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SUPPLY CHAIN CONTINGENCY ESTIMATION: CALCULATION METHODS TOWARDS BETTER MANAGEMENT OF RISK AND COST-OVERRUN

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Abstract: Contingency estimation methods are largely misapplied in the construction industry and currently align inadequately with risk and cost-overrun. The work discussed here addresses this gap, to present a newly developed structured mechanism to help the project-team choose an appropriate calculation method based upon project type, supply chain, and (on & off) site complexities to minimise cost overrun. Three contingency estimation methods, namely: deterministic methods; probabilistic methods; and, modern mathematical methods are reviewed, then, using a mixed-methods research approach that includes qualitative semi-structured interviews with key Western-Australian industry experts to build necessarily upon relevant secondary research, the work presents a means to select a best estimation method, depending on the project's (on or off) site circumstances. This work clarifies that deterministic methods can be used for simple, repetitive and low complex projects and supply chains - suitable contingency percentages can be applied from past, similar project risk factors and complexities; it is determined here that this estimation method provides a simple and quick decision-making tool to determine the project contingency. On the other hand, complex and large-scale projects, typically with a multitude of uncertainties and risks, are apt to incur additional costs and delay the project; thus, the project team can be guided towards individual risk events, calculate the consequences in terms of cost and time, and finally define risk mitigation strategies. A structured mechanism is presented that allows precedential experience, (on or off) site conditions, internal and external factors, and key risk events' identification, to guide choice of the most appropriate, contingency estimation analyses method for a project at hand.

Keywords: Supply-Chain; Contingency-Estimation; Risk

1 BACKGROUND

Construction projects experience threats and uncertainties during scheme process. Some of the uncertainties are foreseeable and some are unforeseeable due to the uniqueness of the project (Jubilee 2015). Industry practitioners, contractors, designers, and other stakeholders define risk in & across different perspectives; in traditional terms – risk is a harm and a hazard that creates negative consequences (Karimi-Azaria, et al. 2011). Through risk management, the project team will reduce the consequences of the negative events and attain project progression predictions; a development team must identify and evaluate all risks and related causes and effects towards determining risk magnitude (Xia, Zou, et al., 2018).

Construction risks are usually shared between the Contractor and the client (Touran, 2003). The probability and impacts' percentages are usually determined for risk estimations, and these calculations establish the contingency allocations of a project. Risk management adds value to the project through analysing all risk consequences; risk management necessitates the creation of a team to implement organisational decisions and good practices in an impartial manner (Benta, et al. 2011). Project related risk(s) should be calculated before considering contingency allocation. Risk registers assess potential risks and effects; teams determine the cost of the contingency allocation to cover the cost of risk(s), through project risk management; proper contingency allocation helps minimise the overrun cost and total risk allowances through the project (Humphreys 2009). Contingency amounts should be calculated and included in the project total budget during the planning and designing stage (Touran, 2003).

Ad-hoc contingency amounts are commonly applied in industry; expert opinions or statistical methods are used to evaluate the actual contingency amount (Touran, 2003). Anecdotally, time poor companies simply allow 5 to 10 percent of the contract sum predetermined as contingency in projects towards managing the uncertainty; this method eases implementing a fixed contingency percentage. This allocation fits smaller projects, however, does not consider significant risk events, scope-creep, nor tech. changes (Scott 2004).

2 LITERATURE REVIEW

All construction projects are risky, and they must be carefully managed to complete the project successfully. Risk is an uncertain outcome of an event that negatively impacts the project deliverables. Through risk management, the project team will reduce the consequences of the negative events and increase the project's positive outcomes. Therefore, the project team must evaluate all risks related to causes and effects and determine how small or large the risk is (Xia et al., 2018). Risk management reduces the negative outcomes and is ideally shared. Several risk management techniques are used in construction industry such as risk transfer, risk mitigation, risk avoidance and risk retention (Shahid, et al. 2015). Project success often depends on the amount of contingency allocation during the planning process, as this will mitigate the cost overrun of the project. Risk management plans will not be successful without project contingency; methods employed to estimate and manage contingency vary (Salah, 2012).

Contingency calculations are categorising within three main approaches: the Deterministic approach, in which the project manager allocates a contingency amount from experience without further cost breakdown; the Probabilistic approach which develops contingency based on historical data and functional requirements; and thirdly, Modern theory methods to accurately calculate the allowance with the assistance of statistical and mathematical tools (Rana 2016).

In short, the project related risk should be calculated before considering contingency allocation. A risk register notes potential risks, including their effects, such that a project team will determine the cost of the contingency allocation to cover the cost of risks through project risk management.

3 METHODOLOGY

This research study analyses contingency calculations methods, then formulates an explicit contingency model multiplier to control cost overrun. A hybrid qualitative, case-study research approach, notes:

- Construction industry expert opinion from six Western Australian participants informed an exploration of contingency determination, in line with a Creswell (2023) lived-experience, qualitative approach.
- Contingency modelling sought comprehension of circumstances that impact contingency estimation.
- Case study analyses applied hypothetical modeling in real-world situations towards confirmation or otherwise of a contingency model multiplier as advantageous and suitable for construction projects.
- Market circumstance factors governing frameworks were noted.
- Real projects' consequences' evaluation sought inconsistencies in any hypothetical predictions.
- Data validation cross-checked replies with relevant follow-up questioning, such that a new unique recommendations' contingency estimation flowchart was developed.

4 RESULTS

Interviewees were selected based on lived-experience - all having more than ten years in construction estimating. During face-to-face interviews predefined questions, related to theoretical contingency estimation techniques, sought participant reflections, summarised very briefly as follows:

The first method, a deterministic method, is a simple calculation method and percentage of the contingency amount determined with the help of the historical data and expert's input; participants agreed that when risk factors are high, it is recommended to use hybrid approaches to derive accurate values. The second method - probabilistic methods - are used to analyse the potential uncertainties and its effects to determine the contingency amount. Participants suggested that this method is mostly needed for complex projects. The third method - the modern mathematical method – attained consensus that this permits various risk scenarios under different project conditions, in which teams determine contingency depending on project duration and risk events. Overarching reflections found that three participants mentioned probabilistic as a best method for complex projects, with three participants stating that a deterministic with probabilistic approach will enhance the accuracy of contingency amount calculations.

There are several risk factors determining contingency amounts that should be allocated to a project to minimise cost-overrun. Experts in this study determined contingency allocation is based on such risk factors. Three participants stated the procurement stage and the design stage, as best suited to determine risk, with three participants suggesting the design stage alone as most apt; thus, the consensus here finds the design phase as best placed to determine the contingency amount; indeed all agreeing that the project contingency team needs to analyse updates and evaluate the actual risk data, and then clearly communicate with clients to emphasise evolving difficulties to be faced, to re-examine initial Vs actual difficulties to best complete the project. All note that more care is needed for complex and large-scale projects; all six participants find that a contingency buffer is required for uncertainties' management to minimise the cost overrun.

In conclusion briefly, it is found here that smaller scale projects may use past similar project details, and then adjust for new requirements; however, larger sale complex projects should be set different levels of contingency amounts to cover cost from design phase through to the completion phase.

5 DISCUSSSION

More care is needed for complex and large-scale projects due to the uncertainties, namely: multiple teams; multiple inter-related tasks; coordination issues related to labour and potential material variances; procurement issues; technical and scope complexities; environmental factors, and political motivation. All six Western Australian experts recruited and questioned here, mention that a high contingency buffer is required for uncertainties' management to minimise cost overrun.

This qualitative study aligns with literature; questions derived (and posed to participants of this study) from a literature review of somewhat historical approaches to contingency estimation, find that factors deemed appropriate then, remain contemporary now. Participants agreed with Bello and Odusami (2008), that the size and complexity of a project is the most important factor to consider for contingency allocation; Participants here agreed with Andi (2004) and Byrne (1999) that construction type, size, and the difference between the client's representatives' bid amount and lowest selected bid amount influence cost overrun. Interviewees here were in agreement with Baccarini (1996) that complexity is principally a differentiation of the number of varied elements of tasks, specialists, components, and that the interdependence or connectivity and degree of (high) interrelatedness between such elements, may be termed as a 'complex' project. Participants here find that contingency estimation is to be considered in terms of a project's related factors and agree with Jimoh and Adama (2014) that the contingency allocation is a major determinant of a project's on-budget success and, echo Jubilee (2015) that it must be adequately allocated.

Given the above reflections the model developed here for this work, shown below in figure-1, is applied to a large complex project (*detailed below in section 6.2.4.1, method-3's $75,000*) to facilitate this contingency model's multiplier, towards (re)testing by (further) localised case-study to (re)validate this calculation model. Figure-1 shows this work's developed, recommended flowchart decision-making tool.

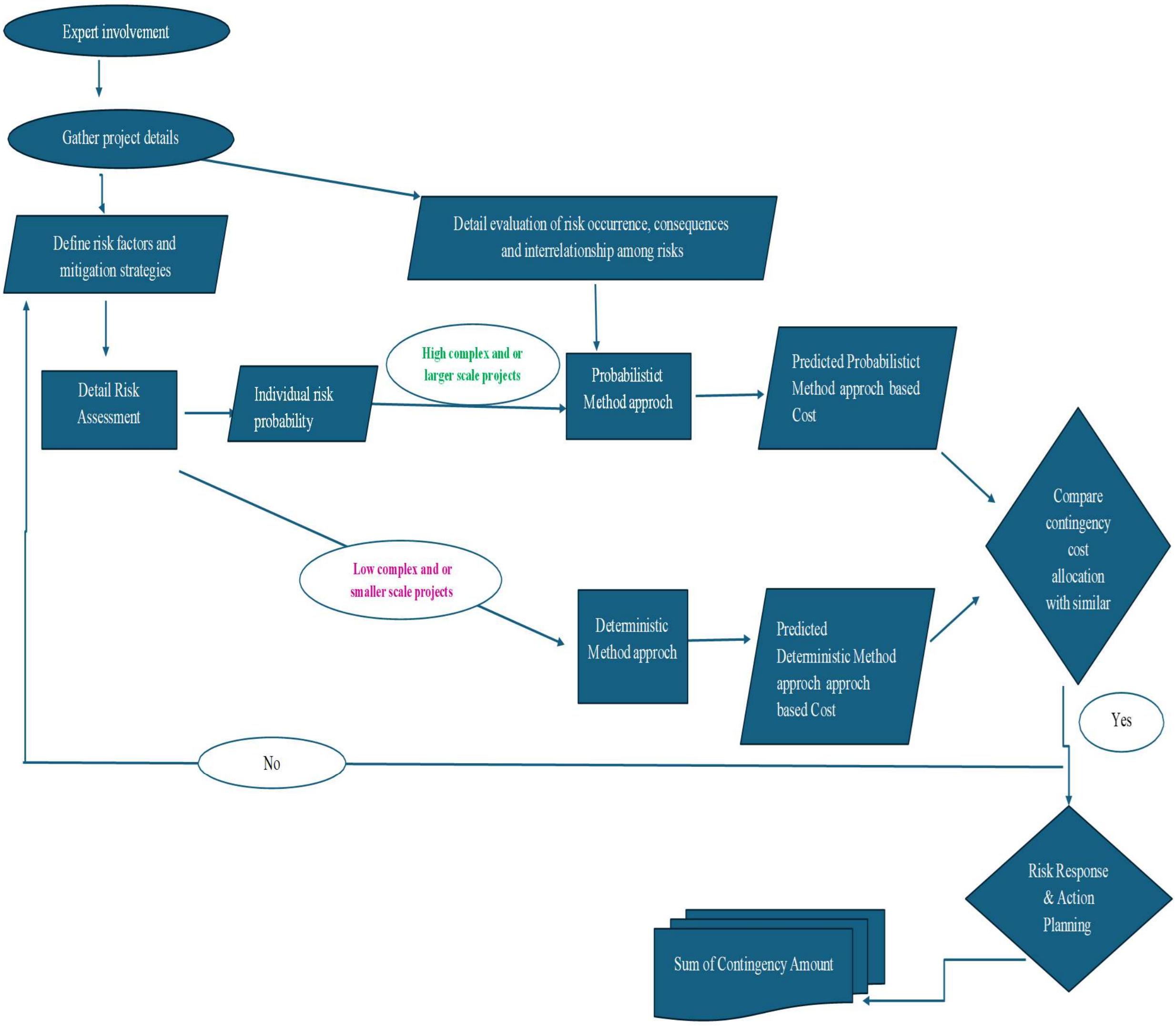

Figure-1: Flowchart towards (deterministic et al) estimation selection

6 CONCLUSIONS AND RECOMMEDNATIONS

6.1 Conclusion

Contingency calculation is categorised into 3 major approaches. One method is a Deterministic approach where a project manager allocates contingency amounts with experience without further cost breakdown. The second method is a Probabilistic approach which develops contingency based on the historical data and functional requirements. The third is a Modern Theory approach where several mathematical/ statistical methods accurately calculate an allowance. Effective risk management is a component of project management to successfully deliver the project in terms of time, cost and quality; it facilitates the creation of a team to implement organisational decisions and good practices in an impartial manner. Project related risks should be calculated before considering contingency allocation, within a risk register with potential risks, including effects, determining a contingency allocation cost. Overall, deterministic methods are used for simple, repetitive and low complex projects. Suitable contingency percentage are applied with the assistance of the past similar project risk factors and complexities, towards a simple and quick decision-making tool to determine contingency. On the other hand, complex and large-scale projects always have several uncertainties and risks which incur additional costs and delay projects, with teams needing to clearly identify individual risk events, calculate the consequences in terms of cost and time and finally define risk mitigation strategies. With the help of experts, past experience, site conditions, internal and external factors, and all risk events may be identified. Probability methods help analyse the consequence and likelihood of each risk events and determine the cost for each; subsequently, experts compare risk factors and allocations with past similar project details to confirm the cost allowances and assess missing details. Contingency values are selected depending on calculated contingency P values & organisational policies.

6.2 Recommendation

The recommendations to be implemented from this research study are based on the following steps, and the flowchart shown above in Figure-1.

6.2.1 Step 1: Gather project details

Project teams should collect project details including project type, duration, size, scope of works, site conditions, stakeholders' analysis, project constrains and other external factors. The comprehensive project information helps determine how to predict the uncertainties and the consequences within the project.

6.2.2 Step 2: Define risk factors and risk assessment

Project related risks such as environmental, regulatory factors, and internal, external, technical, and financial factors should be clearly understood by project teams by brainstorming historical data and site conditions, towards an understanding of risk factors to define accurate contingency assessment allocation.

6.2.3 Step 3: Option 1- Low complex, small scale and repetitive projects

Experts suggest deterministic methods where project size is small, with low complexity based on low task inter-relatedness. Deterministic methods are a simple time-conscious method. Similar past project contingency allocation including risk factors for location, guide new project contingency amounts; project teams may allocate contingency amounts as percentages based on similar past project historical data. Low complex, small scale and repetitive projects utilise deterministic estimate contingency allocation.

The model developed here, displayed above in Figure-1, has been applied to a smaller scale, low complex project; 15% applied as a contingency model multiplier may be further validated and tested via a future localised case-study to validate the calculation model.

6.2.4 Step 3: Option 2- High complex and large scale projects

6.2.4.1 Individual risk probability and impact matrix

Experts examine individual project related risks under major categories at the specific stages of procurement, &/or the design stage. All identified risks are prioritized by probability and impact distribution. Experts identify mitigation strategies to mitigate the risks. Three probability methods are suggested by the respondents of this study to determine the contingency amount.

Method 1: Expected Monetary Value method to calculate risk. EMV = Risk event probability × Impact (recommended by 1 of the six expert respondents of this work)

Method 2: Montecarlo Simulation estimates each risk event likelihood, consequence, and mitigation strategy. Team experts rank each risk event based on high to low-risk consequences and assess an appropriate amount, including its mitigation activities. Contingency values are selecting depending on the calculated contingency P value and organisational policies. (two experts recommend this approach)

Method 3: Probability-Impact Matrix used to estimate specific risk events' impacts, to provide a clear explanation for the cost with a visual representation of the allocated contingency amount.

One expert recommends this use such that:

Risk = Likelihood x Impact

A much-simplified numerical illustration of Method 3 might be represented as:

Each risk event 1 = 0.7 x $50,000 = $35,000

Each risk event 2 = 0.3 x $35,000= $10,500

Each risk event 3 = 0.4 x $10,000 = $10,000

Each risk event 4 = 0.5 x $15,000 = $7,500

Each risk event 5 = 0.6 x $20,000 = $12,000

Total Contingency = $75,000.00

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