Estimating Project Cost Contingency – Beyond the 10% syndrome

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ABSTRACT

Projects require budgets to set the sponsor's financial commitment and provide the basis for cost control and measurement of cost performance. A key component of a project budget is cost contingency. This paper reviews the traditional approach of estimating project cost contingency by means of a percentage addition to the base estimate and analyses its many conceptual flaws. Over the past decade there has been a significant increase in interest by both practitioners and academics into more robust methods for estimating cost contingency. This paper reviews the literature of some of these methods for estimating project cost contingency.

INTRODUCTION

The cost performance of construction projects is a key success criterion for project sponsors. Cost contingency is included within a budget estimate so that the budget represents the total financial commitment for the project sponsor. Therefore the estimation of cost contingency and its ultimate adequacy is of critical importance to projects. There are three basic types of contingencies in projects: tolerance in the specification, float in the schedule, and money in the budget (CIRIA 1996). This paper deals with project cost contingency. Patrascu (1988:115) observes, "Contingency is probably the most misunderstood, misinterpreted and misapplied word in project execution". Contingency has been defined as the amount of money or time needed above the estimate to reduce the risk of overruns of project objectives to a level acceptable to the organization (PMI 2004)

CONTINGENCY - ESTIMATION

A range of estimating techniques exist for calculating project cost contingency- see Table 1.

Table 1: Contingency - Estimating methods

Contingency Estimating methods	References (Examples)
Traditional percentage	Ahmad 1992, Moselhi 1997
Method of Moments	Diekmann 1983; Moselhi, 1997, Yeo 1990
Monte Carlo Simulation	Lorance & Wendling 1999, Clark 2001
Factor Rating	Hackney 1985, Oberlander & Trost 2001
Individual risks – expected value	Mak, Wong & Picken 1998; 2000
Range Estimating	Curran 1989
Regression Analysis	Merrow & Yarossi 1990; Aibinu & Jagboro 2002
Artificial Neural Networks	Chen & Hartman 2000; Williams 2003
Fuzzy Sets	Paek, Lee, & Ock, 1993
Influence Diagrams	Diekmann & Featherman 1998
Theory of Constraints	Leach 2003
Analytical Hierarchy Process	Dey, Tabucanon & Ogunlana 1994

Traditional Percentage

Traditionally cost estimates are deterministic i.e. point estimates for each cost element based on their most likely value (Mak et al 1998). Contingencies are often calculated as an across-the-board percentage addition on the base estimate, typically derived from intuition, past experience and historical data. This estimating method is arbitrary and difficult to justify or defend (Thompson and Perry 1992). It is an unscientific approach and a reason why so many projects are over budget (Hartman 2000). A percentage addition results in a single-figure prediction of estimated cost which implies a degree of certainty that is not justified (Mak et al 1998). The weaknesses of the traditional percentage addition approach for calculating contingencies has led for a search for a more robust approach as evidenced by the range of estimating methods set out in Table 1.

Individual Risks - Expected Value

The amount of contingency reserve can be based on the "expected value" for individual risk events. Expected value is the mean of a probability distribution of a risk. For example, the Hong Kong Government's Works Branch introduced Estimating using Risk Analysis (ERA) for construction projects for determining contingencies using expected value (Mak et al, 1998; Mak & Picken, 2000). Firstly, a risk-free estimate of known scope is produced then risk events are identified and costed in terms of an average and maximum risk allowance is calculated. There are two types of risks:

- Fixed Risk – These are events that will either happen in total or not at all e.g. whether an additional access road will be required. If it happens, the maximum cost will be incurred; if not, then no risk will be incurred. The maximum risk allowance will be the cost if the risk eventuates, whilst the average cost = maximum cost * probability of its occurrence.
- Variable Risk – These are events that will occur but the extent is uncertain (e.g. depth of piling foundations). The maximum risk allowance, which is assumed to have a 10% chance of being exceeded, is estimated by the project team based on past experience or records (e.g. most expensive piling at the maximum length). The average risk allowance is estimated as the value that has a 50% chance of being exceeded, and may have a mathematical relationship to the maximum or estimated separately. This 50% level is chosen on the rationale that the worst values for all risks will not occur but rather there will be swings and roundabouts effects of the totality of the risk events identified.

The summation of all events' average risk allowance becomes the contingency. – See Table 1:

Risk	Type	Probability (Fixed Risks only)	Average risk ($)	Max. Risk ($)
Site Conditions	Variable		525,000	1,000,000
Additional Space	Fixed	70	11,760,000	16,800,000
		CONTINGENCY	12,285,000	

Table 1 (adapted from Mak & Picken, 2000)

The accuracy of contingencies was tested for completed ERA and non-ERA projects (i.e. using traditional percentage addition). It was found that the ERA-derived contingency was significantly more accurate.

Method of Moments

Each cost item in an estimate is expressed by a probability distribution, reflecting the risk within the cost item. Each cost item distribution has its expected value and variance. The expected values and variances for all cost items are added to arrive at the expected value and standard deviation for the total project cost. Total project cost can be assumed to follow a normal distribution based on the central limit theorem, but only if the cost items are independent. Then, using probability tables (z scores) for a normal distribution, a contingency can be derived from the probability distribution based on a desired confidence level i.e. level of probability of total project cost not being exceeded. For example using table 2, if a sponsor wants a baseline budget set at the EV of $116.67 and then add contingency that will have a 90% probability of not being exceeded, then the contingency will need be $67.61

Table 2 Method of Moments - Example

Variable (Cost)	Distribution	a Min. ($)	b Most Likely ($)	c Max ($)	EV*	V**	SD***
Foundation	triangular	25	30	65	40.00	1415.00	
Walls	triangular	40	60	80	60.00	1200.00	
Roof	triangular	10	15	25	16.67	175.00	
TOTAL PROJECT COST	**Normal (CLT)**				**$116.67**	**$2790**	**$52.82**

* $EV = (a+b+c)/3$; ** $V = (a^2 + b^2 + c^2 - ab - ac - bc)/18$; *** $SD = \sqrt{V}$

Monte Carlo Simulation (MCS)

MCS allows us to examine what would happen if we undertook many trials of a project. MCS is a quantitative technique for analysing risk and provides a structured way of setting the contingency value in a project cost estimate (Clark, 2001). The output of MCS is a probability distribution for total cost of the project. An example of its application is provided by Honeywell Performance Polymers and Chemical, which used MCS in 47 projects ranging from US$1.4m to US$505m (Clark, 2001). Contingency is be set at 50% probability level (median), based on the rationale that many projects make up the total annual budget, so cost variations on one may be offset by another project. This approach often yields a recommended contingency value of less than 5%, or zero for a well-defined project (Clark, 2001). However, for very large or strategic projects, an 80% or 90% probability level is chosen for contingency; and at a preliminary stage of a project, 95% is usually required.

Many authors (e.g. Lorance & Wendling 1999) advocate assigning contingency so that the Base Estimate + Contingency = 50/50 point (median) because this establishes a target for the project team where they have an equal chance of underrunning or overrunning the estimate. The US Federal Aviation Administration (FAA) uses the median (50/50) point as its budget baseline, and contingency is the different between the 50% and 80% confidence level (Fenton et al, 1999).

Estimate Quality

Oberlander & Trost (2001) developed a quantitative model to predict the amount of cost contingency required based the quality of the project cost estimate and historical cost data. The accuracy of an estimate depends on four determinants: who is involved in the estimate

(16% influence); how the estimate is prepared (23%); what is known about the project (39%); and other factors considered whilst preparing the estimate (22%). These four determinants were decomposed into 45 elements used to measure the quality of an estimate. The model was based on detailed analysis of 67 completed capital projects (US$5.6bn) in the process industry For the estimate, each element is rated, from 1 (best) to 5 (worst). Examples of these elements are: relevant experience of estimating team; time allowed for preparing estimate; what is known about technology.

The score for each element is entered into the model and an overall score for estimate quality is automatically derived. An ordinary least-square (OLS) fit through the data of the 67 projects provides the basis for predicting of the accuracy of an estimate. The prediction model is y = mx + b, where y represents the percentage contingency and x represents the estimate score, m is the slope and b is the intercept. This score then predicts the accuracy of the estimate; the higher the score, the greater the inaccuracy and therefore the need for more contingency for a chosen confidence level. For example, a score of 41.8 has a 90% chance of underrunning, if 34.9% contingency is added to the base estimate. This information can be used to check the amount of contingency determined by other methods, as well as a method of predicting its won contingency

Regression Analysis

Regression models have been used since the 1970s for estimating cost (Kim et al, 2004). The purpose of linear regression is to use the linear relationship between a dependent variable (e.g. estimated final cost) and independent variables (e.g. location, size) to predict or explain the behaviour of the dependent variable. Multiple regression analysis is generally represented in the form: $y = a + b_1x_1 + b_2x_2 + ...b_nx_n$. Where y is the total estimated cost; x_1, x_2 etc are the measures of variables that may help estimate y; and b_1, b_2 etc are the coefficients estimated by regression analysis. The regression equation can then be used to predict the value of a dependent variable once the values of the independent variables are inserted. For example Merrow & Yarossi (1990) have y as the estimated cost/actual cost and x variables such as level of scope definition, and level of unproven technology.

Artificial Neural Networks (ANNs)

ANNs are an information processing technique that simulates the biological brain and its interconnected neurons (Chen & Hartman, 2000). The structure of ANNs mimics the nervous system by allowing signals to travel thorough a network of simple processing elements (akin to neurons) by means of interconnections among these elements. These processing elements are organised in a sequence of layers consisting of an input layer, followed by one or more hidden layers and culminating in an output layer. The input processors accept the data into the ANN (e.g. variables that have a relationship to the amount of cost overrun in projects), the hidden processors represent relationships in the data and the output layer produces the required result (e.g. predicted amount of cost overrun). ANNs employ a mechanism to learn and acquire problem-solving capabilities from 'training' examples by detecting hidden relationships among data and generalising solutions to new problems. ANNs are suitable for non-linear modelling of data, which contrasts with the linear approaches using regression

Over the past decade the use of ANNs for cost estimating has grown. ANN can be used to predict project cost overruns and thereby assist management in developing an appropriate contingency (Chen & Hartman, 2000). Examples of the application of ANNs to predict the level of cost overrun/underrun include:

- Chen & Hartman (2000) used ANN to predict the final cost of completed oil and gas projects from one organisation using 19 risk factors as the input data. It was found that 75% of the predicted final cost aligned with the actual variance i.e. where the ANN model predicted an overrun/underrun, an overrun/underrun actually occurred. The prediction accuracy of ANN outperformed multiple linear regression
- Chau et al (1997) used 8 key project management factors to predict the final cost of construction projects. It was found that more than 90% of the examples did not differ by more than one degree of deviation from the expected
- Gunaydin & Dogan (2004) used 8 design parameters to estimate the square metre cost of reinforced concrete structure systems in low-rise residential buildings and found that the ANN provided an average cost estimation accuracy of 93%

The research on the application of ANN to predict cost performance often compares the accuracy of ANN with multiple linear regression and in most cases ANN produce more accurate predictions (e.g. Chen & Hartman, 2000; Sonmez, 2004; Kim at al, 2004)

SUMMARY

Traditionally, contingencies are often calculated as an across-the-board percentage addition on the base estimate, typically derived from intuition, past experience and historical data. This estimating method is serious flaws. It is usually illogically arrived at and may not be appropriate for the proposed project. This judgmental and arbitrary method of contingency calculation is difficult for the estimator to justify or defend. A percentage addition results in a single-figure prediction of estimated cost, which implies a degree of certainty that is simply not justified. It does not encourage creativity in estimating practice, promoting a routine and mundane administrative approach requiring little investigation and decision making.

This paper briefly reviews more robust and justifiable approaches to estimating project cost contingency. In particular the application of Monte Carlo simulation is growing as project cost estimators become more aware of its improved effectiveness over the traditional approach.

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