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CONSTRUCTION COST CONTINGENCY PLANNING: AN ART OR A SCIENCE?

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Abstract

Cost contingency is typically defined as an amount added to the base cost estimate to cover uncertainty and risk exposure. Contingency is included in the client's project budget. To decide on the contingency amount, clients refer to experience (recorded in a manner specific to the business entity) and analysis of risk related with a project (initial – based on information available at the moment of defining the budget). The literature argues that progress in data analysis techniques will enhance predictive powers of cost planners. However, the plausibility of predictions depends on the reliability of input, and the accuracy is the effect of a particular project team's ability to react to an individual combination of "problems" encountered in the course of works under constraints of a particular contract. This paper investigates into recent developments in contingency planning focusing on the assumptions behind the tools and methods. On the basis of a sample of recent research papers (2021-2025) the authors conclude there is no paradigm shift in the general approach to risk-aware budgeting of projects. However, the analyses behind this process have a great potential of being integrated and accelerated with machine learning and artificial intelligence.

Keywords: project cost contingency, budget, data reliability.

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1. Introduction

A considerable fraction of the rich body of literature on project risk management is devoted to a practical problem of defining the amount of funds to be set aside to enable the project team to react to uncertain conditions and events capable of affecting the project objectives. This amount is often referred to as cost contingency [1], though the nomenclature is non-uniform and thus confusing [2], [3] (Fig.1).

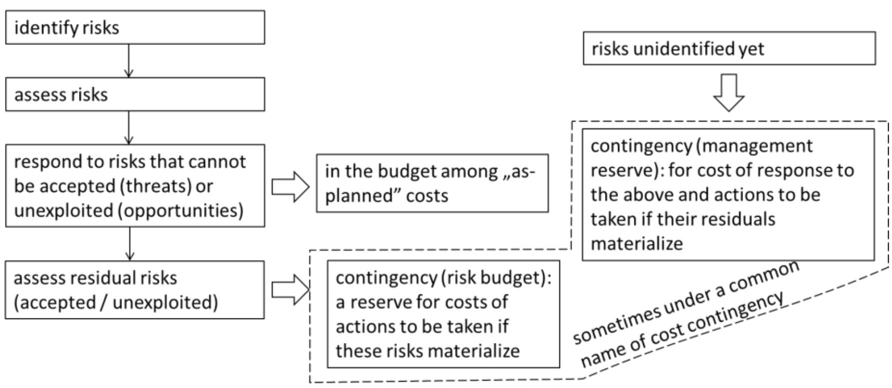

Fig. 1. Meaning of "contingency"

Some use this notion to describe a cost reserve only for identifiable/partly identifiable risks; thus a separate reserve (frequently referred to as management reserve or cost uplift) is advised to be kept outside the project budget to handle emergent risks and/or risks outside the defined scope [4], [5], [6]. In some sources (e.g. [1]) *contingency* stands for a reserve for the unidentified risks only, whereas the residual risks (i.e. identified and accepted after deciding on threat mitigation/ opportunity exploitation

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measures) have their separate risk budget. Nevertheless, the sum of a risk-free cost estimate and reserves/contingencies is considered the amount of money reasonable to be spent on the project – with the acceptably low chance that the actual cost becomes higher. The purpose of contingency is in fact twofold. First, it is to keep the project viable if reality deviates from assumptions. Second, it helps set a realistic target to motivate the project team to actively search for solutions that keep the project on the budgetary track: the contingency is a buffer – a limited buffer – which must be used sparingly (approach adopted, among others, in Prince2: using tolerances rather than contingencies [7]).

From the point of the project owner, it necessary to decide if the project is worth proceeding with. If the contingency proves too low, the feasibility of the project may be compromised half way through implementation. If too large, it keeps the estimate on the safe side, but may lead to rejecting the project as too costly. If the decision to proceed is taken anyway and a too generous contingency amount becomes an element of the authorized budget, the cost/value management discipline may suffer.

Evidence-based methods that give at least some insight into the likelihood that a particular contingency will suffice and/or plausibly justify the scale of contingency are preferred over deterministic one-point estimates provided by expert judgment predefined official rate [8]. The methods, though frequently classified according to mathematical tools they rest upon [9], [10], [11], can be roughly divided into two groups [3], [12], [13]:

- based on observing performance of previously completed projects assuming that the project in question is not coming from a completely different class of ventures, i.e. it is likely to follow patterns observed with previous projects (“outside view”)
- based on the analysis of individual risks related with the project in question (“inside view”), which involves defining these risks and assessing their impact on the project outcomes; these can naturally deal only with identified risks, but inevitably draw from experience with previous projects to list risks, and estimate likelihood and impact.

The purpose of this paper is to browse (and not to systematically review) recent publications on the topic of setting (not managing) the client’s contingency budgets in construction projects. The focus is on Web of Science-listed publications from an arbitrarily selected short period of 2021-2025, in search of fresh assumptions, procedures, tools and methods that help quantify cost uncertainties.

2. Methodology

A quick search in the Web os Science, conducted in April 2025 with the search phrase: TS=("cost contingency" AND “construction"), limited to the papers published between 2021 and 2025, returned 19 publications.

Table 1. Initial sample of papers, WOS, 2021-2025

Source	Type	Topic
[2], [3], [14]	Systematic reviews	Understanding, aspects, and methods of cost contingency planning and management
[15], [16]	Original model (inside view)	Modified Monte Carlo simulation
[8]	Case study (arbitrary uplift)	Official method of estimating contingencies
[17]	Factors related with cost overrun (outside view)	Project features, risks and causes for overrun (survey)
[18]		As above, but document analysis, plus scale of overrun
[19]	Original model (outside view)	CART model
[20]		Statistical regression
[21]		ML model to scale cost contingency (outside view)
[22]		Point estimate based on statistics from other projects and estimated cost escalation of key materials
[23]	Original model (mixed view)	Project complexity measure & risk analysis based on adjustable rules to support experts in generating risk ratings; elicits contingency uplift (%);

Three papers were excluded due to no access to the full text, 2 due to the focus on contingency management and not scaling, and 1 for being a position paper on heuristics using contingency scaling as an example of the class of problems. The composition of this small sample is described in Table 1. Further publications on the topics found interesting were searched within their references and citations.

3. Findings and discussion

3.1. "Outside view"- based methods of contingency scaling: assumptions and input

Instead of relying solely on the analysis of particular risks, whose list is naturally incomplete at the moment of deciding on the scale of contingency in the budget, one can refer to statistical distributions of actual cost deviations observed in a reasonably sized sample of "similar" completed projects. Assuming that a new project belongs to a population of projects represented by this sample, inferences on the probability of its actual cost overrun can be made based on the distribution of such overruns observed in the sample and help scale the sufficient cost reserve. This simple approach, referred to as Reference Class Forecasting (RCF) is argued to eliminate bias and strategic misrepresentation that lead to serious underestimation of cost [2], [3], [14]. The method was intended for big public infrastructure projects to improve the reliability of estimates at early stages of project development [12]. Though the rationale behind RCF has been strongly criticized [24], [25], [26], it has attracted a considerable degree of interest in both research and practitioner communities [27], [28]. It has been included in the official project estimating guidelines by a number of public agencies worldwide (e.g. [29], [30]) as an approach complementary to quantitative risk analysis, and is reported to perform satisfactorily [31], [32].

Regression models (parametric and non-parametric) that relate the scale of cost deviation from the risk-free baseline with project characteristics (especially of quantitative character) are an option to RCF with no need to divide the sample of reference records into small sub-samples. The results of the classic multiple regression [20] would be the easiest to interpret (relative importance of predictors, prediction intervals). More advanced algorithms might offer better fit by capturing complex non-linear relationships among large number of project features and the scale of cost overrun (SVM, regression trees, random forests, ANN, algorithm ensembles [11], [19], [21], [33], [34], [35] and deep learning [36].

Nevertheless, the methods of inferring about the future case on the basis of previous cases' data share certain drawbacks. The first is the problem of input consistency and availability. The understanding of what is included in the baseline estimate (the initial risk-free estimate) is likely to differ case by case (the moment of creating the estimate vs. available input), and the baseline itself may be subject to error [37]. Similarly, the interpretation of the outturn cost is unequivocal, as the moment of its definition, treatment of variations, escalation, values in dispute, or late claims can be differently treated in the cases on which the predictive model has been built. This problem is considered reduced if all cases in the reference class / sample used for building the regression model come from the same organization with clear cost planning and reporting standards (this is the case with public agencies that included these methods into their cost management procedures [29], [30]).

However, the datasets should be not only large enough and consistent, but also recent. As the Fourth Industrial Revolution is making its way into construction, utilization of data changes. Novel (more flexible and collaborative) project procurement methods are developed, and the approach to risk distribution changes, the "similarity" of new projects to these completed in the past is not certain. No paper from the analyzed sample referred directly to this fact.

Second, results will strongly depend on the set of project features used to define the reference class (RCF) or the set of predictors (regression models). Arbitrary selection of a small number of features defining "what is being built", under what contract type etc. may result in poor quality of estimates [38]. The features correlated with the scale of the cost overrun can be found using analytical methods: some rely on classic correlation ([29], [30]). A broad selection of classification and regression algorithms can easily deal with finding relationships between historic data, but the most influential features discovered in the analysis of a particular sample of cases may be a) uncertain at the point of estimating the contingency for a new case, b) less influential with other samples – judging by a surprising variety of predictor sets used in cost prediction models, some of them being root causes of overrun, some risk factors, and some – project features not clearly related with risks [11], [17], [33], [34], [35], [36].

Confidence with results depends on confidence with the input, regardless of the advancement of data processing methods [39].

Third, the contingency uplift to the base estimate defined on the basis of statistical distribution depends on the “risk appetite” of the decision-makers (assumed probability of the project’s cost not exceeding the uplifted estimate) – and the “rules of thumb” of setting them seem to be used most frequently.

3.2. “Inside view”- based methods of contingency scaling: assumptions and input

Quantitative risk analysis (QRA) consists in translating the probability and impact of particular risks on the selected measures of project outcomes. By definition, its methods tackle risks that have been identified at the moment, and they lead to defining the “risk budget” part of the contingency (Fig. 1).

The most prominent representant of methods used in QRA is currently Monte Carlo simulation. Available software using the idea of Monte Carlo simulation helps analyze the combined effects of variability risks (expressed by probability distributions, usually of durations and costs of particular project tasks) and event risks (expressed in terms of probability of occurrence and impact on particular tasks or groups of tasks) modeled as stochastic branches [1]. Variability risks’ distribution types are usually set arbitrarily (triangular, normal, beta, lognormal, …) and their parameters come from expert judgement sometimes supported by evidence from previous projects. As for stochastic risks, their occurrence is typically modeled using Bernoulli distribution. The impact of stochastic risks is set as a fixed value or percentage change of cost/duration, but bespoke models allow to describe it as probability distribution [15].

The simulation model is run multiple times, each time using a different set of inputs generated from the chosen distributions. The results form an experimental distribution of the project outcome (cost), thus the amount corresponding to the cost contingency is the difference between the selected percentile of this distribution and the baseline estimate.

However, sometimes the planners may be incapable of directly expressing risks in terms of probability and impact. This might be the case with epistemic (ambiguity) risks [1]: they can be perceived, but their probability and impact can be assessed only in some verbal scale (as “big” or “small”). Semantic scales are nevertheless possible to be translated into ranges of values (for instance, a “small” probability would be between 0 and 5%), though this is somehow arbitrary. Curto et al. [15], [16] adopted this approach assuming that probability of occurrence and impact of epistemic risks can be represented by uniform distributions and this way included them in their Monte Carlo simulation-based model.

3.3. Mixed models

These models draw from observations from previous projects helping the decision-makers analyze current projects and scale contingencies while drawing, in parallel, cost deviation logic discovered in past cases and analysis of features of the project in question. Where there are no grounds to express them as probabilities (e.g. no statistical data available), fuzzy sets can be used to capture the scale of risks, and causal relationships between the risk factors and the project outcomes replace statistical relationships [23], [40], [41], [42].

An example is an expert system proposed by Dikmen et al. [23] that helps elicit verbal measures of scale of predefined risk types in a particular project. The scale of risk is defined by rules combining presence/partial presence/absence of particular project complexity features and influencing factors. The rules have been elicited from the analysis of a sample of completed projects and expert judgments. The decision-maker then estimates the cost impacts of risks, and the tool calculates cost contingency based on these cost values. This element is not clearly described, but the authors require that users specify the background information when assigning a cost to risk factors, as the cost impact of project risks depends on factors such as assumptions on controllability and contract conditions.

4. Conclusions

The issue of scaling cost reserves is a frequent research topic, and no reality-proof method of dealing with inherent uncertainty has been proposed so far. Nevertheless, all current methods are based on experience gained from previous projects to:

- define what amount of reserve proved sufficient for projects belonging to a particular category of projects (assuming that there should be some patterns between the type of a project and the set of events and conditions likely to have an impact on it, and the ability of project teams to deal with them),
- learn on the selection, likelihood and impact of uncertain events or conditions that affect projects, as well as efficacy of the measures adopted to deal with risks and issues.

The actual cost performance of the project is less a result of a lucky guess of a cost figure at the outset than the effect of the project team's skills and open-mindedness in managing risks (anticipating new threats and opportunities, quickly inventing problem solutions using no more funds the budget can bear). Thus, the way to make projects more predictable may be not in improving prediction methods, but in investing in engineering skills of project participants, improving information flows, and shaping project organizations in a way that, in the face of the unexpected, promotes looking for solutions rather than for someone to blame.

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References

[1] D. Hillson and P. Simon, Practical Project Risk Management, Third Edition : The ATOM Methodology, 3rd ed. [S.l.]: Berrett-Koehler Publishers, 2020.
[2] G. Su and R. Khallaf, "Research on the Influence of Risk on Construction Project Performance: A Systematic Review," Sustain. 2022, Vol. 14, Page 6412, vol. 14, no. 11, p. 6412, May 2022, doi: 10.3390/SU14116412.
[3] L. Zhang, Y. Li, N. Sun, and Y. Ning, "Understanding project cost contingency estimation: a holistic risk perspective," Int. J. Manag. Proj. Bus., vol. 18, no. 1, pp. 139–164, Jan. 2025, doi: 10.1108/IJMPB-07-2024-0162/FULL/PDF.
[4] Project Management Institute, A Guide to the Project management Body of Knowledge (PMBOK® Guide)., 6th ed. Newtown Square, PA: Project Management Institute, 2017.
[5] AACE, "AACE® International Recommended Practice No. 10S-90. Cost Engineering Terminology." Accessed: May 01, 2025. [Online]. Available: https://library.aacei.org/terminology/welcome.shtml#C
[6] G. D. Oberlender, Project Management for Engineering, 2nd ed. New York: McGraw-Hill Higher Education, 2000.
[7] OGC, Managing Successful Projects with PRINCE2, 5th ed. London: Office of Government Commerce, 2009.
[8] N. T. T. Nguyen, M. T. X. Dang, and T. Q. Nguyen, "Cost Contingency Estimation in Public Projects in the Construction Digitalisation Era: A Case of Vietnam," Int. J. Sustain. Constr. Eng. Technol., vol. 12, no. 5 Special Issue, pp. 106–115, 2021, doi: 10.30880/ijscet.2021.12.05.011.
[9] P. Bakhshi and A. Touran, "An overview of budget contingency calculation methods in construction industry," Procedia Eng., vol. 85, pp. 52–60, 2014, doi: 10.1016/j.proeng.2014.10.528.
[10] A. Khodabakhshian, T. Puolitaival, and L. Kestle, "Deterministic and Probabilistic Risk Management Approaches in Construction Projects: A Systematic Literature Review and Comparative Analysis," Buildings, vol. 13, no. 5, 2023, doi: 10.3390/buildings13051312.
[11] M. C. P. Sing, Q. Ma, and Q. Gu, "Improving Cost Contingency Estimation in Infrastructure Projects with Artificial Neural Networks and a Complexity Index," Appl. Sci., vol. 15, no. 7, 2025, doi: 10.3390/app15073519.
[12] B. Flyvbjerg, M. Skamris Holm, and S. Buhl, "Cost Underestimation in Public Works Projects: Error or Lie?," J. Am. Plan. Assoc., vol. 68, no. 3, pp. 279–295, 2002, doi: https://doi.org/10.1080/01944360208976273.
[13] Y. Fu and N. Gil, "Financial Buffers in Megaprojects: A Contingent Model of Joint Value Production and Policy Implications," IEEE Trans. Eng. Manag., vol. 71, pp. 11855–11871, 2024, doi: 10.1109/TEM.2023.3308163.
[14] T. Ammar, M. Abdel-Monem, and K. El-Dash, "Appropriate budget contingency determination for construction projects: State-of-the-art," Alexandria Eng. J., vol. 78, no. June, pp. 88–103, 2023, doi: 10.1016/j.aej.2023.07.035.
[15] D. Curto, F. Acebes, J. M. González-Varona, and D. Poza, "Impact of aleatoric, stochastic and epistemic uncertainties on project cost contingency reserves," Int. J. Prod. Econ., vol. 253, no. February, 2022, doi: 10.1016/j.ijpe.2022.108626.
[16] D. Curto, D. Poza, F. Villafáñez, and F. Acebes, "Cost Contingency Estimation: a New Method for Quantitative Risk Analysis Applied To a Real Construction Project," Dyna, vol. 99, no. 1, pp. 1–11, 2024, doi: 10.6036/10815.
[17] M. Abdel-Monem, K. T. Alshaer, and K. El-Dash, "Assessing Risk Factors Affecting the Accuracy of Conceptual Cost Estimation in the Middle East," Buildings, vol. 12, no. 7, 2022, doi: 10.3390/buildings12070950.
[18] M. Welde and R. E. Dahl, "Cost escalation in road construction contracts," Transp. Res. Rec., vol. 2675, no. 9, pp. 1006–1015, 2021, doi: 10.1177/03611981211005462.
[19] M. Arifuzzaman, U. Gazder, M. S. Islam, and M. Skitmore, "Budget and Cost Contingency Cart Models for Power Plant Projects," J. Civ. Eng. Manag., vol. 28, no. 8, pp. 680–695, 2022, doi: 10.3846/jcem.2022.16944.
[20] T. Ammar, M. Abdel-Monem, and K. El-Dash, "Regression-based model predicting cost contingencies for road network projects," Int. J. Constr. Manag., 2024, doi: 10.1080/15623599.2024.2411082.
[21] J. Bae, "Supervised learning to covering cost risk through post-construction evaluation of transportation projects by project delivery methods," Eng. Constr. Archit. Manag., 2024, doi: 10.1108/ECAM-01-2024-0136.

[22] P. Franklin and G. Berlin, “Early Risk Assessment Based on Partial Information,” Proc. - Annu. Reliab. Maintainab. Symp., pp. 1–3, 2024, doi: 10.1109/RAMS51492.2024.10457701.
[23] I. Dikmen, G. Atasoy, H. Erol, H. D. Kaya, and M. T. Birgonul, “A decision-support tool for risk and complexity assessment and visualization in construction projects,” Comput. Ind., vol. 141, p. 103694, 2022, doi: 10.1016/j.compind.2022.103694.
[24] S.-S. Leu, Y. Liu, and P.-L. Wu, “Project Cost Overrun Risk Prediction Using Hidden Markov Chain Analysis,” Buildings, vol. 13, no. 3, p. 667, 2023, doi: 10.3390/buildings13030667.
[25] P. E. D. Love and D. D. Ahiaga-Dagbui, “Debunking fake news in a post-truth era: The plausible untruths of cost underestimation in transport infrastructure projects,” Transp. Res. Part A Policy Pract., vol. 113, no. May, pp. 357–368, 2018, doi: 10.1016/j.tra.2018.04.019.
[26] L. Ika, J. K. Pinto, P. E. D. Love, and G. Pache, “Bias versus error: why projects fall short,” J. Bus. Strategy, vol. 44, no. 2, pp. 67–75, 2022, doi: 10.1108/JBS-11-2021-0190.
[27] A. I. Amadi, “Towards methodological adventure in cost overrun research: linking process and product,” Int. J. Constr. Manag., vol. 23, no. 3, pp. 528–541, 2023, doi: 10.1080/15623599.2021.1894632.
[28] M. Siemiatycki, “The making and impacts of a classic text in megaproject management: The case of cost overrun research,” Int. J. Proj. Manag., vol. 36, no. 2, pp. 362–371, 2018, doi: 10.1016/j.ijproman.2016.07.003.
[29] TII, “Cost Management Manual.” Accessed: Apr. 02, 2025. [Online]. Available: https://cdn.tii.ie/publications/PE-PMG-02044-01.pdf
[30] Oxford Global Projects, “Updating the evidence behind the optimism bias uplifts for transport appraisals 2020.” Accessed: Apr. 02, 2025. [Online]. Available: https://www.gov.uk/government/publications/tag-updated-evidence-for-optimism-bias-uplifts
[31] J. Batselier and M. Vanhoucke, “Practical Application and Empirical Evaluation of Reference Class Forecasting for Project Management,” Proj. Manag. J., vol. 47, no. 5, pp. 36–51, Oct. 2016, doi: 10.1177/875697281604700504.
[32] J. E. Park, “Curbing cost overruns in infrastructure investment: Has reference class forecasting delivered its promised success?,” Eur. J. Transp. Infrastruct. Res., vol. 21, no. 2, pp. 120–136, 2021, doi: 10.18757/EJTIR.2021.21.2.5504.
[33] P. Karadimos and L. Anthopoulos, “A taxonomy of machine learning techniques for construction cost estimation,” Innov. Infrastruct. Solut., vol. 9, no. 11, Nov. 2024, doi: 10.1007/S41062-024-01705-0.
[34] W. Feng and Y. Zou, “Construction cost prediction based on adaptive boosting and artificial neural networks,” Proc. Inst. Civ. Eng. - Smart Infrastruct. Constr., vol. 178, no. 1, pp. 1–9, Feb. 2025, doi: 10.1680/JSMIC.22.00027.
[35] M. Juszczyk, “The Challenges of Nonparametric Cost Estimation of Construction Works with the use of Artificial Intelligence Tools,” Procedia Eng., vol. 196, no. June, pp. 415–422, 2017, doi: 10.1016/j.proeng.2017.07.218.
[36] H. Liu, M. Li, J. C. P. Cheng, C. J. Anumba, and L. Xia, “Actual construction cost prediction using hypergraph deep learning techniques,” Adv. Eng. Informatics, vol. 65, no. PB, p. 103187, 2025, doi: 10.1016/j.aei.2025.103187.
[37] D. Makovšek, “Systematic construction risk, cost estimation mechanism and unit price movements,” Transp. Policy, vol. 35, pp. 135–145, 2014, doi: 10.1016/j.tranpol.2014.04.012.
[38] T. Servranckx, M. Vanhoucke, and T. Aouam, “Practical application of reference class forecasting for cost and time estimations: Identifying the properties of similarity,” Eur. J. Oper. Res., vol. 295, no. 3, pp. 1161–1179, Dec. 2021, doi: 10.1016/J.EJOR.2021.03.063.
[39] M. Regona, T. Yigitcanlar, B. Xia, and R. Y. M. Li, “Opportunities and Adoption Challenges of AI in the Construction Industry: A PRISMA Review,” J. Open Innov. Technol. Mark. Complex., vol. 8, no. 1, p. 45, 2022, doi: 10.3390/joitmc8010045.
[40] A. Leśniak and F. Janowiec, “Application of the Bayesian Networks in Construction Engineering,” Civ. Environ. Eng. Reports, vol. 30, no. 2, pp. 221–233, 2020, doi: 10.2478/ceer-2020-0028.
[41] M. S. Islam, M. P. Nepal, M. Skitmore, and R. Drogemuller, “Risk induced contingency cost modeling for power plant projects,” Autom. Constr., vol. 123, no. November 2020, p. 103519, 2021, doi: 10.1016/j.autcon.2020.103519.
[42] S. H. Fateminia and A. R. Fayek, “Hybrid fuzzy arithmetic-based model for determining contingency reserve,” Autom. Constr., vol. 151, p. 104858, 2023, doi: 10.1016/j.autcon.2023.104858.