

Risk Identification and Quantification of Contingency Reserve Allocation

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ABSTRACT

Infrastructure developments in emerging nations heavily rely on construction projects. It has been noted that most infrastructure projects fall short of their budget and timeline targets, resulting in a low return rate on investment. The amount and significance of each risk may vary depending on the project's nature, scale, and complexity. Many projects fail to accomplish their objectives because they are exposed to several hazards. Most projects compute the contingency reserve using the conventional percentages specified in standards, typically 5–10%. A probabilistic model, in which risks are described as probability distribution functions (PDFs) rather than as static values, is now the preferred method for determining contingency reserves for large projects. This shift has occurred over the past 20 years with the development of desktop computing power. This strategy aims to understand project uncertainty better so that risk management strategies can be created on that foundation.

In order to create a "right-sized" contingency model that integrates an explicit understanding of the risks facing a project with the size of the contingency reserve, this research investigates how probabilistic methodologies might be applied.

Keywords: *Cost Contingency, Known Uncertainties, Project Risk factors, Methods to Estimate Cost Contingency.*

INTRODUCTION

The construction project performance is generally expressed in terms of time and cost variance against its baseline. Out of the four fundamental constraints, namely scope, cost, time and quality, cost performance is the most essential and common issue in the global construction industry (A. Cindrela Devi, 2017). The progress of construction projects is directly linked with the cash flow, and hence any unlikely performance will directly hit the financial commitments. Cost overruns in construction projects around the world are very common. It represents the project's

performance and indicates the project's economic losses. Over the past 70 years, project cost overruns have not been systematically improved. There is no established pattern for the occurrence of cost overruns. Cost overruns have the same magnitude as 30 years before; no improvements exist (A. Cindrela Devi, 2017).

The definition of a project says that every construction project is unique. The uniqueness is also an uncertainty in construction (Luke Judson, 2019). Uncertainty, introduced by different

factors, can jeopardize the objectives of projects. As a result, Projects often employ a contingency to accommodate unforeseen circumstances to deal with uncertainties. This way, the projects have more confidence to finish within the budget or schedule.

PMBOK defines a contingency as "An event or occurrence that could affect the execution of the project, which may be accounted for with a reserve." A contingency Reserve is a time or money allocated in the schedule or cost baseline for known risks with active response strategies. Risk can be defined as "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives" (PMBOK Guide (7th Edition), 2021). The goals of contingency allocation are to ensure that the budget allotted for project execution is adequate and realistic to reduce the risk of unanticipated cost increases. A realistic estimate is crucial for two reasons: first, it provides a basis for determining whether a project proposal is commercially viable, and second, it acts as a benchmark for project management. However, Contingency, as determined via risk analysis, is not a measure of estimate accuracy. Instead, it reflects risk at any specified or desired probability of not completing the project within the estimate (41R-08, 2008).

Since stakeholders must invest a significant amount of time and money, failure to correctly identify and allocate Uncertainties (or risks) in projects can have catastrophic consequences for the parties involved. The project and organization managers must access crucial financial and legal agreements to allocate resources and reduce operational uncertainty. The uncertainty factor ultimately causes a risk to appear in a project; thus, the estimators assign

contingency costs to prevent losses (Hoseini, Bosch-Rekveltdt, & Hertogh, 2020). Each party to a contract will view risks differently depending on their particular circumstances. These hypothetical situations are only offered to highlight a few significant connections, but they do not address all risks.

Owners, the contract's primary beneficiaries, might only consider the project regarding market share or production needs. Owners typically use traditional design services agreements or contracts to obtain the design services necessary to construct their facilities. In some instances, a knowledgeable owner may have a specialised project management team to carry out many duties required to design and build facilities. Many people hire outside consultants to handle project design. As a result, the consultant assumes the design risk while the owner bears the overall project risk. In contrast, a contractor's estimated value of the extraordinary risks they will face on a project can be considered contractor contingency.

The project budget includes contingency reserve funds to allow for uncertainty. Contingency reserves are set aside to implement a risk response or to respond to risk events should they occur (PMBOK Guide (7th Edition), 2021). The contingency's goal is to ensure the project's budget is reasonable and ample to cover all unforeseen cost increases. A project's cost contingency caters to "known unknowns" and "unknown unknowns" events. "Unknown unknowns," in the context of projects, are unforeseeable situations within the project's scope. "Known unknowns," or risks, are the events that can be identified and may or may not occur in a project. Many construction projects fail to adequately recognize that any cost estimate (or schedule) involves

uncertainty and that this uncertainty should be incorporated into an estimate. The result of a cost estimate is comprised of two components:

- the base cost (BC) (also recognized as "known knowns") and

- the cost contingency.

The BC is the likely risk-free cost of the project developed using historical data and cost-estimating techniques. Cost contingency is a provision to mitigate cost risk (Hoseini, Bosch-Rekvelde, & Hertogh, 2020).

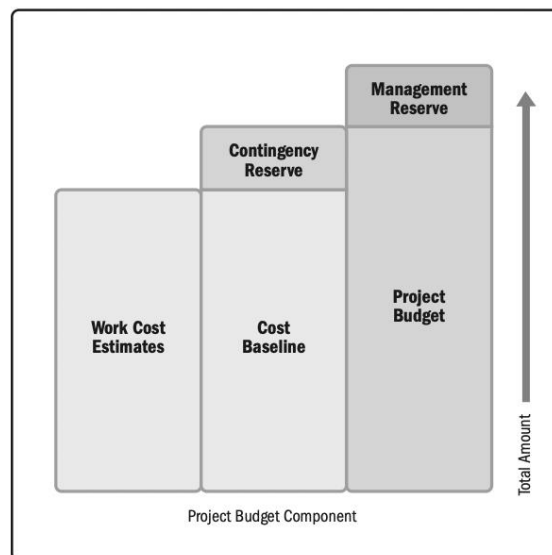


Fig.1:-Budget Build-Up (Source: PMBOK Guide 7th Edition)

RESEARCH DESIGN

The methodology used in this research is based on combining Monte Carlo Simulation with Double Triangular Distribution. One of its main objectives is exploring the possibilities of a statistical method for risk categorization and using probability concepts for risk quantification and interpretation. According to the most optimistic and pessimistic scenarios, the estimator must assign a lower and upper limit to a most probable base estimate for each estimating-cost item using this approach.

(41R-08, 2008) Recommends using Monte Carlo software for risk analysis. For this methodology, it is necessary to identify a probability density function (PDF) for each important factor. An adequate PDF reflects that not all values in a range are likely to have an equal likelihood of happening. Rarely a key item's behaviour

is known to follow a particular sort of PDF, such as a lognormal or beta distribution, which captures things that may strongly skew one side of a distribution. That PDF should represent the item if a distribution like this is acceptable. However, it is uncommon for the right PDF to accurately portray the known object. Consequently, a fair estimation is to use one of two distributions:

- the triangular distribution
- the double triangular distribution

The double triangular distribution may be adjusted to conform to the implicit skew of the project team's probability estimate, making it a better approximation in most circumstances. Instead of having the triangular distribution prescribe an almost always incorrect probability, the double triangle enables the risk analyst to utilise

the probabilities that the project team feels appropriate (41R-08, 2008). Therefore, A double trigen distribution is used to

quantify the effect of each unique risk probabilistically. A triangular distribution looks like this:

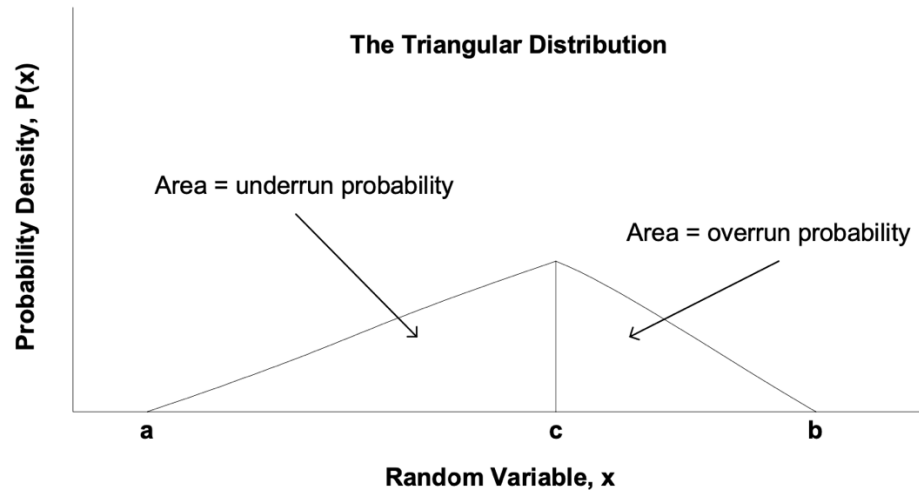


Fig.2:-Triangular Distribution (Source: (41R-08, 2008))

Assigning the triangular distribution without first making sure it truly applies is a typical mistake. The range denotes a probability in a triangle distribution, as with any PDF. The likelihood that a value will be larger than or less than the estimate is proportional to the areas of the triangle's two sides on the left and right of the estimated value. The likelihood of being under the estimate is $(4000-2000)/(5000-$

2000) or 66.7%, for instance, if the range is 2000 (a) to 5000 (b) with an estimate of 4000 (c). The triangular distribution won't suffice if the project team thinks this inferred probability is unreasonable (which it is, more often than not). The double triangular is far more often used. The double triangular distribution looks like this:

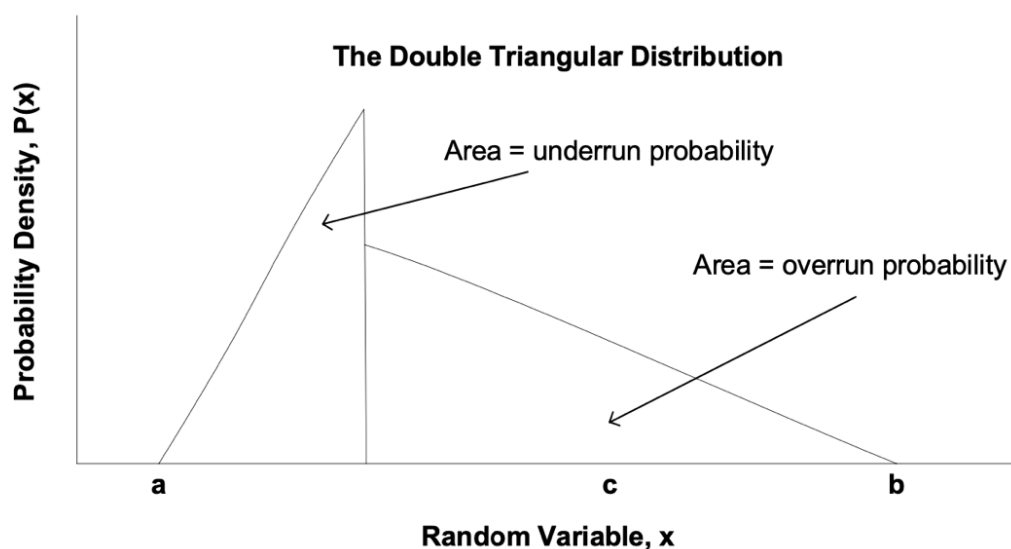


Fig.3:-Double Triangular Distribution (Source: (41R-08, 2008))

The nomenclature for the distributions above is:

a = the minimum value of the range for the item in question

b = the maximum value of the range for the item in question

c = the estimated value of the item in question, i.e. what is believed to be the most likely (the mode)

x = a randomly selected value for the item in question

P(x) = the probability associated with the random value of x

It must be noted that the double triangle is two triangular distributions, one representing values that underrun the estimate and the other values that overrun the estimate. The term "impact" of risk will refer to the potential influence the risk may have on the base or point cost estimate for a specific line item. If the point estimate for site work is \$1M, for instance, then a particular risk (such as unforeseen geologic conditions) may have an impact on that amount by actually decreasing the cost (low), increasing the cost (high), or both. The project team may feel that the most likely scenario is even slightly different than the point estimate. These parameters are expressed as percentages. To put it another way, the project team may determine that the best-case scenario is that the danger of unknown geological circumstances may lower the cost by 5%, in which case they would input -5.0% or -0.05 for the low estimate. Similar entries are created for the high case and the most likely scenario for each risk.

Once the parameters for each risk effect have been calculated, a trigen probability distribution, available in @Risk 8 (Palisade) as an Excel function, may be used to characterise the risk impact in a different column. The double trigen distribution was chosen because of its simplicity and partially offsets the tendency of even the most knowledgeable technical specialists to underestimate the extremes of a risk impact. The probability of risks in this methodology will be considered as an "even chance", i.e. 50%.

Once both the impact and probability of individual risk are quantified, the "overall risk" can be computed as follow:

Overall Risk = Probability (Risk Discrete) x Impact (Risk Trigen)

The risk identification table will summarise risk, probability, impact, and overall risk. The methodology for the cost risk calculations is as follows:

- I. For each cost line, the spreadsheet determines by formula if each risk applies to that line item.
- II. If the risk applies, the expected value of the risk is calculated by multiplying the point estimate for that line item by the proportion of the line item impacted by the risk) and then finally, by multiplying that result by the overall risk probability distribution function established.
- III. For each cost line item, the expected values of the applicable risks are summed and treated as an output, summarizing the total risk profile for that line item. Similarly, for each risk, the expected risk value as it applies to each cost line item is summed, providing an impact profile for that risk across the entire project.
- IV. The expected values of all individual risks are summed and added to the project point estimate, thus creating a probability distribution function that provides a risk-informed view of the total project cost.
- V. With all formulas and probability distribution functions identified, the

Monte Carlo simulation runs up to 10,000 iterations. In each iteration, any cell defined by a PDF has a value randomly chosen based on the applicable PDF. The cost risk formulas are then calculated using the randomly chosen value for each iteration.

IDENTIFIED PROJECT RISK FACTORS

The uncertainty factors that repeatedly appeared in the literature are shown in Table 4, which lead to cost overruns in construction projects. Based on the frequency of repetition, 18 risk factors are considered. The following uncertainty factors are - Frequent Design Change, Additional Work beyond the margin stated in the contract, Slow Decision Making from the owner, Fluctuation of Materials Prices, Shortages of labour or skilled professionals,

Adverse Weather Conditions, Wrong method of estimation or Poor preliminary estimates and understanding, Contractors Poor Site Management and Supervision, Unrealistic schedule or project duration, Rework due to error in execution, Poor labour productivity, Project complexity (method, specialized & technical),

Use of improper construction methods, Inadequate experience of contractor or PM, Delay in obtaining permission from authorities, Incomplete Specifications, Force majeure, Damage or Other Loss – General and Cost of land. These uncertainty factors pertain to various stakeholders, resources, and processes during the project life cycle stages.

Table 1: Uncertainty Factors leading to Project cost overrun. (Source: Author)

SN	UNCERTAINTY FACTORS LEADING TO PROJECT COST OVERRUN.	(Luke Judson, 2022)	(Sharma & Gupta, 2020)	(Rauzana, 2018)	(Maniar, 2019)	(A. Cindrela Devi, 2017)	(Befrin & Bingol, 2016)	(Enshassi & Ayyash, 2014)	(Baccarini, 2004)	(Shete & Kothawade, 2016)	(Vaibhav Y Katre, 2016)	(Abdel-Monem & El-Dash, 2022)	(Bohn G. R., 1999)	(Yeo K. T., 1990)	(Nawar, 2017)	FREQUENCY
1	Frequent Design Changes.	X	X	X	X	X	X	X	X	X		X	X	X	X	13
2	Slow Decision Making from the owner.	X	X	X			X		X	X	X	X			X	9
3	Fluctuation of Materials Prices.	X			X	X	X		X	X	X	X	X	X	X	11
4	Shortages of skilled labour/professional.	X	X		X		X			X		X	X	X	X	9
5	Cash flow problems of Owner.	X		X	X	X	X		X							6

6	Delay in approvals (Design Related).	X	X			X	X		X	X	X	X				8
7	Improper Management (Poor leadership and management qualities) by Project Management Team.	X	X			X			X	X	X		X		X	8
8	Ambiguity in Contract Conditions.	X				X	X		X			X			X	6
9	Adverse Weather Conditions.	X	X	X			X		X	X					X	7
10	Wrong method of estimation/ Poor preliminary estimates.	X	X		X		X			X	X	X	X	X	X	10
11	Contractor's Poor Site Management and Supervision.	X	X		X	X			X	X		X				7
12	Delayed Payment to the contractor.	X		X	X	X	X		X			X			X	8
13	Unrealistic schedule.		X	X		X					X	X		X		6
14	Rework due to an error in the execution.		X	X	X		X	X		X	X	X	X			9
15	Poor labour productivity.		X			X	X					X	X	X	X	7
16	Improper planning during the bidding stage.		X	X		X	X		X	X	X	X			X	9
17	Project complexity (method, technological & technical)/ Use of improper construction methods.		X			X	X					X	X	X		6
18	Inadequate experience of contractor/PM.		X		X	X	X		X						X	6
19	Delay in obtaining permission from authorities and work started without approvals.		X	X		X	X		X			X	X		X	8
20	Project Location.			X		X	X	X	X			X			X	7

RISK ASSESSMENT

The identified risk from the literature was revised to accommodate a few additional risk factors previously not identified from the literature but were materialised in the

actual project. A few risk factors were subsequently removed as well. Table 6 shows the risk factors considered for the analysis with their respective description as follows:

Table 2: Risk Characterisation and Classification (Source: Author)

RISK	DESCRIPTION
Frequent Design Change	Changes in cost (including deletion) arise from discretionary, owner-driven changes to design.
Fluctuation of Materials Prices	Changes in cost due to Economic conditions such as escalation or de-escalation of the currency (due to any global activity).
Shortages of labour/ skilled professional	Changes in cost due to worker absenteeism or lack of skilled professionals required for a specialised job.
Adverse Weather Conditions	Uncertainty in cost due to additional costs related to accommodating unanticipated weather conditions.
Wrong method of estimation/ Poor preliminary estimates and understanding	Uncertainty is introduced in cost estimates because the estimator has limited knowledge or familiarity with the proposed design. The cost estimate contains errors or omissions that would change the estimate.
Contractor's Poor Site Management and Supervision	Uncertainty in overall cost may arise due to the complexity of controlling site activities, safety and security.
Unrealistic schedule	Cost implication due to delays in the project.
Rework due to an error in the execution	The client must bear the cost implication of architect or contractor errors and omissions.
Poor labour productivity	Uncertainty in overall cost may arise due to lacking critical skills needed.
Project complexity (method, technological & technical)	Additional cost uncertainty arises in the project due to new technology or improper construction methods. The uncertainty associated with project location and subsurface condition.
Inadequate experience of contractor/ PM	Uncertainty is introduced because the contractor/PM lacks the critical skills to understand the proposed project, key components or general cost drivers, such as the local market.
Additional Work beyond the margin stated in the contract	Uncertainty in cost due to additional cost incurred related to accommodate additional work.

Incomplete Specification	Uncertainty arises in the cost estimate because the project is poorly or partially specified.
Force Majeure	The cost implication of damages to the building due to an Act of God.
Damages or other Loss - General	The cost implication of all other damages or losses.
Cost of Land	Uncertainty about the land cost may need to be acquired through purchase, trade or expropriation.

RISK IMPACT RANGE FROM ANALYSIS.

Data collected from the case study is analysed to quantify the risk, which is represented as follows:

Table 3: Risk Impact Range on Cost (Source: Author)

RISK DESCRIPTION	MIN	MOST LIKELY	MAX
Frequent Design Change	10.12%	18.90%	100.00%
Fluctuation of Materials Prices	9.71%	11.73%	13.76%
Shortages of labour/ skilled professional	7.00%	8.50%	17.00%
Adverse Weather Conditions	15.76%	38.59%	100.00%
Damages or other Loss - General	-4.00%	4.83%	23.34%
Contractor's Poor Site Management and Supervision	4.37%	12.43%	24.89%
Unrealistic schedule	21.20%	26.82%	100.00%
Rework due to an error in the execution	18.28%	30.20%	38.20%
Poor labour productivity	8.60%	11.06%	13.53%
Project complexity (method, technological & technical)/ Use of improper construction methods	17.00%	34.55%	100.00%
Inadequate experience of contractor/ PM	6.97%	12.02%	16.31%
Additional Work beyond the margin stated in the contract	6.12%	6.32%	6.53%

Incomplete Specification	4.83%	42.01%	100.00%
Force Majeure	43.07%	71.54%	100.00%
Wrong method of estimation/ Poor preliminary estimates and understanding	9.53%	34.26%	100.00%
Cost of Land	13.00%	21.17%	29.34%

QUANTIFICATION OF THE OVERALL RISK

Table 8 below demonstrates the critical data captured in the risk assessment process and how it would be represented in Excel.

Table 4: Overall Risk Impact Matrix (Source: Author)

RISK DESCRIPTION	PROBABILITY	RISK IMPACT			RISK-ADJUSTED IMPACT	OVERALL RISK
		MIN	MOST LIKELY	MAX		
Frequent Design Change	50%	10.12 %	18.90%	100.00 %	0.1897%	0.0948%
Fluctuation of Materials Prices	50%	9.71%	11.73%	13.76%	0.1119%	0.0560%
Shortages of labour/ skilled professional	50%	7.00%	8.50%	17.00%	0.0833%	0.0417%
Adverse Weather Conditions	50%	15.76 %	38.59%	100.00 %	0.3379%	0.1689%
Damages or other Loss - General	50%	- 4.00%	4.83%	23.34%	0.0280%	0.0140%
Contractor's Poor Site Management and Supervision	50%	4.37%	12.43%	24.89%	0.1043%	0.0521%
Unrealistic schedule	50%	21.20 %	26.82%	100.00 %	0.2757%	0.1379%
Rework due to an error in the execution	50%	18.28 %	30.20%	38.20%	0.2689%	0.1344%
Poor labour productivity	50%	8.60%	11.06%	13.53%	0.1041%	0.0520%
Project complexity (method,	50%	17.00 %	34.55%	100.00 %	0.3147%	0.1573%

technological & technical)/ Use of improper construction methods						
Inadequate experience of contractor/ PM	50%	6.97%	12.02%	16.31%	0.1065%	0.0532%
Additional Work beyond the margin stated in the contract	50%	6.12%	6.32%	6.53%	0.0627%	0.0314%
Incomplete Specification	50%	4.83%	42.01%	100.00 %	0.3279%	0.1639%
Force Majeure	50%	43.07 %	71.54%	100.00 %	0.6394%	0.3197%
Wrong method of estimation/ Poor preliminary estimates and understanding	50%	9.53%	34.26%	100.00 %	0.2903%	0.1452%
Cost of Land	50%	13.00 %	21.17%	29.34%	0.1899%	0.0950%

INFERENCES

From the analysis, it is found that based on the overall risk computed – Force Majeure is ranked first for the overall risk it

possesses, meaning that it would require more significant consideration while planning for the allocation of contingency reserve.

RANK	RISK FACTOR	OVERALL RISK (%)
1	Force Majeure	0.6394
2	Adverse Weather Conditions	0.3379
3	Incomplete Specification	0.3279
4	Project complexity (method, technological & technical)/ Use of improper construction methods	0.3147
5	Wrong method of estimation/ Poor preliminary estimates and understanding	0.2903
6	Unrealistic schedule	0.2757
7	Rework due to an error in the execution	0.2689
8	Cost of Land	0.1899

9	Frequent Design Change	0.1897
10	Fluctuation of Materials Prices	0.1119
11	Inadequate experience of contractor/ PM	0.1065
12	Contractor's Poor Site Management and Supervision	0.1043
13	Poor labour productivity	0.1041
14	Shortages of labour/ skilled professional	0.0833
15	Additional Work beyond the margin stated in the contract	0.0627
16	Damages or other Loss - General	0.0280

CONCLUSION

The subjective test of the methodology described in this paper is simply insufficient to conclude the accuracy or effectiveness of the approach. However, the test was sufficient to demonstrate that linking risk analysis to individual cost line items and using that data to generate risk-based contingency reserves is feasible.

At the highest level, the principal recommendation arising from this paper is to rank the risk factors in the proposed contingency allocation methodology for projects. While a more informed approach to setting contingency reserves is a worthwhile goal, contingency reserves are but one of a repertoire of risk management tactics that should be employed, particularly for large-scale projects.

It is evident, however, from even the small-scale subjective test of the methodology undertaken for this paper, that the practice of risk identification and quantification is a competency that demands attention and practice. As a result, the implementation of a standard risk management framework for all projects and the commitment to risk management discipline is an essential prerequisite for anyone.

FUTURE SCOPE OF RESEARCH

According to the analysis of the results produced by the risk-based cost contingency on a case study project, this research shows that applying the risk-based cost contingency estimation method can calculate a more accurate, reasonable contingency. In addition, the proposed methodology is based on data collected from the case studies, and it can also be revised or updated when more information on risks is available. As a result, the proposed risk-based contingency estimation method will be continuously improved.

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