the planned response actions could not cover the risk as a variability, which is an unexpected uncertainty that cannot be identified. Thus, the reserves estimated by the previous methods were enough to cover all risks. The management reserve for unidentified risks must be estimated and included in the project budget, even though unidentified risks could not be managed by the project management team. Because unforeseen work due to unidentified risk is also within the scope of the project, Figure 5 describes the scope of a project and budget. When work breakdown structures are developed, all works must have their own budgets. The project budget must cover all the scope of work for constructing the project's result. Project scope generally includes both certain and uncertain events. While the certain events become the basis for developing the WBS, the uncertain events become the basis of risk response plans. Thus, the PE is the most highly accurate feature of the budget, whereas the management reserve is the lowest accuracy and the contingency reserve is moderate. One of the best ways to improve the accuracy of the project budget is to transfer uncertain scopes of work to certain scopes by analyzing and

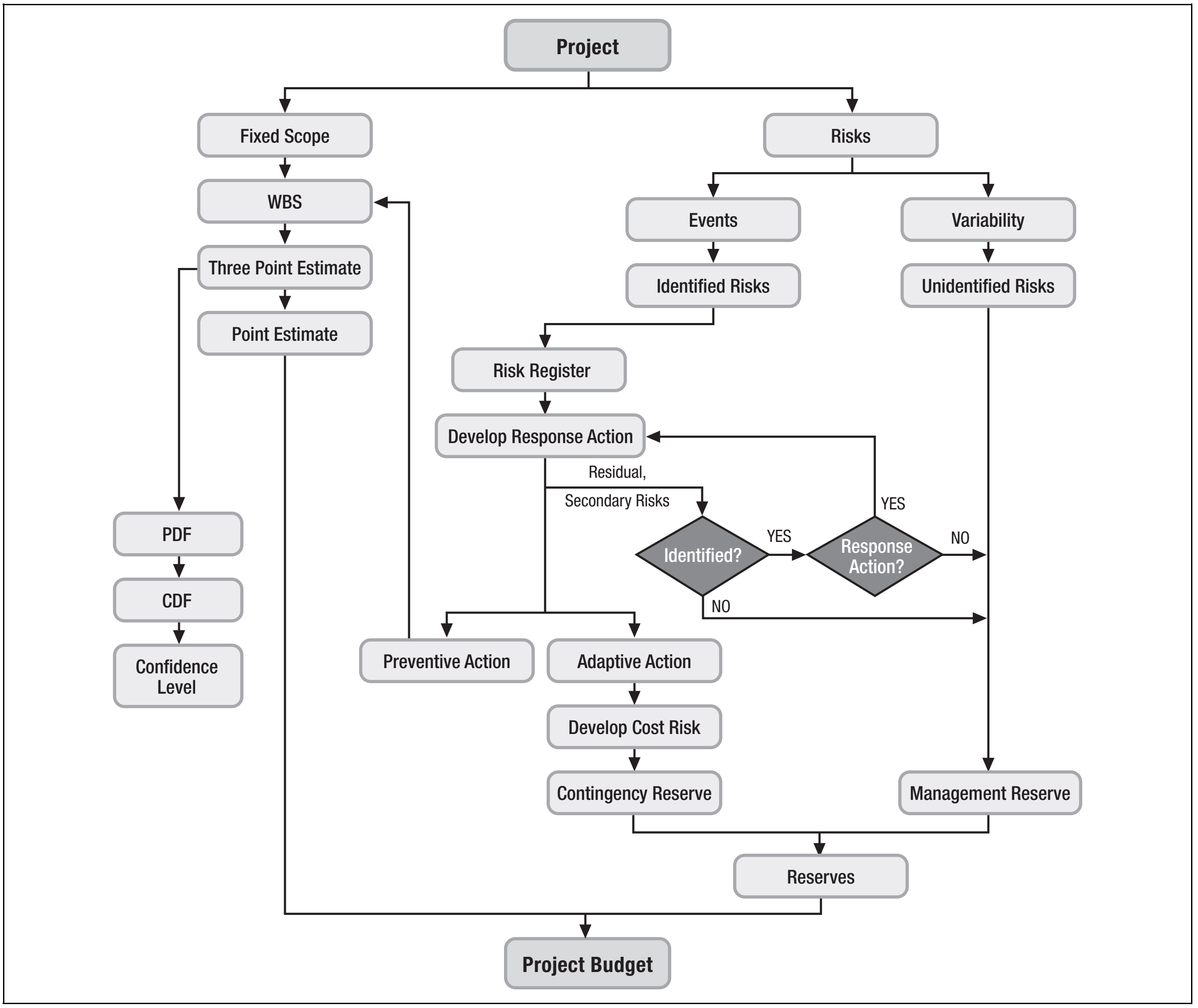

Figure 5. Scope of a project and budget.

quantifying the uncertainty; for example, the reserves against risks is the budget for the uncertainty. The reserves can be divided into the preventive action and the adaptive action by analyzing risks. The preventive action becomes the certain scope while the adaptive action remains in the uncertain scope. Thus, the works of preventive action against risk should be moved to the WBS.

The project budget should be estimated and determined to the approximate actual costs in order to minimize cost variances. The actual costs of each budget component such as the PE, the contingency reserve against identified risks, and the management reserve against unidentified risks can be recorded separately for project performance information. Analyzing and evaluating the variance between budgets and the actual costs of each budget component are essential to improving project cost management. However, it is very difficult to evaluate and analyze the variances due to lack of budget estimation of each budget component by previous budget estimation method. The advantage of the estimation method proposed in this article is to estimate reserves as the contingency reserve and the management reserve against both identified and unidentified risks separately to improve budget accuracy. This method can be used to analyze the differences between budgets and actual costs and obtain feedback for future projects as lessons learned. Project management performance can be improved by conducting these processes iteratively and updating the best practice. Furthermore, re-estimating risk costs using a three-point estimation technique by evaluating the *R*-value is suggested in order to minimize cost variances due to risks. That is another way to improve budget precision. The PE is the budget for the certain scope and the basis for developing a funding and payment schedule to construct the project result during project execution, because the budget and schedule of the uncertain scope are almost unchangeable. On the other hand, the risk cost is the budget for the uncertain scope of the project. Thus developing the funding and payment schedule for the uncertain scope is inaccurate. Therefore, the full amount of the risk cost should be kept in the project fund over the entire project period to avoid the lack of cash. It also incurs the capital costs, so that the less the risk cost, the fewer the additional capital costs. We verified this by applying the proposed method to five ongoing projects. The results demonstrated an improvement in budget accuracy and precision, with smaller cost variances between the re-budget and EAC than between the preliminary budget and the actual.

This research can extend in several directions. Cash flow management is one of the most important determinants of the success of construction project management. Poor cash flow may result in inadequate working capital and thus undermine the sustainability of a project. Thus, the method described in this article can be applied to improve project cash flow management.

This research mainly emphasized estimating a budget for a single project, especially estimating reserves against both identified and unidentified risks to minimize cost variances by improving budget accuracy and precision. Budget compositions are provided—including net cost, allowance, contingency reserve, and management reserve—and are to be controlled by different people or departments to save cost by analyzing the variances between budgets and actual costs. This method is a more efficient way of conducting project cost management than the current methods used in project cost management.

Declaration of Conflicting Interests

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