ACCURACY IN ESTIMATING PROJECT COST CONSTRUCTION CONTINGENCY – A STATISTICAL ANALYSIS

David Baccarini

Department of Construction Management, Curtin University of Technology, PO Box U1987, Perth 6845, Western Australia, Australia.

ABSTRACT

The cost performance of building construction projects is a key success criterion for project sponsors. Project cost performance is typically measured by comparing final cost against budget. A key component of the project budget for the construction contract is construction contingency, which caters for contract variations that arise during the implementation phase of projects. It is important for project sponsors to know the level of accuracy being achieved in estimating construction contingency. Statistical analysis of past projects provides a means for measuring the accuracy of construction contingency. The cost data for 48 road construction projects completed by an Australian government organisation were statistically analysed to investigate the accuracy of contingency. It was found that the average construction contingency was 5.24% of the Award Contract Value but the average value of contract variations was 9.92%. The organisation used a traditional percentage approach for estimating construction contingency. This suggests that the organisation has room to improve the accuracy of its construction contingency estimates by seeking alternative estimating methods. An investigation of an alternate estimating approach derived from the analysis of the data found that there were no significant correlations between project variables and construction contingency that might be used to create a prediction model for construction contingency.

Keywords: cost contingency, project cost performance, risk management

INTRODUCTION

The cost performance of construction projects is a key success criterion for project sponsors. Construction projects are notorious for running over budget (Hester et al 1991, Zeitoun & Oberlander 1993). Cost contingency is included within a budget to represent 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 is no standard definition for contingency as Patrascu (1988:115) observes, "contingency is probably the most misunderstood, misinterpreted and misapplied word in project execution. Contingency can and does mean different things to different people". Contingency has been defined as:

> "An amount of money or time (or other resources) added to the base estimated amount to (1) achieve a specific confidence level, or (2) allow for changes that experience shows will likely be required" (AACE 2000: 28)
>
> "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 2000: 199)

The key attributes of the concept of project cost contingency are:

- *Reserve* - Cost contingency is a reserve of money (AACE 2000).
- *Risk* – The need and amount for contingency reflects the existence of risk in projects (Thompson & Perry, 1992). Contingency covers for two categories of risks – known unknowns and unknown unknowns (PMI 2000, Hillson 1999). Contingency caters for events within the defined project scope that are unforeseen (Moselhi 1997, Yeo 1990), unexpected (Mak et al 1998), unidentified (Levine 1995), or undefined (Clark and Lorenzoni 1985, Thompson and Perry 1992).
- *Risk Management* – There is a range of risk management strategies for risk in projects such as risk transfer, risk reduction, and financial treatments for retained risks e.g. contingency (Standards Australia 1999). So contingency is used in conjunction with other risk treatment strategies.
- *Total Commitment* - Cost estimates are prepared and contingencies added in order to indicate the likely total cost of the project. The inclusion of contingencies within a budget estimate means that the estimate represents the total financial commitment for a project.
- *Project Outcomes* - Contingency can have a major impact on project outcomes for a project sponsor. If contingency is too high it might encourage sloppy cost management, cause the project to be uneconomic and aborted, and lock up funds not available for other organisational activities; if too low it may be too rigid and set an unrealistic financial environment, and result in unsatisfactory performance outcomes (Wideman 1995, Dey et al 1994).

Two major categories of contingency can be identified for construction projects (HM Treasury, 1993):

- *Design Contingency* – this is for changes during the design process for such factors as incomplete scope definition and inaccuracy of estimating methods and data **(**Clark & Lorenzoni, 1985).
- *Construction Contingency* - this is for changes during the construction process. Under a traditional procurement arrangement, the project sponsor procures professionals to produce the design before competitively selecting the construction contractor. A contract is signed between the project sponsor and the contractor, which typically contains a variations clause to allow for changes and provide a mechanism for determining and valuing variations (Staugas, 1995). Construction contingency exists to cater for these variations allowable under the contract between the sponsor and contractor. Mak & Picken (2000) state that contingency can be compared with the total approved value of contract variations to assess the accuracy of the contingency

RESEARCH DESIGN

Construction contingency is the focus of the research reported within this paper. Figure 1 set outs a model for estimating construction contingency by the project sponsor prior to the commencement of construction phase of projects. The sponsor needs an estimate of the final cost of the project for budgeting purposes. This budget is a combination of the awarded contract value plus construction contingency.

Key elements of this model are:

1. *Contingency estimating methods* - There are numerous estimating methods available for project cost contingency. Traditionally cost estimates have been treated as being 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 approach is considered arbitrary, as Thompson and Perry (1992:1) observe, "all too often risk is either ignored or dealt with in an arbitrary way: simply adding a 10% 'contingency' onto the estimated cost of a project is typical". And it is difficult for the estimator to justify or defend (Newton 1992, Yeo 1990). It is an unscientific approach and a reason why so many projects are over budget (Hartman 2000). Nowadays more sophisticated estimating methods are available, such as Monte Carlo simulation and artificial neural networks.
2. *Influential variables* - There are several variables that may influence the estimating process and the amount of estimated contingency (e.g. organisational, project, cognitive).
3. *Contingency Accuracy* - Construction contingency is added to the award contract value to represent the sponsor's predicted final cost of the project. The actual final cost is the award contract value plus/minus contractual variations. The accuracy of the contingency can be measured by comparing the predicted final cost against the actual final cost.

Using the model in Figure 1, the following two research questions for estimating accurate project cost contingency can be identified:

1. *How accurate are construction contingencies?*
2. *What project variables are correlated with construction contingency so that a predictive model for estimating construction contingency can be derived?*

So, the objectives of the research are to quantitatively analyse cost data of completed construction projects to attempt to answer these research questions.

Case Study

This research used a case study research methodology. A case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context" (Yin, 1991:23). The case study for this research is an organisation and the phenomena being researched is construction contingency for road construction projects. The case study uses quantitative research to measure aspects of a phenomenon (Kumar, 1996).

The organisation is an Australian government road authority managing a network of highways and roads with a value of more than A$13 billion and employing 860 full time staff. Its project cost management guidelines for infrastructure projects refers to cost contingency as ‘provisional sum,’ which is defined as an amount of money set aside to cater for the uncertainty associated with the delivery of the project. The organisation uses a traditional percentage approach to calculate contingency.

Sample

The research population consisted of road construction project sponsored by the case study organisation. The selection of a research sample of 48 projects was derived based on the following criteria:

1. The time span for the sample was from 1997 to 2002, because cost data was readily accessible between these years. Ten projects were randomly identified from each year to provide a sample of 50. A review of the 50 projects found two projects that specific factors which resulted in their values being clearly discernable as outliners that would distorted the analysis. Therefore 48 projects were analysed.
2. All sample projects had reached practical completion.
3. All sample projects used traditional procurement with open competitive tendering using the Australian Standard AS 2124 – 1992, General Conditions of Contract.
4. Sample projects included areas in all regions of the state.
5. The range of dollar value was from A$0.05m to over A$35m

The following information was obtained for each project in the sample:

- Date of bid
- Location
- Project Duration
- Number of Bidders
- Mean Value of Bids
- Award Contract Value
- Final Contract Value
- Variations Value
- Contingency

The data obtained was statistically analysed using SPSS (Statistical Package for the Social Sciences) software. Two forms of statistical analysis were undertaken:

- *Descriptive statistics* - This provided general statistical information such as the mean, standard deviation and co-efficient of variation of variables.
- *Correlation* - Correlation to examine the relationship between two variables (bi-variate).

ACCURACY OF CONSTRUCTION CONTINGENCY

Construction contingency caters for variations allowable under the contract between the sponsor and contractor (Mak & Picken, 2000). A comparison of predicted final cost against actual final cost indicates the accuracy of contingency. Broadly, the smaller the difference between these two costs the more 'accurate' the contingency value. This would indicate whether there is a problem is accurately estimating project cost contingency.

Contingency Accuracy (CA)

Contingency Accuracy (CA) is measured by comparing construction contingency and approved contract variations, expressed as a percentage of Award Contract Value:

$$CA = \Sigma V\% - \Sigma C\%$$

Where:

ACV = Award Contract Value (successful construction tender, expressed in A$)
C% = Construction Contingency, expressed as % of ACV
V% = Variations, expressed as % of ACV

In order to measure Contingency Accuracy, variables C% and V% need to be calculated.

Contingency (C%)

Contingency (C%) is the ratio of the construction contingency to the ACV, expressed as a percentage:

$$C\% = \frac{\Sigma C}{\Sigma ACV} \times 100$$

Where:

C = Construction contingency, expressed in A$

Table 1 displays the range of contingency (C%) in the sample projects. It shows that construction contingency averaged 5.24% of ACV. The variability is relatively limited, suggesting that the traditional percentage approach to estimating results in conservative estimates, anchored around 5-10%, and not reflecting the wider range of risks in the projects

Contingency (%)	Nr of Projects (n=48)
0_5.00%	26
5.01_10.00%	16
10.01_15.00%	4
15.01_20.00%	0
>20.00%	2
5.24%	**Mean**
4%	**Std Devn.**
80%	**C of V**

Table 1: Contingency (C%)

Variation (V%)

Variation (V%) is the ratio of the value of contract variations to the Award Contract Value (ACV), expressed as a percentage:

$$V(\%) = \frac{\Sigma V}{\Sigma ACV} \times 100$$

Where:
V = approved contract variations, expressed in $A

Table 2 displays the results for variation (V%). Of the 48 projects, variations decreased the ACV in 7 projects and increased the ACV in 41 of projects. The average variation (V%) for all projects was 9.92% of ACV. The variability for variations (V%), as measured in terms of standard deviation and co-efficient of variation, is much greater than the variability for construction contingency (C%). This indicates that the estimation of contingency is not fully tareflecting the variability of contract variations.

Variation (%)	Nr of Projects (n=48)
>-20%	1
-15.01_-20%	1
-10.01_-15%	0
-5.01_-10%	3
0.00_-5%	2
0.00_5 %	14
5.01_10%	14
10.01_15%	4
15.01_20%	4
>20%	5
9.92%	**Mean**
21%	**Std Devn.**
208%	**C of V**

Table 2: Variation (V%)

Contingency Accuracy (CA)

As stated previously, Contingency Accuracy can be expressed as the difference between Contingency and Variation, thus:

$$CA = \Sigma V\% - \Sigma C\% = 9.92\% - 5.24\% = 4.68\%$$

The smaller the difference between these two values then the more accurate the contingency. A positive percentage shows that Variation exceeded Contingency; a negative value shows that Contingency exceeded Variation. Table 3 shows that 19 projects had a contingency of greater value than contract variations, whilst 29 projects had a contingency of lesser value than contract variations. Overall, construction contingency was an average 5.24% of Award Contract Value, whilst variation was 9.92% of Award Contract Value. This shows that there was an increase in the ACV of 4.68% not covered by construction contingency. Furthermore, only in 19 (12+7) projects was contingency and variation within 5% of each other.

Contingency Accuracy (%)	Nr of Projects (n=48)
>-20.00%	1
-15.01_-20.00%	1
-10.01_ -15.00%	4
-5.01_-10.00%	6
0.00_-5.00%	7
0.00_5.00 %	12
5.01_10.00%	7
10.01_15.00%	3
15.01_20.00%	0
>20.00%	7
4.68%	**Mean**
2063%	**Std Devn.**
44033%	**C of V**

Table 3 – Contingency Accuracy

Another way of measuring contingency accuracy, which provides similar information, is to express contingency (C%) and variation (C%) as a ratio:

$$CA2 = \frac{C}{V} \times 100 = \frac{5.24\%}{9.92\%} \times 100 = 52.82\%$$

This shows that construction contingency covered only for 52.25% of approved contract variations ie it did not cater for 47.18% of total value of contact variations.

In summary, the analysis of construction contingency shows that it is more often than not insufficient to cater for contract variations and that, in the case study, it should be increased in future projects. This is an extremely useful piece of information for the organisation to instigate consideration its approach to estimating construction contingency. It highlights the inaccuracy inherent in the traditional percentage approach to estimating contingency and stimulates the search for more accurate estimating approaches. One approach is to identify any variables that have a relationship to the accuracy of project cost contingency that may provide a basis for a predictive model for estimating contingency.

PREDICTION MODEL - VARIABLES

It is useful to identify if any project variables have a relationship to the accuracy of project cost contingency, for example project size or location. Any variables that are found to have a relationship might then be used to predict a more accurate project cost contingency; or simply highlight to estimators that when these variables are present there is a need to pay particular consideration to them when estimating contingency.

Project variables

The following variables were selected, due to availability of data, for investigation:

Project Size

Project size can be measured in terms of financial value. Table 4 categorises projects by ACV, which is the value of the successful tender. The ACV ranged from $57,000 to $ 34,000,000. The mean ACV was $5,462,742.10 and the majority of projects (58%) below $4,000,000.

Award Contract Value (A$)	Nr of Projects (n = 48)
<$2.00m	21
$2.01_4.00m	7
$4.01_6.00m	4
$6.01_8.00m	5
8.01_10.00m	4
>$10.00m	7
$5,462,742	**Mean**
$7,034,520	**Std Devn.**
129%	**C of V**

Table 4: Project Size ($)

Bid Variability

The bid variability is the ratio of Award Contract Value (ACV) and the Mean Bid Value (MBV) of all bids, expressed in percentage terms:

$$\text{Bid Variability} = \frac{\Sigma\ MBV}{\Sigma\ ACV} \times 100$$

Table 5 categorises projects by MBV, which is the total of all bids for a project divided by the number of bids. The MBV for all projects was $6,311,267, which is higher than the mean ACV of $5,462,742, as one would expect because the ACV is usually the lowest bid and therefore below the MBV.

Mean Bid Value (A$)	Nr of Projects (n = 48)
< $0.50m	5
$0.51– 2.00m	15
$2.01 – 5.00m	9
$5.01– 10.00m	12
>$10.00m	9
$6,311,267.95	**Mean**
$8,300,856.91	**Std Devn.**
132%	**C of V**

Table 5: Mean Bid Value

Table 6 displays the results for bid variability. A bid variability value of:

- 100 % denotes the two values are same.
- >100% denotes that MBV is higher than ACV.
- <100% denotes that MBV is lower than MBV

Bid Variability (%)	Nr of Projects (n=48)
<100%	1
100_110%	13
111_120%	18
121_130%	5
131_140%	6
>140%	5
1.29	**Mean**
0.68	**Std Devn.**
53%	**C of V**

Table 6: Bid Variability

Of the 48 projects there was only one where the ACV was higher than MBV. The mean Bid Variability was 129%, that is the MBV exceeded the ACV by an average 29%. The aim of this measure is to provide an indication of the competitiveness of the Award Contract Value. It might be expected that the greater the difference between the ACV and MBV, the more competitive the ACV. Consequently, a very competitive ACV might lead to the more 'claims conscious' contractor, leading to higher variations and contingency.

Bids Received

An alternative measure for the competitiveness of the ACV is the number of bids received per project – see Table 7. It might be reasoned that the higher the number of bids, the more competitive the ACV, which might lead to the more 'claims conscious' contractor, leading to higher variation and contingency. Only conforming bids are considered as being received for the purpose of this analysis. The median number of bids received was 5 per project.

Nr of bids (n)	Nr of Projects (n= 48)
2	6
3	6
4	10
5	10
6	5
7	11
4.71	**Mean**
1.68	**Std Devn.**
36%	**C of V**

Table 7: Bids Received per Project

Project Duration

Table 8 shows the project duration from contract award to practical completion, which ranged from 4 weeks to 127 weeks. The mean Project Duration was 34 weeks. Most projects (60%) were less than 30 weeks duration. It might be expected that the longer the project, the greater the potential significant risks to eventuate and therefore higher values for contingency and variation.

Project Duration (weeks)	Nr of Projects (n=48)
<15	10
16-30	19
31-45	6
46-60	8
>60	5

Table 8: Project Duration

Project Location

The organisation delineates three locations for its projects - Metropolitan, South and North. Table 9 shows that the vast majority of projects are undertaken in two regions: Metropolitan and North. It might be expected that as the North region covers a vast area of varying conditions, then location may influence the amount of risk and therefore the level of contingency and variation.

Location	Nr of Projects (n=48)
Metropolitan	21
South	7
North	20

Table 9: Project Location

Year

Table 10 shows the year of each project, defined as the mid-period date i.e. date between the contract award and the practical completion of the project. The years 2000 and 2001 were the two highest categories and represented nearly 50% of all projects. It might be expected as economic conditions change through the years that this may influence the level of contingency and variation.

Project Year	Nr of Projects (n=48)
1997	5
1998	9
1999	8
2000	12
2001	11
2002	3

Table 10: Project Year

Correlation Analysis

In order to identify any project variables that may be correlated with contingency, an analysis undertaken was Pearson's Correlation analysis. Correlation is a technique that examines the relationship between two variables (bi-variate). There are two types of correlation: Pearson's (r) and Spearman's rank order correlation (r_s). Pearson's correlation was used to examine the relationship between data that was collected on an interval or ratio scale.

A correlation can be used to identify characteristics of the relationship between two variables:

1. The *direction of the relationship*, that is, whether the relationship is positive or negative. In a positive relationship (+) the two variables tend to move in the same direction, whereas in a negative relationship (-) the two variables go in the opposite direction.
2. The *form of the relationship*, that is whether the relationship is linear.

Correlations - Results

Pearson's Correlation analysis was undertaken on the cost data set using SPSS software – see Table 11. There was no significant correlation value at the 0.01 level. The following is a list of correlations that might have been expected:

- *Contingency and Variation* – It would be anticipated that the amount of contingency and variation would be strongly correlated, because the former is estimated to cater for the latter. A weak correlation would indicate that the estimating methods for contingency needs to be evaluated for ways to improve accuracy.
- *Bid Variability*– It might be expected that the higher the bid variability, the higher the expected variations value and contingency. A high bid variability may indicate that the accepted tender is lower than average and hence the contractor might be aggressive in claims on variations to cover additional cost not originally included within their tender.
- *Location* – It would be expected that the more remote and isolated the project the higher the variations. This is the case in the North of the state where resources are harder to acquire and there are more unknowns.

CONCLUSIONS

Project cost data of 48 road construction projects from an Australian government road authority was used for quantitative analysis of the estimating of construction contingency. The outcomes of this analysis were:

- Construction contingency was an average 5.24% of Award Contract Value, whilst variations was 9.92% Award Contract Value. This shows a shortfall in contingency of 4.68%. Contingency accuracy was inadequate by 47.18% to cater for the total value of contact variations. Furthermore, the variability of contract variation values was not reflected in the construction contingency.
- There were no significant correlations between project variables and cost contingency that might be used to predict cost contingency. It would have be anticipated that the amount of contingency and variation would be strongly correlated, because the former is estimated to cater for the latter. A weak correlation would indicate that the estimating methods for contingency needs to be evaluated for ways to improve accuracy.

This research is a case study of one organisation's experiences and therefore has provided a very narrow view of cost contingency as applied within industry. One suggestion for future research is to conduct further case studies on other public and private organisation.

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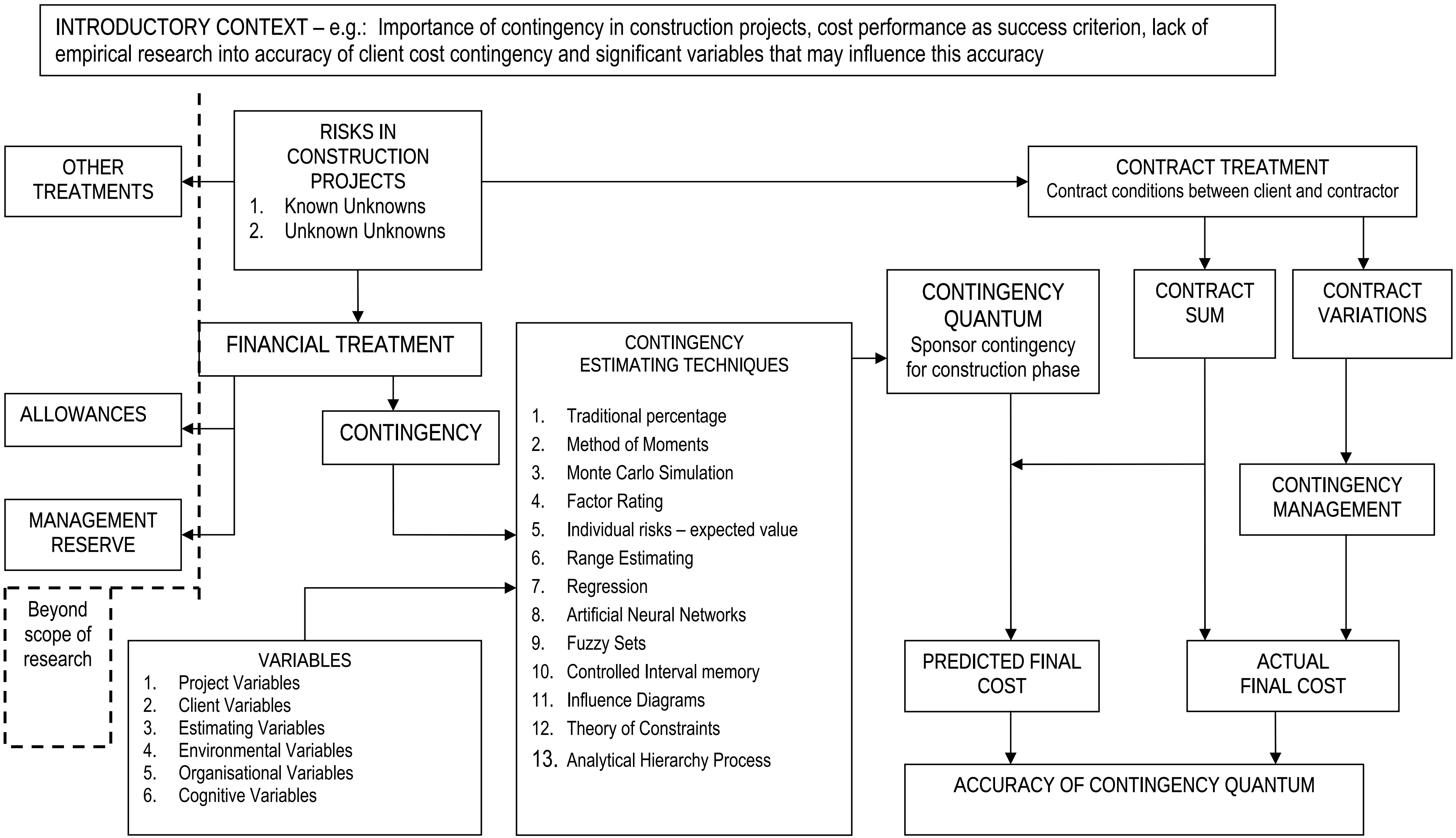

Figure 1: Model - Sponsor Project Cost Contingency

		Award_cv	bid_var	Location	m_bid	N_bids	C%	cont_acc	C	T_days	variation
Award_cv	Pearson	1.000	-.167	-.166	.992	.125	-.128	-.086	.439	.671	.447
	Sig. (2-tailed)	.	.246	.250	.000	.387	.377	.551	.001	.000	.001
bid_var	Pearson	-.167	1.000	.160	-.133	-.148	.013	-.054	-.123	-.182	-.082
	Sig. (2-tailed)	.246	.	.267	.357	.304	.930	.708	.395	.207	.573
Location	Pearson	-.166	.160	1.000	-.136	.026	.152	-.003	.010	-.237	-.247
	Sig. (2-tailed)	.250	.267	.	.345	.857	.291	.985	.948	.098	.084
m_bid	Pearson	.992	-.133	-.136	1.000	.143	-.124	-.087	.451	.674	.422
	Sig. (2-tailed)	.000	.357	.345	.	.322	.393	.549	.001	.000	.002
N_bids	Pearson	.125	-.148	.026	.143	1.000	-.077	-.234	.214	.104	-.022
	Sig. (2-tailed)	.387	.304	.857	.322	.	.597	.102	.135	.471	.877
C%	Pearson	-.128	.013	.152	-.124	-.077	1.000	.077	.243	-.090	-.049
	Sig. (2-tailed)	.377	.930	.291	.393	.597	.	.594	.089	.533	.734
cont_acc	Pearson	-.086	-.054	-.003	-.087	-.234	.077	1.000	.275	.135	-.048
	Sig. (2-tailed)	.551	.708	.985	.549	.102	.594	.	.053	.349	.739
C	Pearson	.439	-.123	.010	.451	.214	.243	.275	1.000	.433	.119
	Sig. (2-tailed)	.001	.395	.948	.001	.135	.089	.053	.	.002	.410
T_Days	Pearson	.671	-.182	-.237	.674	.104	-.090	.135	.433	1.000	.395
	Sig. (2-tailed)	.000	.207	.098	.000	.471	.533	.349	.002	.	.005
variation	Pearson	.447	-.082	-.247	.422	-.022	-.049	-.048	.119	.395	1.000
	Sig. (2-tailed)	.001	.573	.084	.002	.877	.734	.739	.410	.005	.

Table 11: Correlation Analysis