INTUITIVE AND USABLE RISK-BASED COST CONTINGENCY ESTIMATION MODEL FOR GENERAL CONTRACTING FIRMS

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ABSTRACT: Construction projects inherently possess uncertainties, which represent risks and opportunities to contracting business entities. Their business success, therefore, is largely defined by how these uncertainties are managed from the planning and estimating to execution phases. Traditionally risks, in particular, have been dealt by converting them into the form of a contingency. Ironically, however, cost estimators have relied on deterministic ways of predicting project cost by producing point estimates. Moreover, contingencies have been typically determined as a percentage of the project cost.
This practice is not enough to assess the impact of the project uncertainties. To remedy this situation, researchers have developed various analytical models, aiming at improving contingency estimation. These tools, however, have not been embraced as much by contracting firms mainly because they generally do not have expertise of the formal modeling techniques required to use these complex models. From this perspective, this paper proposes a cost contingency estimation model implemented as an add-in to Excel, the most common spreadsheet platform, which can be easily adoptable by contracting firms without special training required. This model uses a well-defined project risk management process and Monte Carlo simulation as its engine to model uncertainties and a project risk register. This paper focuses on the model's contribution of separating complex analytical aspects from its input and output processes to emphasize the following reality - Contracting firms, after all, need an intuitive and yet flexible contingency estimating model, which should help them focus on extracting their experience and expertise in adequately determining contingency.

Keywords: *Contingency, Risk Management, Risk Register*

1. INTRODUCTION

Construction projects inherently possess uncertainties, which represent risks and opportunities to contracting business entities. Their business success, therefore, is largely defined by how these uncertainties are managed from the planning and estimating to execution phases. Traditionally risks, in particular, have been dealt by converting them into the form of a contingency. Ironically, however, cost estimators have relied on deterministic ways of predicting project cost by producing point estimates. Moreover, contingencies have been typically determined as a percentage of the project cost.

This practice is not enough to assess the impact of the project uncertainties. To remedy this situation, researchers have developed various analytical models, aiming at improving contingency estimation. These tools, however, have not been embraced as much by contracting firms mainly because they generally do not have expertise of the formal modeling techniques required to use these complex models [1,2]. From this perspective, this paper proposes an integrated risk-based cost contingency estimation model, which separates complex analytical aspects from its input and output processes. This approach helps contracting firms focus on extracting their experience and expertise in adequately determining a reasonable estimate and contingency. The following section describes conceptual risk analysis steps and the implantation of the proposed contingency estimation model.

2. MODEL DESCRIPTION & IMPLEMENTATION

The proposed integrated cost contingency model uses a risk management process as depicted in the figure below (Fig. 1) and Monte Carlo simulation as its engine to model uncertainties. The model implementation has been done using a VBA based on Palisade's @Risk Excel add-in program. This section describes each step in detail with examples of the model.

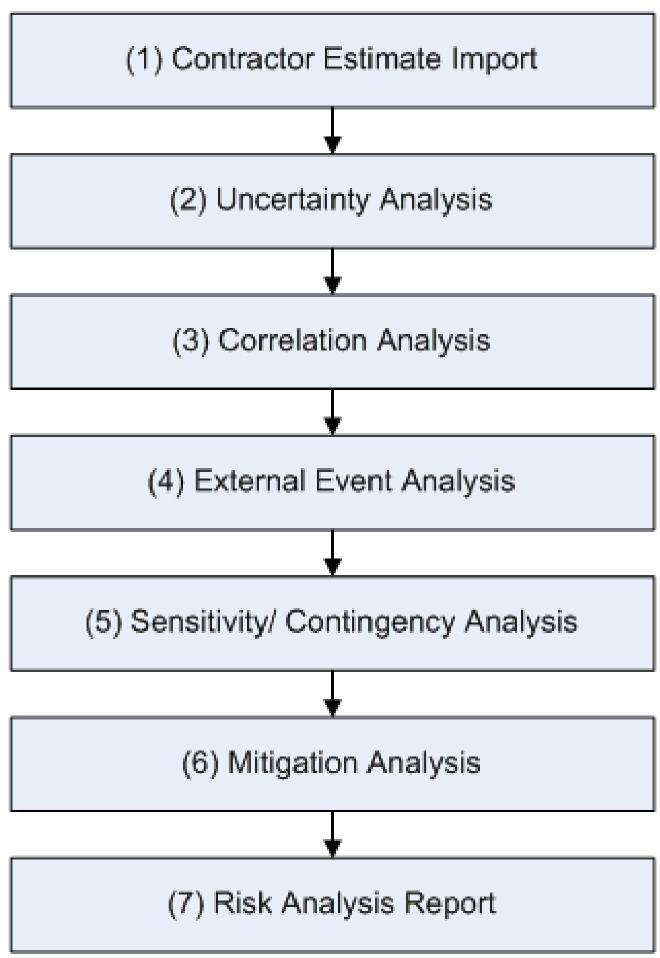

Fig. 1 Risk Analysis Steps in the Proposed Model

(1) Contractor Estimate

Contracting firms have their own established practice of determining project budget and contingency. They typically have estimating templates in a spreadsheet format, which encapsulate their estimating experience and process. It is important, therefore, to preserve their process in the risk analysis so that they can focus on extracting their experience and expertise, not learning the new system. Thus the proposed model is based on a contracting firm's estimating spreadsheet as a starting point for the series of risk analyses. Fig. 2 shows an example of the estimate template and data of a firm, which provides a deterministic base estimate.

PRO FORMA PCS DATA	
[A] BILLABLE HOURS	***47828***
AVERAGE HOURLY RATE	$30.00
BILLABLE LABOR	$1,434,840
[B] NON-REIMBURSIBLE HOURS	***5700***
AVERAGE HOURLY RATE	$40.91
NON-REIMBURSIBLE LABOR	$233,205
TOTAL LABOR	$1,668,045
PAYROLL BURDEN	$2,001,654
[C] ODCs	***$2,341,965***
[D] EQUIPMENT & MATERIALS	***$7,856,799***
[E] SUBCONTRACTS	***$8,916,650***
[F] NON-REIMBURSABLE	***$52,568***
REC. CREDITS	$0
CONTINGENCY/RESERVE	$0
TOTAL CONTRACT COSTS	$22,837,681
GROSS PROFIT	$2,662,319
TOTAL REVENUE	$25,500,000
EFFECTIVE MULTIPLIER	3.80

SUPPORTING DETAILS				
LABOR HOURS	HRS.	%	EQUIP/MAT'L COSTS	COST
Program/Project Management	9,320	19%	Equipment Costs	$3,356,443
Project Controls	5,960	12%	Materials (aggregate, concrete, dowels)	$4,500,356
Contracts	4,108	9%	<<List approprite equip/mat'l categories>>	$0
Finance	632	1%	<<List approprite equip/mat'l categories>>	$0
Health and Safety	6,000	13%	<<List approprite equip/mat'l categories>>	$0
Quality	6,000	13%	<<List approprite equip/mat'l categories>>	$0
Technical Support	2,520	5%	<<List approprite equip/mat'l categories>>	$0
General Superintendents	6,120	13%	<<List approprite equip/mat'l categories>>	$0
Administrative	7,168	15%	<<List approprite equip/mat'l categories>>	$0
<<List appropriate technical disciplines>>	0	0%	<<List approprite equip/mat'l categories>>	$0
<<List appropriate technical disciplines>>	0	0%	<<List approprite equip/mat'l categories>>	$0
<<List appropriate technical disciplines>>	0	0%	<<List approprite equip/mat'l categories>>	$0
<<List appropriate technical disciplines>>	0	0%	<<List approprite equip/mat'l categories>>	$0
<<List appropriate technical disciplines>>	0	0%	<<List approprite equip/mat'l categories>>	$0
<<List appropriate technical disciplines>>	0	0%	<<List approprite equip/mat'l categories>>	$0
All Others	0	0%	All Others	$0
[A] TOTAL BILLABLE HOURS	***47,828***		***[D] TOTAL EQUIP/MAT'L COSTS***	***$7,856,799***
ODC'S	COST		SUBCONTRACT COSTS	COST
HI GET	$1,109,864		AC Pavement	$4,120,450
GL Insurance	$133,570		Landscaping	$1,510,000
Bond	$239,478		Guardrails	$2,925,000
Builders Risk	$54,150		Concrete	$361,200
Small Tools	$161,196			$0
Escalation	$426,214		<<List major subcontract packages>>	$0
Safety Costs other than Labor	$214,928		<<List major subcontract packages>>	$0
Misc Construction Expenses	$2,565		<<List major subcontract packages>>	$0
<<List ODC accounts as appropriate>>	$0		<<List major subcontract packages>>	$0
All Others	$0		All Others	$0
[C] TOTAL ODC'S	***$2,341,965***		***[E] TOTAL SUBCONTRACT COSTS***	***$8,916,650***

NON-REIMBURSABLE COSTS ON GMAX CONTRACTS (Include discretionary costs on lump sum contracts)			
NON-REIM. HOURS	HOURS	NON-REIM. COSTS (NON-LABOR)	COST
Project Set up	4,500	Travel and Expenses	$50,000
<<List appropriate disciplines or tasks>>	0	<<List ODC accounts as appropriate>>	$0
<<List appropriate disciplines or tasks>>	0	<<List ODC accounts as appropriate>>	$0
<<List appropriate disciplines or tasks>>	0	<<List ODC accounts as appropriate>>	$0
<<List appropriate disciplines or tasks>>	0	<<List ODC accounts as appropriate>>	$0
<<List appropriate disciplines or tasks>>	0	<<List ODC accounts as appropriate>>	$0
<<List appropriate disciplines or tasks>>	0	<<List ODC accounts as appropriate>>	$0
All Other Non-re Hours	1,200	All Others	$2,568
[B] TOTAL NON-RE LABOR HOURS	***5,700***	***[F] TOTAL NON-RE COSTS (NON-LABC***	***$52,568***

Fig. 2 Contracting Firm's Estimate Template and Data

(2) Uncertainty Analysis

One of the basic components needed for the risk analysis is the identification of uncertainties affecting the base cost estimate, affecting unit prices or quantities in the cost estimate. Internal uncertainty is the uncertainty associated with the items listed in a cost estimate or activity durations; this uncertainty is caused by incompletely defined estimation parameters or incomplete knowledge. External uncertainty arises from risks that are beyond the immediate scope for the project [3].

In the cost risk analysis model, every cost component with a potential for variability is modeled as a random variable. The most common way to model this variability is the use of probability density distributions. A Monte Carlo simulation (MCS) adopted in the model uses the probability distribution functions (PDFs), from which a random sample of values is generated to represent the variability. Several authors claim that the triangular distribution is as good as other distributions and is preferred due to its simplicity [4,5]. The generated random values and the constant cost figures (cost components that are considered to have no variability) are added up and a value for the total cost is computed. This procedure is repeated thousands of times so a cumulative distribution function (CDF) for the project cost can be obtained. Fig. 3 shows a cost item in the contractor's estimate whose variability is specified through the triangular distribution.

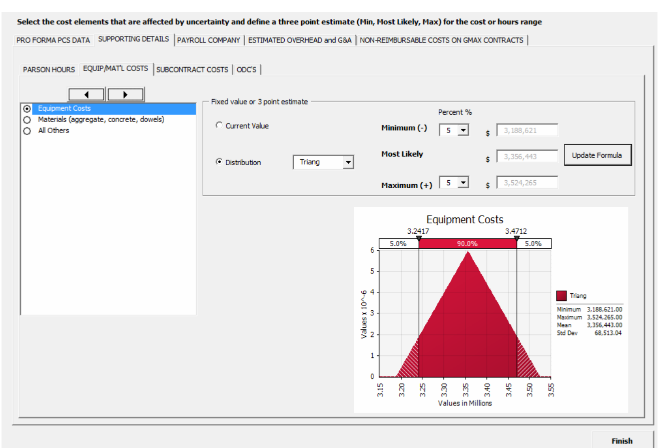

Fig. 3 Assignment of Triangular Distribution to a Cost Item

(3) Correlation Analysis

In construction cost estimating the assumption of independence is usually adopted due to the difficulty of modeling dependence. Under the independence assumption, the single figure estimate of the system variable is almost guaranteed to be exceeded if the summation of the estimates is a large number of small subsystem variables[6]. When historical data are not available, subjective judgment is needed for the estimation of correlation coefficients. Dependency can be categorized in: negative strong, negative medium, negative weak, independent, positive weak, positive medium, positive strong with coefficients of -0.85, -0.55, -0.25, 0, 0.25, 0.55, and 0.85 respectively [6]. Touran [7] gives values of 0.15, 0.45, and 0.8 for weak, moderate and strong correlation correspondingly. Fig. 4 shows the correlation between cost items in the model.

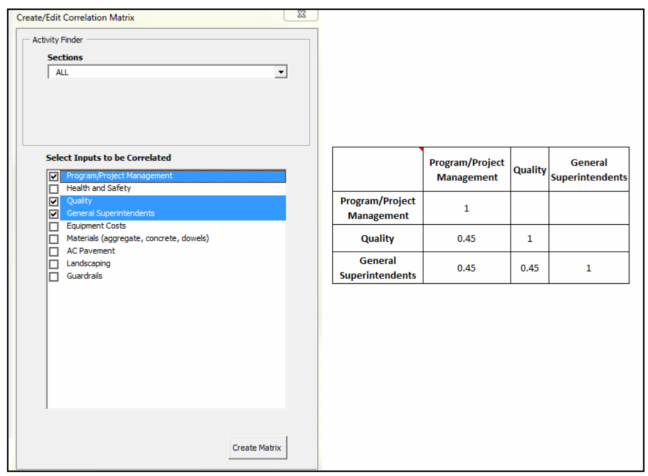

Fig. 4 Correlation between Cost Items

(4) External Event (Risk/ Opportunity) Analysis

Internal uncertainty is best characterized by specifying a feasible range of values and probability distributions, while external uncertainty is more appropriately modeled by assessing the likelihood of that risk event happening or not[8].

External risks are relatively uncontrollable while internal factors are more controllable and vary between projects [9].

To handle these external risks systematically in the risk analysis, a "risk register" is created. The general procedure first assesses qualitatively the probability of occurrence of each risk and then its consequences on project performance. In a similar way the consequence of certain risk on project cost can be also evaluated. Once the occurrence probability and consequences of each risk are scored they can be mapped into a matrix where the importance of each one can be evaluated. Fig. 5 provides a way to rank the importance of each risk affecting the project. For example, risks that fall in the upper right area of the matrix are the ones to be considered critical and need to be investigated in order to avoid undesirable results on project performance targets; conversely, risks mapped in the lower left area of the matrix are less critical. The benefits of this methodology are visible for risk prioritization and communication; however, it is limited when assessing and planning for consequences in terms of money.

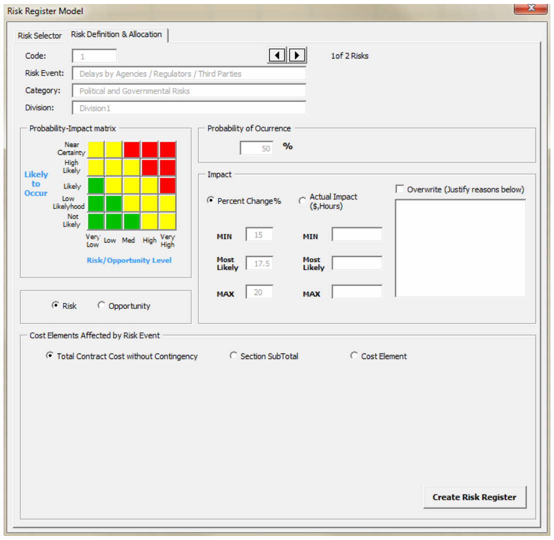

Fig 5 Project Risk Register

(5) Contingency Analysis

If risk can be assessed, it can be reflected by the inclusion of a contingency sum. Probabilistic risk analysis directly helps the process of contingency determination and allocation. The use of the results generated by the risk analysis (i.e., CDF of project cost) as shown in Fig. 6 allows management to analyze probabilities of exceeding certain targets. By determining the level of risk acceptance or confidence level, the amount of contingency and tender price can be determined. By comparing the base cost estimate total and the estimate based on a certain confidence level, a contingency can be determined.

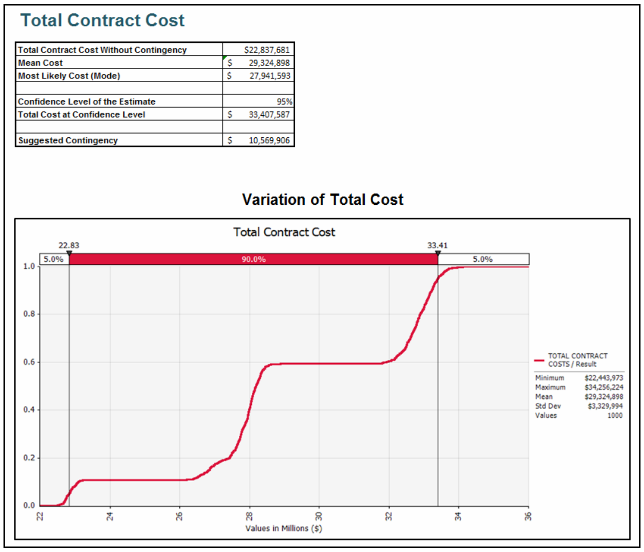

Fig. 6 Contingency Calculation from the CDF

As a rule of thumb, the tornado chart can be used to distribute the determined contingency for the cost items in the estimate. Fig 7 shows the tornado chart example.

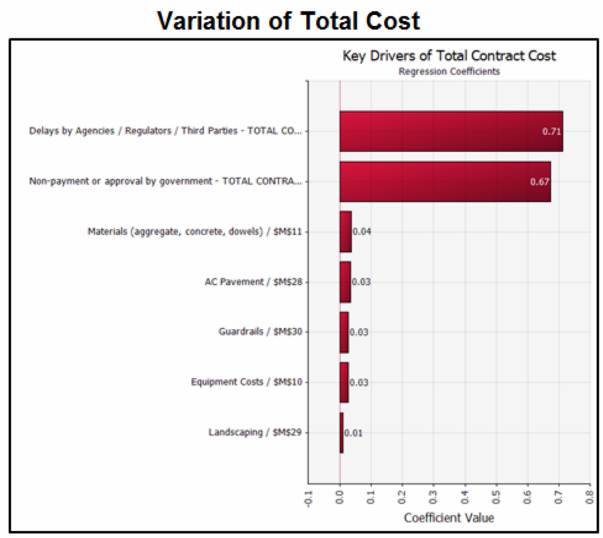

Fig. 7 Tornado Chart for Total Cost Variation

(6) Mitigation Analysis

Since the contingency depends on the variability of the cost items, before finalizing it, one can attempt to reduce the range of the uncertainty by implementing some mitigation strategies. As shown in Fig. 8, a mitigation strategy can be implemented at a certain cost, resulting in lowering the probability of occurrence of an uncertain event and/ or its level of impact. This process can be repeated for other cost items and one more round of Monte Carlo simulation will be performed.

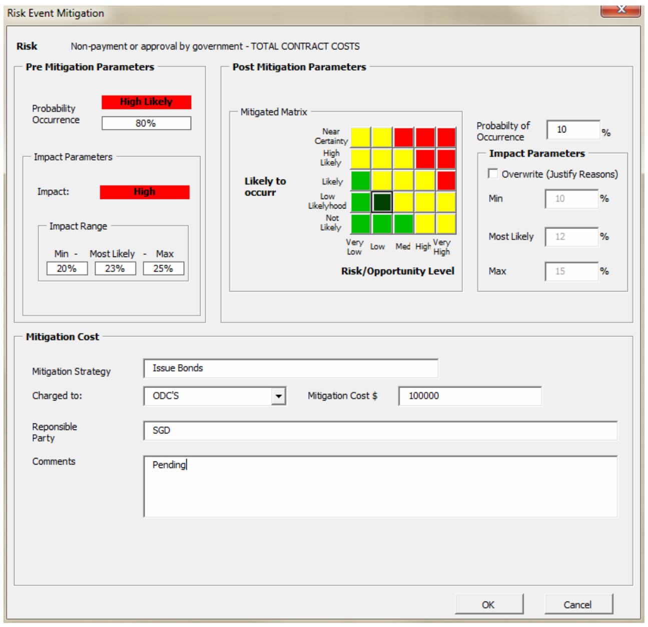

Fig. 8 Uncertainty Mitigation Strategy

(7) Risk Analysis Report

After the mitigation strategies implemented in the risk simulation, estimators can make a decision on the contingency by evaluating the contingencies before and after the mitigation. Fig. 9 shows two contingencies where the reduction in the contingency is justified because it is exceeds the mitigation-related expense at the same level of confidence.

Total Contract Cost

	PreMitigation		PostMitigation	
Total Contract Cost without Contingency	$	23,213,269	$	23,237,681
Mean Cost	$	29,302,154	$	23,630,522
Most Likely Cost (Mode)	$	28,119,956	$	23,298,813
Confidence Level of the Estimate		85%		85%
Total Cost at Confidence Level	$	33,004,234	$	23,602,902
Suggested Contingency	$	10,166,553	$	565,221

Total Cost of Mitigation	$	200,000

Variation of Total Cost

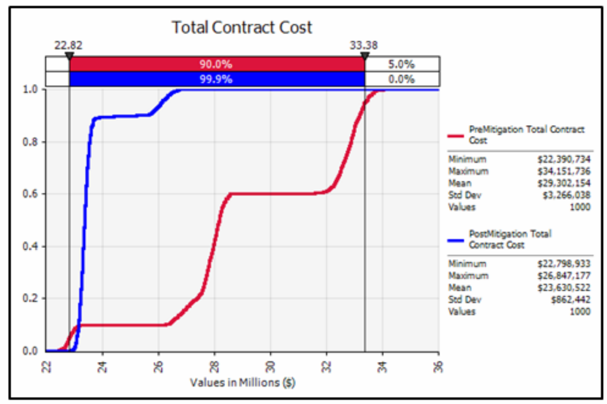

Fig. 9 Total Cost Comparison Before and After Mitigation

3. CONCLUSION

This paper described an integrated cost contingency estimation model implemented as an add-in to Excel, the most common spreadsheet platform, which can be easily adoptable by contracting firms without special training required. This model used a well-defined project risk management process and Monte Carlo simulation as its engine to model uncertainties and a project risk register.

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