Interpreting traditional cost contingency methods in the construction industry

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Abstract: This research investigates how contingency is currently calculated in project budgets within the building industry. This is an important aspect to consider as a large proportion of construction projects are significantly over-budget. The study presents three non-simulation methods and one simulation method for calculating cost contingency following the results of a forthcoming journal paper. These methods are applied against a case study project in attempt to highlight the most reliable method, and to create a methodology that will be useful to the industry. This paper identifies that the traditional fixed percentage approach is not sufficient and suggests that this could be one of the main reasons why construction projects are over budget. While it is unclear which method is the most reliable, this study provides a focus for future research into reliability and utilisation of contingency methods in the building industry. The research demonstrates that current practice needs to change to reduce the large number of construction projects that run over budget.

Keywords: Cost; contingency; construction; traditional contingency calculation.

1. Introduction

Flyvbjerg et al. (2002) identified that in global construction, nine out of ten projects had a cost overrun. His research was based on a sample of 258 companies across twenty countries and five continents. Flyvbjerg et al. concluded in a later study that the main cause of project overrun is the underestimation or ignorance of the risks around complexity, scope changes, lack of knowledge, etc. (Flyvbjerg et al., 2009). Cost estimation and control is also a significant challenge in the construction industry (Shane et al., 2009). Ultimately, project managers in the construction industry are underestimating the uncertainty or contingency on a project. Contingency is defined as "an amount of funds added to the base cost estimate to cover estimate uncertainty and risk exposure" (England and Moreci, 2012, p.1).

Cost control, as defined by The Chartered Institute of Building, involves the closest possible estimation of the following six factors in order to successfully manage the project within the approved budget (The Chartered Institute of Building, 2010, p.31):

- Establishing project costs to date

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- Anticipating the final cost of the project
- Determining the future cash flow
- Assessment of ongoing project risks to costs
- Consideration of the operational cost of the project
- Potential project savings

This paper focusses on the fourth factor by investigating how contingency is currently calculated in the construction industry. The study also attempts to identify which contingency method will more reliably predict risk and uncertainty in order to improve project success. The success of construction projects is important in New Zealand because the construction sector contributed to eight per cent of New Zealand's Gross Domestic Product (GDP) in 2015 and over the last three years has seen a GDP growth of seventeen per cent, becoming the eight largest contributing sector to the country's GDP (Rice and Forgan, 2016). Controlling risks and uncertainties through accurate contingency estimations could have a significant impact on New Zealand's GDP.

One of the first written definitions of uncertainty is "the subjective uncertainty resulting from the imperfection of man's knowledge is uncertainty" (Willett, 1901, p.33). Unreliable contingency estimating techniques and lack of knowledge around uncertainties is possibly one of the main reasons that construction budgets exceed the initial estimated cost.

Three studies have identified the ways in which contingency is calculated (Bakhshi and Touran, 2014; Baccarini, 2005a; El-Touny et al., 2014). Table one lists each method identified and demonstrates that these methods were developed between 1983 and 2003.

Table 1: Contingency calculation methods and authors. Table recreated from Baccarini (2005a) and Bakshi and Touran (2014).

Contingency estimating method	**Author**
Traditional percentage	Ahmad 1992, Moeslhi 1997
Expert Judgement	Heemstra, 1992
Method of Moments	Diekmann 1983, Moselhi 1997, Yeo 1990
Monte Carlo simulation	Lorance and Wendling 1999, Clark 2001
Factor rating	Hackney 1985, Oberlender and Trost 2001
Expected value	Mak et al,. 1998; 2000
Range estimating	Curran 1989
Regression analysis	Merrow and Yarossi 1990; Aibinu and Jagboro 2002
Artificial neural networks	Chen and Hartman 2000; Williams 2003
Fuzzy sets	Paek et al., 1993
PERT	Naval Weapons Department of the Navy Washington, D.C 1957
Optimism Basis Uplifts	Ove Arup and Partners Scotland, 2004
Probability tree/influence diagrams	Diekmann and Featherman 1998
Theory of Constraints	Leach 2003
Analytical hierarchy process	Dey et al., 1994

The paper by Baccarini (2005a) reviews the flaws of the traditional fixed percentage estimation approach. While it is important to identify the reliability of each contingency method, the research and developed methods are at an early stage of development and no clear model exists. Chapman and Ward have researched risk and uncertainty management for over twenty years and conclude that a simplistic approach is the best way to control risk and uncertainty (Chapman and Ward, 2003). Salah (2012) identified that project managers and estimators avoid using alternative contingency calculation methods because the methods can be complex, and the accuracy of models is assumed to be lower than the traditional approach. While the aforementioned papers and the wider literature describe cost contingency calculation methods, no study explicitly details how each of these methods can be applied against a case study project. This paper aims to describe several of the most familiar methods and uses a case study to provide a mathematical example so that these methods can be implemented in the industry. The contingency calculated from applying each method is compared to the actual contingency required on the project. The hypothesis presented is that the typical fixed percentage method is the least reliable. Understanding that this most commonly used approach does not work effectively can begin to pave a way for a change in behavior in the industry to estimate contingency.

2. Scope of the study

Bakhshi and Touran (2014) reviewed each of the contingency calculation methods described above and determined the advantages and disadvantages of each. They concluded that the modern mathematical techniques, such as fuzzy sets and artificial neural network analysis, require more time and budget to be implemented in the industry. For these reasons, these two methods are excluded from the study. Burroughs and Juntima (2004) compare the traditional percentage method, expert judgement, Monte Carlo simulation and regression analysis. They identify that regression analysis requires historical data to estimate a contingency percentage. Since no historical data has been gathered for the case study project due to time constraints, this technique is also excluded from the study. Steyn (2001) identified that the Theory of Constraints (TOC) method was initially developed for project scheduling or programming. The TOC method, when applied to cost management, is more of an approach to life cycle costs rather than being explicitly used to calculate contingency therefore this method was also excluded from the study. A forthcoming journal paper created a methodology which describes how the rest of the twelve methods can be applied to case study data. This paper presents three non-simulation methods and one simulation method that predicted the closest amount of contingency when compared to the actual contingency amount in the case study.

3. Methodology

A recently completed Wellington, New Zealand case study project was selected for this study. This project was selected because it is one of the most current projects in the building industry, the actual cost could be determined, and a large level of detail around risks and uncertainties was known on the project. The project involved the construction of a new eight-metre-high, twenty-two-metre long shotcrete retaining wall. First, the original budget and the actual cost of the project was obtained then the actual contingency amount was determined by subtracting the final cost from the original budget. The contingency required was $89,016.28 or 46.59 per cent of the original budget (refer to table two). This cost overrun was caused by several factors including large scope change, site constraints and programme constraints. Four non-simulation methods and one simulation method will be applied to this data set in attempt to identify the most reliable contingency method, that being which most closely estimates the actual contingency amount required.

Table 2: Original budget and actual cost breakdown of case study project. Source: Octa Associates Limited.

	Summary	Description	Project budget	Actual cost
1	Contract works	Demolition	$10,000.00	$7,000.00
		Remediation	$5,000.00	$8,000.00
		Retaining Wall	$90,000.00	$137,200.00
		Other Trades	$29,706.00	$44,016.16
		Preliminary and General	$15,294.00	$22,500.00
		Subtotal	$150,000.00	$218,716.16
2	Professional fees	Structural Engineer	$1,800.00	$1,800.00
		Project Manager	$15,000.00	$22,275.00
		Civil Design	$21,250.00	$28,505.00
		Fencing	$0.00	$683.38
		Specialist Consultant	$0.00	$2,700.00
		Disbursements	$0.00	$462.00
		Subtotal	$38,050.00	$56,425.38
3	Miscellaneous	Resource/Building Consent	$3,000.00	$4,924.74
		Subtotal	$3,000.00	$4,924.74
		Total	**$191,050.00**	**$280,066.28**
		Contingency amount		**$89,016.28**
		Contingency percentage		**46.59%**

3.1 Traditional fixed percentage

Statista undertook a global survey to identify the range of fixed contingency percentages used in construction projects. The survey was answered by 109 respondents, senior leaders and CEO's. The survey found that the most common fixed percentage used in the construction industry is somewhere between five and ten per cent (Statista, 2014). Applying a ten per cent fixed percentage, the contingency estimated for the case study project was $19,105.

3.2 Optimism bias uplifts

The optimism bias technique builds upon the fixed percentage of ten per cent. *"Optimism bias is the tendency of individuals to expect better than average outcomes from their actions"* (Reyck et al., 2017, pp. 2). This can lead to underestimation of project durations, overestimation of benefits and underestimation of the total cost. MacDonald (2002) studied cost escalations of eighty projects during the early stages of project design, and at a late stage before the tender award. The results of the study are depicted in table three, six project types were identified. The formula for expected project cost is:

$$EV = \text{original budget} * \text{early-stage OB uplift} \quad (1)$$

Where EV is expected value and early-stage OB uplift is a percentage selected from table three. The case study used in this research is a standard civil engineering project, therefore after applying the optimism bias technique the total project cost was $275,112 or forty-four per cent more than the original budget.

Table 3: Optimism bias uplift identified across eighty construction projects in the UK. Source Revck et al. (2017) recreated from MacDonald (2007).

Project type	**Early-stage OB uplift**	**Late-stage OB uplift (before contract award**
Standard buildings	24%	2%
Non-standard buildings	51%	4%
Standard civil engineering	44%	3%
Non-standard civil engineering	66%	6%
Equipment/development	200%	10%
Outsourcing	41%	0%

3.2 Program evaluation and review technique (PERT)

Each cost element can be expressed by a probability distribution that is; the minimum, most likely and maximum value. Each distribution has expected values and variance, calculated as follows:

$$EV = (min + 4 * most\ likely + max)/6 \quad (2)$$

$$SD = (max - min)/6 \quad (3)$$

Where EV is expected value, SD is standard deviation, min is the minimum estimated value, most likely is the most likely estimated value, and where max is the maximum estimated value. The expected values and standard deviation for all cost elements are summed to calculate the total expected value and standard deviation for the total project cost (Ozcelik, 2015). To calculate the contingency required for a 99.73% confidence interval, the standard deviation is again multiplied by three. The optimistic, most likely and pessimistic values were estimated by the first listed author of this paper, the project manager on the case study project. Therefore, the total project cost is calculated at $269,630 or $78,580 more than the original budget.

Table 4: PERT method applied to the case study data set.

Description	**Optimistic**	**Most likely**	**Pessimistic**	**EV**	**SD**
Demolition	$7,000.00	$10,000.00	$15,000.00	$10,333.33	$1,333.33
Remediation	$3,000.00	$5,000.00	$7,000.00	$5,000.00	$666.67
Retaining wall	$80,000.00	$90,000.00	$140,000.00	$96,666.67	$10,000.00
Other trades	$15,000.00	$29,706.00	$45,000.00	$29,804.00	$5,000.00
Preliminaries and general	$9,552.50	$15,294.00	$22,000.00	$15,454.75	$2,074.58
Fees	$28,657.50	$38,050.00	$52,000.00	$38,809.58	$3,890.42

Consent	$2,000.00	$3,000.00	$5,000.00	$3,166.67	$500.00
Total project cost		$191,050.00	Expected cost	$199,235.00	$23,465.00
			Contingency at 99.73% confidence		$70,395.00

3.3 Expected value

The amount of contingency can be calculated based on the expected value for individual risk events. First, the risks are identified for the project. These risks are assigned an impact (monetary value) and a probability of occurrence. The sum of the expected value for each risk is the contingency amount required for the project (Baccarini, 2005a). The equation is:

$$EV = I * P \tag{4}$$

Where EV is expected value, I is impact in terms of cost, and P is the probability of the risk occurring. The risks, impacts and probabilities were also estimated by the first listed author of this paper, the project manager on the case study project. Table five demonstrates that $72,500 of contingency is required when the expect value method is applied.

Table 5: Expected value method applied to the case study data set.

Risk	**Impact (I)**	**Probability (P)**	**Expected value (EV)**
The demolition scope increases	$5,000.00	20%	$1,000.00
The remediation scope increases	$2,000.00	40%	$800.00
The retaining wall cost was estimated incorrectly	$60,000.00	90%	$54,000.00
Variations occur	$10,000.00	50%	$5,000.00
Preliminaries and general item overruns	$4,000.00	70%	$2,800.00
Fees increase as project cost increases	$9,000.00	90%	$8,100.00
Consent item overruns	$2,000.00	40%	$800.00
Expected value (contingency)			$72,500.00

3.4 Monte Carlo

A Monte Carlo simulation requires each cost element to be defined as a probability distribution; that is a minimum cost, most likely cost, and a maximum cost (Bouayed, 2016). The probability distributions for each cost element identified above are the inputs into the Monte Carlo simulation model. Visser (2016) used two case studies to compare the Triangular, Gumbel, Lognormal, Normal, Weibull and Frechet distributions. He identified that the mean and standard deviations calculated only varied a fraction of a per cent between distribution types and concluded that the distribution method selected will not significantly alter the results. Each input was assigned a triangular distribution because it derives its statistical properties from its geometry and so will better reflect the probability distributions selected (Vose, 2018). The formula when using the free ModelRisk software is:

EV = VoseInput(“element1”) + VoseTriangle(min, mostlikely, max) (5)

Where EV is expected value, min is the minimum estimated value, most likely is the most likely estimated value, and where max is the maximum estimated value. After each cost element has been assigned a Triangular distribution input, the output of the model is set as the sum of the inputs. This is defined as the total project cost and can be calculated using the following formula:

TotalProjectCost = VoseOutput("TotalProjectCost") + SUMPRODUCT(sum of EV's) (6)

The Monte Carlo simulation builds upon the Method of Moments technique as it uses the same formulae to calculate the mean, variance and the standard deviation (Vose, 2018). The model was run to simulate 10,000 different scenarios within each cost elements' distribution triangle. Figure one shows that the total expected project cost for a confidence interval of 99.73% is $251,200 which is $60,150 more than the original budget or 31.48%.

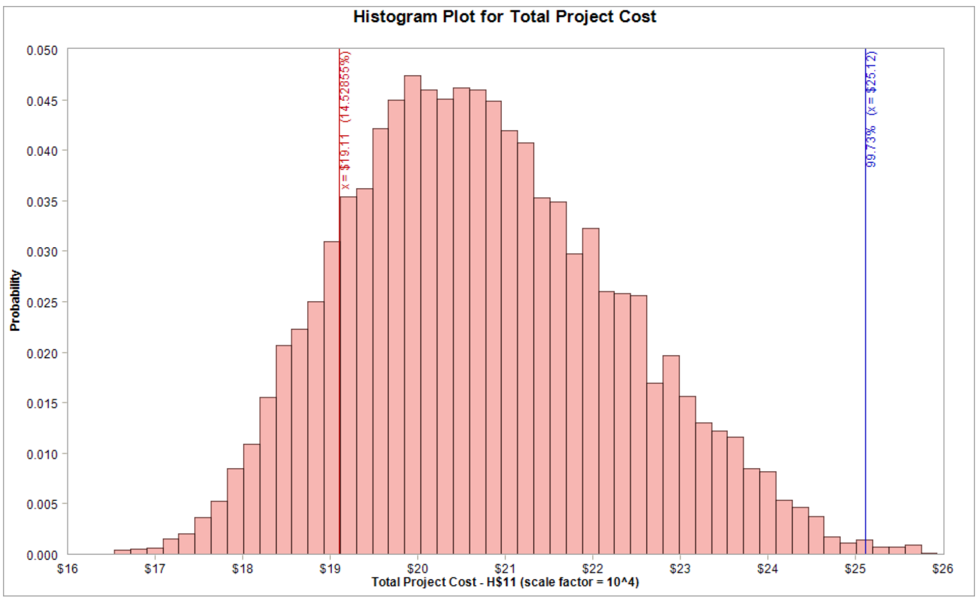

Figure 1: Monte Carlo simulation results using the cost distributions in tables three and four above. Source: ModelRisk software.

4. Results and interpretation

The contingency calculated by applying each method to the case study data set is presented in table six. As expected, the traditional fixed percentage approach was one of the least reliable. This is likely to be one of the main reasons why project budgets in the building industry overrun. The Optimum Bias Uplift technique calculated the closest contingency required at forty-four per cent. Second was the PERT, estimating 41.13 per cent of contingency. Third was the expected value technique which calculated 37.95 per cent of contingency. Lastly was the Monte Carlo Simulation which calculated 31.48 per cent of contingency. While the case study required 46.59 per cent of contingency, this has significant political implications in that there are usually tight restrictions on budget increases and this level of budget increase may not be possible in a large portion of industry construction projects. Further analysis is required to understand how budgets are determined in the building industry.

Table 6: Contingency calculations when applying different models against the data set.

Method	Contingency Calculated ($)	Contingency Calculated (%)
Case study	$89,016.28	46.59%
Fixed percentage	$19,105.00	10.00%
Expected value	$72,500.00	37.95%
Optimism bias uplifts	$84,062.00	44.00%
Pert	$78,580.00	41.13%
Monte carlo simulation	$60,150.00	31.48%

5. Conclusion

Three non-simulation methods and one simulation method for calculating cost contingency were described and then applied against a case study project to estimate the contingency value. Each estimate was compared to the actual amount of contingency required, presented in table six. The traditional fixed percentage approach proved to be one of the least suitable for estimating the actual contingency required. The three methods presented were relatively simple to understand and use, suggesting that any one of these techniques may be better that the traditional fixed percentage approach to calculating cost contingency in the construction industry.

6. Future research

Further research could compare these methods against multiple case study projects in order to determine the most reliable method as this was not evident from a test of one case study. Further work is also required to test the implementation of these methods in the construction industry. Some papers attempt to identify what methods are being used in practice though there is little research that test actual implementation. Current cost models and cost management standards could be developed further to increase implementation in the industry. These will need to be mandated or automated in some way to significantly affect current practice. Jackson (2012) identifies that lack of time and resources are two of the reasons why cost management procedures are not followed. Baccarini (2005b) identifies that of seventy-eight project practitioners; seventy-seven per cent continue to use the traditional fixed method approach, forty-six per cent work in an organisation that does not have a policy for calculating contingency, and thirty-six per cent do not manage contingency at all. Further investigation is required to identify exactly why the industry is not currently using these techniques and proposed ways to overcome these issues.

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