International Journal on Computational Engineering

Journal Homepage www.comien.org/index.php/comien

The Influence of Project Risk on Building Construction Cost Contingency

I Putu Artama Wiguna [a,*], Putri Suci Mawariza [a], Nelda Maelissa [a]

[a] *Department of Civil Engineering, Institut Teknologi Sepuluh Nopember, Sukolilo, Surabaya, Indonesia*
*Corresponding author: *artama.wiguna@gmail.com*

***Abstract*—Contingency costs estimation plays a crucial role in construction project management, as inaccurate allocation of contingency allowance can lead to significant cost overruns. However, in practice, the determination of contingency cost often relies on subjective judgment rather than empirical analysis. This study aims to examine the relationship between project risk and contingency cost using data from six high-rise building projects. The level of risk was evaluated based on the risk events that occurred during the construction phase, while contingency cost data were obtained from the company's operational records. A simple linear regression analysis was employed to quantify the relationship between project risk and contingency cost. The results reveal a positive correlation, indicating that higher risk levels are associated with higher contingency costs. The regression equation, y = -0.692 + 0.092x, suggests that for every one unit increase in risk, the contingency cost increases by 0.092 units. These findings highlight the importance of systematic risk assessment in developing more objective and data-driven contingency cost estimation frameworks. This study used data from one construction company with limited historical records; future research should expand the dataset and timeframe for more accurate results. Comparing risks and contingency costs is essential, given the project's complexity and size. Using methods like PERT, Monte Carlo simulations, parametric modeling, or fuzzy logic for contingency cost calculation is recommended. Technology like project management software and risk simulation tools helps monitor hazards in real time, allowing early detection of issues and faster, more accurate decisions.**

***Keywords*—Building construction; cost contingency; high-rise building; project risk.**

Manuscript received 5 Nov. 2025; revised 9 Jan. 2026; accepted 26 Feb. 2026. Date of publication 31 Mar. 2026.
International Journal on Computational Engineering is licensed under a Creative Commons Attribution-Share Alike 4.0 International License.

I. INTRODUCTION

The construction industry is inherently susceptible to various risks, such as technical issues, financial instability, operational inefficiencies, regulatory changes, and force majeure events. Cost overruns, delays, and overall project inefficiencies may result from these risks if they are not effectively managed. A fundamental financial strategy to alleviate these uncertainties is the allocation of contingency costs [1]. Contingency costs have become an important part of project management in estimating project cost budgets.

Contingency costs are defined as cost reserves or cost estimates to anticipate uncertain conditions allocated to work items based on experience and implementation of previous projects, and are the integrated costs of the estimated project costs [2]. Contingency costs are crucial in building projects because they are financial buffers to manage uncertainties and unexpected events during construction. Contingency expenses are monies set aside as reserves to address the risks and uncertainties related to construction projects. The purpose of allocating contingency costs is to ensure that the project cost budget is estimated to be proportional, realistic, and sufficient to cover costs arising from risks due to uncertainty caused by lack of information and errors in interpreting project information/data [3]. A well-planned contingency reserve ensures that project stakeholders, including contractors and investors, have a financial cushion to handle risks effectively and maintain project feasibility.

Several studies provide results that the range of contingency costs is 5%-25% [4], [5]. In practice, contingency fees generally vary from 3% to 10%, established through a blend of experience and subjective criteria. Estimating contingency costs is a complicated endeavor. Excessively high rates can increase project bids, diminishing contractors' competitiveness in tenders. Conversely, establishing them excessively low may subject the project to financial pressure, compromising profitability and the capacity to manage risks efficiently. Consequently, a precise and objective assessment of contingency costs is crucial for sustaining financial stability and enhancing project results.

Traditionally, contingency expenses are fixed percentages of the overall project expenditure. Although straightforward, these strategies frequently neglect the risks, resulting in excessive or insufficient allocation. The method often used to calculate contingency costs is based on subjective judgment and predetermined percentages. However, these methods cannot systematically measure or present the uncertainty conditions faced during the project. Existing methods are problematic because of their complexity [6]. A more precise, data-driven process is necessary to improve the accuracy of contingency cost estimation.

Numerous studies have been conducted to determine and mitigate contingency costs in construction projects, particularly those involving building construction. Reference [7] utilized artificial neural networks to forecast contingency costs, whereas a study by [8] proposed a methodology using the Theory of Constraints and Multi-Objective Optimization. Regression analysis has been utilized by [9] while a study by [10] formulated a risk-based contingency cost estimation model for EPC projects, demonstrating notable accuracy in relation to real contingency costs. Furthermore, reference [11] employed fuzzy set logic to improve contingency cost forecasts. Although improving contingency cost prediction is the main goal of these studies, the connection between project risks and contingency cost distribution is not explicitly covered. This study aims to address this gap by analyzing the impact of project risks on contingency cost prediction through linear regression analysis. By developing an empirical model, this study enhances risk management and cost estimation practices, ultimately improving the accuracy of contingency cost predictions in construction projects.

A risk is an uncertain event or condition that, if it occurs, could affect at least one project goal [12]. Risk can have multiple causes, and if it occurs, it can have various impacts, including influencing other risks. Risks in building projects are categorized into two types: internal and external risks [11, 13]. External risks come from outside the project, while internal risks come from inside the project. External risks in building projects arise from ecological, legal, political, economic, and social reasons. This includes natural disasters (earthquakes, hurricanes), resource deficiencies, regulatory changes, political instability, economic fluctuations (inflation, financial crises), and social upheaval (wars, riots, and local disputes). Whereas Internal project risks stem from personnel, technology, design, materials, contractual obligations, and safety concerns. This encompasses labor risks associated with technical, managerial, and supervisory teams; construction technology risks, including inappropriate methodologies, safety oversights, inadequate planning, and unprepared infrastructure; and design risks, such as substandard planning, design inaccuracies, and frequent modifications. Risks associated with materials and equipment encompass supply delays, quality concerns, transportation limitations, and equipment malfunctions. Contractual risks arise from misinterpretations, pricing inaccuracies, and violations, whereas safety risks encompass workplace accidents, equipment malfunctions, and fatalities.

The ISO 31000 standard delineates risk management into seven steps [14], [15], which are:

a. The communication and consultation process encompasses the establishment of communication plans among the people responsible for executing the risk management process and the stakeholders involved.
b. Establishing the context includes the firm's articulation of its objectives, the definition of external and internal elements pertinent to risk management, and the establishment of the scope and risk criteria for the subsequent procedure.
c. Risk analysis seeks to elucidate risk to inform judgments regarding optimal strategies and approaches for mitigation. Risk analysis entails examining the origins and factors contributing to risks, their adverse effects, and the likelihood of these effects materializing.
d. Risk evaluation: the objective of risk evaluation is to enhance decision-making support by assessing which hazards require treatment and prioritizing the implementation of that treatment, based on the findings of the risk analysis.
e. Risk treatment involves selecting one or more strategies to alter risks and executing these strategies through a cyclical process that assesses previously applied treatments, residual risk levels, the implementation of new treatments for unacceptable residual risks, and the evaluation of the proposed treatment's effectiveness. The risk mitigation strategies may encompass the following elements: a) taking measures to eliminate the risk by refraining from initiating or ceasing the activity that generates the risk; b) embracing or amplifying the risk to capitalize on a potential opportunity; c) eliminating the source of the risk; d) modifying its likelihood; e) modifying the outcomes; f) distributing the risk among multiple parties (including via contractual agreements or financing); and g) accepting the risk through informed and rational decision-making.
f. Oversight and rigorous evaluation, monitoring and critical review must be integrated into the risk management process to delineate responsibilities among participants, encompassing all facets of the risk management framework, with the objectives of: a) ensuring the effectiveness and efficiency of controls in design and operation; b) acquiring supplementary information to enhance the risk evaluation process; c) scrutinizing events (including "quasi-incidents"), modifications, trends, successes, and failures (and deriving lessons from them); d) identifying shifts in the external and internal context, including changes in risk criteria and the risks themselves, which may necessitate a reassessment of risk treatments and their priorities; and e) recognizing emerging risks.
g. Monitoring and critical review must be integrated into the risk management process to delineate duties among participants, encompassing all facets of the risk management procedure.

Risk management is essential to effective project management, given the increasing complexity of projects and the intensifying competitiveness [16]. Risk management must be conducted proactively and consistently throughout the project life cycle to minimize anticipated risks and mitigate the impact of threats should those risks materialize [17]. A direct correlation exists between successful risk management and project success, as risks are evaluated based on their potential impact on project objectives [18]. Reference [19] states that a clear correlation exists between effective risk management and project success, as risks are evaluated according to their possible influence on project objectives.

In construction, financial risks are uncertainties that could compromise a project's financial performance, including inflation and price rises, currency rate variations, delays in payments, interest rate changes, and bankruptcy risks [20], [21]. These unknowns can lead to cost overruns and call for a well-planned contingency fund to help minimize their influence. Inflation and price escalation heighten financial uncertainty in construction, directly affecting contingency costs. Higher inflation and changing material costs require larger contingency buffers to prevent budget deficits. Project managers must apply dynamic financial models, risk-based contingency planning, and inflation-adjusted budgeting to control this risk properly. Project managers must employ inflation-adjusted budgeting, risk-based contingency planning, and dynamic financial models to manage this risk successfully. Exchange rate fluctuations are variations in the value of one currency relative to another, which can substantially affect construction expenses, particularly in projects dependent on imported foreign raw materials, equipment, or labor.

In nations with significant currency volatility, these movements create financial risks that require mitigation through contingency cost planning. By raising financial risk, supply chain interruptions, and project inefficiencies, payment delays in building projects notably influence contingency costs. Project managers set contingency funds to cover unanticipated financial loads, ensuring project continuity despite payment uncertainty and reducing these risks. Interest rate fluctuations impact borrowing costs, cash flow stability, and project financing, all of which impact contingency costs.

Interest rate increases put contractors and project owners under more financial duress and necessitate establishing greater contingency reserves to cover unforeseen expenditures. High interest rates may also discourage investment in building projects, which could cause delays and liquidity issues. On the other hand, reduced interest rates can make financing easier and lessen the need for large contingency reserves. Bankruptcy risk raises contingency costs by creating financial uncertainty and raising the possibility of project delays, supply chain interruptions, and contract terminations. To reduce these risks, higher contingency allocations are required to cover re-tendering expenses, legal battles, and financial penalties.

The contingency is regarded as either a reserve, the most well-recognized element of project cost contingency, reflecting risk and uncertainty in projects, or as an indication of overall financial commitment [2], [22]. Traditionally, cost contingency in project cost estimates is determined based on intuition and previous project experience, considering that tender document preparation time is quite short, so it cannot systematically analyze project risks and evaluate the potential impacts associated with risks and uncertainties.

Contingency costs are defined as cost reserves or cost estimates to anticipate uncertain conditions allocated to work items based on experience and implementation of previous projects. They are integrated into the estimated project costs. Reference [23] explained that contingency costs are several funds provided as reserves to deal with uncertainties and risks associated with construction projects. The purpose of allocating contingency costs is to ensure that the project cost budget is estimated to be proportional, realistic, and sufficient to cover costs arising from risks due to uncertainty caused by lack of information and errors in interpreting project information/data [3]. In projects, or an indication of overall financial obligation [2].

A variety of estimation methodologies are available for determining project cost contingencies. These methods are typically categorized as deterministic and probabilistic [22]. The deterministic technique typically quantifies cost contingency as a specific proportion of the base cost. The percentage is either fixed and applied to the total base cost or variable, applied to the total base cost or its subcomponents, contingent upon potential hazards. According to [24], the deterministic approaches are thought to be the most straightforward and widely used techniques for creating a contingency budget. For large and complicated projects, this estimate method is arbitrary and inadequate [25]. According to [26], the deterministic approach typically allocates a proportion for the contingency that ranges from 5 to 10% of the project cost.

Probabilistic models are differentiated from deterministic models by the presence of randomness in forecasting the value of a dependent variable. Probabilistic models are crucial when addressing scenarios characterized by natural variability since they allow an outcome variable to be represented through a probability distribution rather than a point estimate of the dependent variable. Whereas reference [24] suggest there are four methods for calculating contingency costs: 1) Expert judgment (subjective in nature); 2) Predetermined percentage (historical project data); 3) Risk analysis using simulation methods (for example, Montecarlo Simulation); and 4) Parametric Modeling (based on an algorithm and regression analysis).

Based on some literature, it can be summarized that five factors can influence contingency expenses:

1) Risk and Uncertainty: The need for and number of contingencies reflect the risks and uncertainties of the project. Contingencies include events within the defined project scope that were unexpected [23, 27, 28]

2) Risk Management: Contingency serves as a remedy for risk. [29]. There are several risk treatment strategies for managing risk in projects, such as risk transfer, risk reduction, and financial treatment for sustained risk; for example, probabilities once contingency is used with other risk treatment strategies.

3) Total Commitment: A cost estimate is prepared, and contingencies are added to show the total possible cost of the project. Including contingencies in a budget estimate means that the estimate represents the total financial commitment to a project. Contingencies should avoid the need for appropriate additional funding and reduce the impact on costs.

4) Reserves: Cost contingency is a reserve of money. Reserves are a provision in a project plan to reduce cost risk [3].

5) Project Outcomes: Contingencies can have a large impact on project outcomes for the project sponsor. If the probability is too high, it can encourage careless cost management, cause projects to be uneconomical and canceled, and lock in funds unavailable for other organizational activities; if it is too low, it may be too rigid and establish an unrealistic financial environment, and result in unsatisfactory performance results [30].

II. Materials and Method

A. Research Design

This study utilizes a quantitative research methodology to examine the correlation between project risk indicators and contingency expenditures in building projects. A correlational study approach was employed to investigate the impact of various risk variables on the distribution of contingency costs. The study employed a systematic approach, beginning with a literature review to identify critical risk factors, followed by data collection through surveys and project reports.

A linear regression model was utilized to measure the influence of risk factors on contingency costs, facilitating an empirical evaluation of their correlation. Furthermore, fuzzy analysis enhances risk assessments by integrating expert judgment and uncertainty factors. The study approach incorporated descriptive analysis to examine risk distributions and inferential analysis to assess the statistical significance of correlations among variables.

The research examined construction projects from a specific company, utilizing data derived from project reports, cost projections, and stakeholder perceptions. This study sought to enhance the precision of contingency cost estimation and offer insights into effective risk management in the construction industry by integrating statistical and risk-based analytical methodologies.

B. Data Collection

The data used in this study were primary data and secondary data. Primary data was collected via interviews and questionnaires. Participants in the primary data for this study consist of six project heads (project managers) from the contractor associated with each project. One president serves as the director, another as the operational director, and a third as the technical director from the contractor. These insights helped develop the initial compilation of risk factors. A questionnaire survey was thereafter distributed to all project participants to analyze and evaluate the identified risks through a paired comparison method. It is used to assess and prioritize risk.

Project records, including cost budget plans and implementation budget plans, furnish secondary data. These records include historical financial data, which is a foundation for assessing contingency cost allocations. Subsequently, we organize the gathered data into a risk register, classifying and prioritizing risk variables by fuzzy pairwise comparison. This methodology guaranteed that the analysis was founded on expert assessment and actual project data, resulting in a more accurate and data-informed contingency cost estimation. This research used a case study in a single construction company, focusing on six building projects completed between 2019 and 2020. The research project consisted of six projects undertaken by a contractor company based in Surabaya, including hotels, apartments, and hospitals with heights ranging from eight to eighteen floors. These projects were in Yogyakarta, Surabaya, Sidoarjo, and Solo and were constructed between 2014 and 2020. The diversity of building functions and scales provides a representative basis for examining the relationship between project risk and contingency cost.

C. Variable and Measurement

This study analyzed risk factors influencing contingency costs in construction projects. The factors were identified through a literature review, expert interviews, and project reports, and then categorized in a risk register for assessment. The research variables were derived from a literature review of construction work risks and would subsequently be refined using the Delphi approach, which involves a preliminary survey to identify more pertinent variables in the examined projects. The research variables were presented in Table 1. The verification of research variables is conducted through two methods: expert judgment via screening interviews and the utilization of data references from project documentation.

TABLE I

Classification of Research Variables Based on Risk Type and Subtype

Risk Type	Risk subtype	Source
Internal Risk	Quality of technical personnel (Including psychological and moral integrity, operational techniques, and efficiency)	[13, 31]
	Quality of management personnel (including psychological diathesis, moral integrity, and level of management)	[13, 19]
	Immature consideration of field conditions	[13, 32]
	Internal technology system failure	[31, 33]
Design Technology Risk	Construction design deviation	[13, 34]
	Lack of understanding of structural characteristics and design theory	[13, 35]
Equipment and Material Risks	Inappropriate types and quantities of raw materials, completed goods, and semi-finished products	[13, 34]
	Local transportation restrictions	[35, 36]
	Delays in supplying and entering construction equipment	[13, 35, 37]
	Insufficient production capacity of construction equipment	[13, 34, 35, 37]
	Lack of accessories and fuel for construction equipment	[13, 31]
	Construction machinery failures and electrical faults	[13, 34, 37]
	Lack of maintenance of equipment and overloading of construction equipment	[13, 34, 35]
	Equipment damage due to natural factors	[31, 34]

Risk Type	Risk subtype	Source
	Equipment that has not been used for a long time	[31, 35]
	Unavailability or shortage of materials	[31, 34]
	Theft of equipment and materials on-site	[31, 34]
Safety Risk	Accident on site	[31, 35, 37]
	Injury on site	[31, 34, 37]
Construction technology risk	Death by accident	[31, 37]
External risk	Bad weather and environmental conditions	[13, 31, 34, 35]
	Undesirable field conditions (unstable water supply, electricity, etc.)	[13, 31]
	Disadvantageous geographical location	[13, 31, 38]
	Depletion of natural resources	[31, 34]
Social risk	Problems created by residents	[31, 38, 39]

D. Data Analysis Method

The employed analytical techniques include the triangular fuzzy number method for risk assessment and regression analysis to determine the impact of risk on contingency expenditures. The process of risk assessment utilizing the triangular fuzzy number methodology is outlined as follows: 1) Transforming linguistic variables into fuzzy numbers, 2) Computing fuzzy average probability and impact, 3) Risk evaluation (risk calculator), and 4) Defuzzification/validation. The risk level for each project under assessment, utilizing fuzzy logic in risk analysis, was established. The data must be transformed into a percentage representation of the risk level. The proportion of the risk level is determined using the weighted risk analysis approach. To produce results in percentages, a pairwise comparison analysis is required.

Linear regression analyses the relationship between project risk and contingency cost. Regression analysis is a statistical method used to examine and model the relationship between variables [40]. Linear regression is one of the effective statistical methods to obtain the magnitude of the influence of independent variables on dependent variables [41]. The independent variables in this study are project risk and contingency costs, and the dependent variables are. Linear regression permits quantifying the extent to which changes in risk factors affect contingency costs with clear statistical significance. This study applies a structured data analysis approach to examine the influence of project risks on contingency costs in building projects. The analysis is carried out in multiple stages to verify the reliability and validity of the findings.

1) Data Preparation: The collected data, including questionnaire responses and project records, undergo preprocessing to remove incomplete or inconsistent information. Descriptive statistics summarize the data, providing insights into the distribution and patterns of key variables. Descriptive analysis uses a scatter diagram to show the relationship between two variables. It displays data points that show how one variable change relative to the other.

2) Risk Weighting and Scoring: A pairwise-comparison fuzzy approach is used to assign weights to the identified risk variables. This approach helps estimate the relative impact of each risk factor based on expert judgments. The weighted risks are then integrated into the regression model to examine their effect on contingency costs.

3) Regression Analysis: A linear regression analysis was performed to analyze the relationship between project risks and contingency cost allocation. The model estimates the influence of independent variables (risk factors) on the dependent variable (contingency cost percentage). Several statistical tests are conducted to assess the model's robustness, including heteroskedasticity and normality tests. The heteroskedasticity test assesses the homogeneity of error variances, while the normality test assesses the normality of residuals.

4) Analysis and Verification: The regression analysis findings are analyzed to determine the most critical risk factors influencing contingency expenses. The findings are juxtaposed with prior research to substantiate the conclusions.

III. Results and Discussion

The questionnaires collected and completed by several experts at a construction company are summarized. The fuzzy pairwise comparison approach converts them into a pairwise comparison matrix for analytical purposes. To get the sub-risk weight relative to the overall risk weight, each sub-variable weight is multiplied by its corresponding risk variable. A summary of the risk and sub-risk weighting is compiled for use in the weighted fuzzy analysis approach for risk assessment. Table 2 provides a summary of risk assessment via the Weighted Fuzzy Analysis Method. The global weight signifies the relative significance of each risk category, established via expert assessment and fuzzy pairwise comparison. The risk value derives from expert assessments, whereas the risk level is determined by multiplying the global weight by the risk value.

TABLE II
RISK RECAPITULATION WITH WEIGHTED FUZZY ANALYSIS METHOD

Risk type	Global weight	Risk	Risk Level
Internal risks			
Quality of technical personnel (Including psychological and moral integrity, operational techniques, and efficiency).	0.061	10.500	0.639
Quality of management personnel (including psychological diathesis, moral integrity and level of management).	0.061	6.120	0.373
Immature consideration of field conditions.	0.055	6.120	0.334
Internal technology system failure	0.034	6.120	0.206

Risk type	Global weight	Risk	Risk Level
Design technology risk			
Construction design deviation	0.052	15.000	0.774
Lack of understanding of structural characteristics and design theory	0.068	10.000	0.684
Equipment and Material Risks			
Inappropriate types and quantities of raw materials, completed goods, and semi-finished products	0.021	10.500	0.215
Local transportation restrictions	0.010	6.120	0.063
Delays in supplying and entering construction equipment	0.038	6.120	0.230
Insufficient production capacity of construction equipment	0.017	6.120	0.105
Lack of accessories and fuel for construction equipment	0.019	6.120	0.115
Construction machinery failures and electrical faults	0.005	15.000	0.77
Lack of maintenance of equipment and overloading of construction equipment	0.007	6.120	0.042
Equipment damage due to natural factors	0.009	10.000	0.086
Equipment that has not been used for a long time	0.007	10.000	0.068
Unavailability or shortage of materials	0.034	6.120	0.209
Theft of equipment and materials on-site	0.005	6.120	0.031
Safety risk			
Accident on site	0.183	6.120	1.119
Injury on site	0.040	6.120	0.246
Construction technology risk			
Death by accident	0.102	6.120	0.624
External risk			
Bad weather and environmental conditions	0.028	10.000	0.283
Undesirable field conditions (unstable water supply, electricity, etc.)	0.038	6.120	0.235
Disadvantageous geographical location	0.022	6.120	0.136
Depletion of natural resources	0.012	6.120	0.074
Social risk			
Problems created by residents	0.073	6.120	0.447
		Total	7.415

Table 2 provides an overview of building project risks using the Weighted Fuzzy Analysis Method on Project 1. Assessments for Projects 2, 3, 4, 5, and 6 are done similarly. Safety risks, particularly on-site accidents (risk level: 1.119), are the most significant, highlighting the critical need for strict safety protocols. Design technology risks, such as construction design deviations (0.774) and lack of understanding of structural characteristics (0.684), also pose major concerns. Internal risks, including technical personnel quality (0.639), emphasize workforce competence and management integrity. Equipment and material risks underline logistical challenges, such as delays in supplying construction equipment (0.230) and a lack of accessories and fuel (0.115). External risks, like bad weather (0.283), and social risks, such as conflicts with residents (0.447), further influence project performance. The analysis highlights the significance of thorough risk management measures, emphasizing safety, design verification, staff proficiency, and supply chain effectiveness to alleviate adverse effects on building projects.

Contingency cost data, classified as secondary data, is directly sourced from project data overseen by the company's operational and control director. Table 3 below displays the contingency cost data derived from the cost budget plan and implementation budget plan. The cost budget plan represents the value specified in the contract between the owner and the contractor, typically understood as the project's overall value, encompassing the base cost, profit, and contingency. The implementation budget plan encompasses the expenses incurred by the contractor throughout the project's construction, comprising a portion of the actual base cost and cost contingency. Table 3 presents the project budget details, including the planned cost budget (including taxes), the implementation budget (excluding taxes), and the percentage of actual contingency costs incurred during the project implementation. This data provides an initial overview of how the budget was allocated and the extent to which contingency costs contributed to the total project budget.

TABLE III
IMPLEMENTATION BUDGET PLAN AND ACTUAL CONTINGENCY COST OF EACH PROJECT

Project	Implementation budget plan (excluding VAT)	Actual contingency cost
1	IDR 34,313,828,100.00	2.30%
2	IDR 47,555,100,700.00	3.43%
3	IDR 24,926,064,700.00	3.24%
4	IDR 35,679,900,000.00	4.82%
5	IDR 81,843,636,000.00	3.37%
6	IDR 26,400,000,000.00	2.35%

Source: Construction Company Project Data (2020)

The impact of the identified risks on contingency costs is assessed, considering the project budget allocation. As a financial buffer to handle unforeseen circumstances during project execution, contingency charges are crucial to project risk management. The discrepancy between the projected budget and actual expenses demonstrates budget estimation and risk mitigation techniques. Table 4 below shows the relationship between the risk level, the prepared budget, and the contingency costs incurred. The comparison between planned and actual contingency costs provides insight into the effectiveness of budget planning in managing risks during project implementation. The relationship between these tables provides a comprehensive understanding of how risks, budgets, and contingency costs are interrelated in construction project management.

TABLE IV
RECAPITULATION OF RISK LEVELS AND CONTINGENCY COSTS

Project number	Plan contingency cost	Actual contingency cost	Project Risk Level
1	3 %	2.30%	7.415
2	3.5 %	3.43%	7.618
3	3 %	3.24%	7.535
4	3 %	4.82%	7.652
5	4 %	3.37%	7.599
6	3 %	2.35%	7.495

A scatterplot tool was employed to demonstrate the correlation between contingency expenses and risk levels for each research project. The scatter plot was constructed with the x-axis denoting the risk level of each project and the y-axis representing the percentage of contingency cost (CC) in Fig 1.

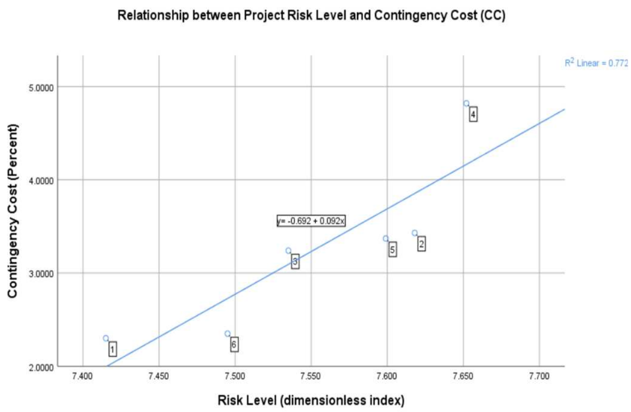

Fig. 1 Relationship between Project risk level and contingency cost (CC)

The figure shows a positive linear relationship between project risk level and contingency cost for six building projects. The scatter plot in Fig. 1 shows how the risk levels (x-axis) and contingency costs (y-axis) relate to six projects. Each point represents a project's associated contingency cost against its degree of risk. A fitted trend line shows the overall correlation between the two variables. The graph clearly shows a positive link between the risk level and the contingency cost, which usually rises. This implies that higher-risk projects require larger contingency budgets to help reduce financial overruns and uncertainty. Project 4 exhibits the highest contingency cost (4.82%) and one of the highest risk levels (7.652), while Project 1 has the lowest contingency cost (2.30%) and the lowest risk level (7.415). This supports the hypothesis that contingency costs are closely linked to the project's risk exposure. It is also important to note that most of the identified risks in these projects had been managed through various risk control measures during construction. As a result, the mitigation efforts may have contributed to reducing overall contingency expenditures.

The linear regression results indicate a correlation between risk level (the independent variable) and contingency cost (the dependent variable). The correlation coefficient R = 0.879 indicates a robust link between risk level and contingency cost. The R Square coefficient value of 0.772 indicates that 77.2% of the variation in contingency costs can be attributed to risk levels. The model remains strong enough to explain this relationship after adjusting for the number of variables, as indicated by the adjusted R Square = 0.716. Based on the analysis, the following regression equation is obtained:

$$y= -0.692 + 0.092x \tag{1}$$

If x represents the risk level and y denotes the contingency cost, then the regression coefficient of 0.092 for risk level signifies that a one-unit rise in risk level would elevate the contingency cost by 0.092, provided all other variables are held constant. The positive slope indicates that higher contingency costs are associated with higher risk levels. The negative intercept indicates that the model's predictions may be inapplicable when contingency costs are absent. To evaluate whether the resulting regression model has a significant relationship between the independent and dependent variables, an analysis was conducted using the Analysis of Variance (ANOVA) test. This test aims to determine whether the independent variables provide a significant contribution to the dependent variable.

The ANOVA test findings indicate that the regression model significantly accounts for the change in contingency cost (CC) relative to risk level. The F-statistic of 13.576, accompanied by a p-value of 0.021 (below the 0.05 significance threshold), signifies that risk level exerts a statistically significant influence on contingency cost. Additionally, the normality test results confirm that the residuals follow a near-normal distribution, and the heteroskedasticity test results indicate that the residuals do not exhibit a significant variance pattern, supporting the model's statistical validity.

The result of this research shows that an increase in risk factors correlates with higher contingency expenditures for the project. This aligns with the research conducted by [42], who determined and assessed important risks in the construction cost estimation process. These risks are seen to be the primary reasons for cost overruns in Nigerian building projects. They identified 29 significant risks that affect the project's contingency budget. This is also consistent with the results of [20], which used a methodical approach based on empirical evaluation to examine the financial impact of risk factors influencing important aspects of construction projects using Fault Mode and Effect Analysis (FMEA) and quantitative analysis. Risk factors such as scope changes, incomplete designs, and economic risks (such as inflation and delayed payments) significantly affect the need for contingency costs. The higher and more complex the risks identified, the greater the need for contingency costs to address these uncertainties and ensure project success. Additionally, reference [20] highlights the significance of contingency estimates grounded in precise quantitative risk assessment rather than a deterministic methodology. They recommend a more reasonable contingency cost range of 13.36% to 17.88%.

The positive relationship between contingency cost and risk level indicates that higher contingency cost allocation is associated with higher risk levels in construction projects [43]. This may be due to greater project complexity or higher uncertainty, which requires additional cost reserves to anticipate potential risks. Projects with a high level of complexity tend to have many interrelated components and require complex coordination [44]. The more complex a project is, the greater the likelihood of unexpected risks arising, thus requiring a larger contingency cost allocation to anticipate potential problems. Simultaneously, building projects frequently encounter uncertainties that influence cost, duration, and quality. These hazards may arise from various causes, including environmental circumstances, alterations in design, or price volatility[45]. Project managers generally designate contingency expenditures as a reserve to address anticipated unforeseen expenses. Accurate contingency cost estimation necessitates a comprehensive comprehension of potential risks and their effects on the project. By methodically identifying and assessing risks, contingency cost estimates can be adjusted to match the degree of risk encountered, thus enhancing the realism and reliability of the project budget.

The precision of contingency cost assessment deemed significant in large, qualified construction firms differs from that of smaller contractors. Reference [46] clarified that small to medium contractors primarily employ contingencies in situations when they regard the evaluation of contingency expenses in the contract as compensable. Risk estimates are typically not used to determine contingency costs; instead, the emphasis is only on their competitive bidding. Consequently, these organizations undertake a proportionately higher business risk than indicated by the literature on contingencies. Numerous contractors believe that incorporating contingency funds into a project's tender price may lead to the forfeiture of the tender. The research undertaken by [47] seeks to rectify this erroneous belief. A more sophisticated approach to risk management acknowledges the potential to avert or mitigate hazards while enhancing opportunities.

Contingency is crucial for effective project management as it offers a safeguard against the emergence of hazards. Contingency cost allocation methods are predicated on an activity's impact on the total project cost variance, encompassing cost, uncertainty, and its status on the critical path [48]. An effective contingency cost management approach is anticipated to regulate expenditures and balance project activity contingency costs while forecasting future requirements [49]. The application of linear regression analysis is one of the probabilistic methods that is quite effective in estimating contingency costs in construction projects. Linear regression predicts the value of a dependent variable (e.g., contingency cost) based on independent variables (e.g., risk factors), acknowledging inherent variability and unmeasured influences on the outcome.

Consequently, linear regression is regarded as a probabilistic model because it incorporates uncertainty and variability in predictions. Using linear regression to assess risk factors enables firms to pinpoint areas that require focused intervention, thereby enhancing overall project performance. Linear regression facilitates the identification of the most significant risks, enabling targeted mitigation actions in the regions of most need. This enhances risk management efficiency and ensures optimal resource allocation. These models use prior project data, offering expert insights for contingency planning without requiring qualified professionals for each project [50]. This research offers significant insights for project managers and stakeholders within the construction sector. Comprehending the correlation between risk factors and contingency costs facilitates more precise cost estimation and efficient risk mitigation techniques. By identifying potential hazards early, project managers can allocate contingency expenses more effectively, reducing the likelihood of budget overruns. Financial risks, including inflation, exchange rate volatility, and payment delays, must be monitored closely to avoid unforeseen liabilities. Real-time risk monitoring and data-driven contingency cost distribution can improve project efficiency.

IV. Conclusion

This study aims to investigate the relationship between risk and contingency cost in building construction projects. Using a quantitative approach with simple linear regression analysis, the research investigated six high-rise building projects implemented by a single construction company. The research findings indicate that the relationship between risk and contingency cost is represented by the equation $y = -0.692 + 0.092x$, suggesting that an increase in risk variables correlates with elevated contingency expenses for the project. The risk level indicates that a one-unit increase would raise the contingency cost by 0.092, assuming all other factors remain constant. The results of the risk evaluation analysis of construction project implementation in the six research projects showed a risk level range of 7.415 to 7.652 and a contingency cost range of 2.30% to 4.82% of the total project contract value.

This study used data exclusively from a single construction company with relatively limited historical records; hence, future research should aim to enhance the dataset and extend the historical timeframe to yield more precise conclusions. A comparison of risks and contingency costs is necessary, considering the project's complexity and magnitude. The application of alternative contingency cost calculation methodologies, such as Program Evaluation and Review Technique (PERT), Monte Carlo simulations, parametric modeling, or fuzzy logic, is strongly advised. Utilizing technology, including project management software and risk simulation tools, facilitates the real-time monitoring and management of hazards. This facilitates the early identification of potential issues and enables swifter, more precise decision-making.

Acknowledgment

The authors gratefully acknowledge financial support from the Institut Teknologi Sepuluh Nopember for this work, under the project scheme of the Publication Writing and IPR Incentive Program (PPHKI) 2025.

References

[1] R. Delima, H. Budi, N. Andriyanto, and A. Wibowo, "Development of Purchasing Module for Agriculture E-Commerce Using Dynamic System Development Model," *Int. J. Adv. Comput. Sci. Appl.*, vol. 9, no. 10, 2018. doi: 10.14569/ijacsa.2018.091012.

[2] M. W. Hammad, A. Abbasi, and M. J. Ryan, "Allocation and Management of Cost Contingency in Projects," *J. Manag. Eng.*, vol. 32, no. 6, Nov. 2016. doi: 10.1061/(asce)me.1943-5479.0000447.

[3] PMI, *A Guide to the Project Management Body of Knowledge 6th Edition*. Project Management Institute, Inc, 2017.

[4] A. Salah and O. Moselhi, "Contingency Modelling for Construction Projects Using Fuzzy-Set Theory," *Eng. Constr. Archit. Manag.*, vol. 22, no. 2, pp. 214–241, Mar. 2015. doi: 10.1108/ecam-03-2014-0039.

[5] T. E. Freese et al., "Recovery Incentives Program: California's Contingency Management Benefit," *Prev. Med.*, vol. 176, p. 107703, Nov. 2023. doi: 10.1016/j.ypmed.2023.107703.

[6] H. Xie, S. AbouRizk, and J. Zou, "Quantitative Method for Updating Cost Contingency Throughout Project Execution," *J. Constr. Eng. Manag.*, vol. 138, no. 6, pp. 759–766, Jun. 2012. doi:10.1061/(asce)co.1943-7862.0000457.

[7] S. C. Lhee, I. Flood, and R. R. A. Issa, "Development of a Two-Step Neural Network-Based Model to Predict Construction Cost Contingency," *J. Inf. Technol. Constr.*, vol. 19, no. 24, pp. 399–411, 2014.

[8] S. A. Gabriel, J. F. Ordóñez, and J. A. Faria, "Contingency Planning in Project Selection Using Multiobjective Optimization and Chance Constraints," *J. Infrastruct. Syst.*, vol. 12, no. 2, pp. 112–120, Jun. 2006. doi: 10.1061/(asce)1076-0342(2006)12:2(112).

[9] A. Aibinu and G. Jagboro, "The Effects of Construction Delays on Project Delivery in Nigerian Construction Industry," *Int. J. Proj. Manag.*, vol. 20, no. 8, pp. 593–599, Nov. 2002. doi: 10.1016/s0263-7863(02)00028-5.

[10] T. J. Adi and S. Yunwanti, "Risk Based Contingency Cost Estimation Modeling for Engineering-Procurement-Construction Project," 2014.

[11] A. Idrus, M. Fadhil Nuruddin, and M. A. Rohman, "Development of Project Cost Contingency Estimation Model Using Risk Analysis and Fuzzy Expert System," *Expert Syst. Appl.*, vol. 38, no. 3, pp. 1501–1508, Mar. 2011. doi: 10.1016/j.eswa.2010.07.061.

[12] PMI, *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)–Seventh Edition and The Standard for Project Management*. Project Management Institute, 2021.

[13] Q.-F. Li, P. Zhang, and Y.-C. Fu, "Research Article Risk Identification for the Construction Phases of the Large Bridge Based on WBS-RBS," *Res. J. Appl. Sci. Eng. Technol.*, vol. 6, no. 9, pp. 1523–1530, 2013.

[14] G. Hutchins, *ISO 31000: 2018 Enterprise Risk Management*. Greg Hutchins, 2018.

[15] U. R. de Oliveira, F. A. S. Marins, H. M. Rocha, and V. A. P. Salomon, "The ISO 31000 Standard in Supply Chain Risk Management," *J. Clean. Prod.*, vol. 151, pp. 616–633, May 2017. doi:10.1016/j.jclepro.2017.03.054.

[16] J. Yang and S. Yin, "Risk Management for Housing and Construction Projects," *J. Eng. Proj. Prod. Manag.*, Jan. 2024. doi:10.32738/jeppm-2024-0011.

[17] Y. N. Sanda, N. A. Anigbogu, L. Y. Nuhu, and O. S. Olumide, "A Life-Cycle Framework for Managing Risks in Public Private Partnership Housing Projects," *J. Eng. Proj. Prod. Manag.*, Jan. 2020. doi: 10.2478/jeppm-2020-0004.

[18] H. Unegbu, D. Yawas, and B. Dan-asabe, "An Investigation of the Relationship Between Project Performance Measures and Project Management Practices of Construction Projects for the Construction Industry in Nigeria," *J. King Saud Univ. - Eng. Sci.*, vol. 34, no. 4, pp. 240–249, May 2022. doi: 10.1016/j.jksues.2020.10.001.

[19] P. X. Zou, G. Zhang, and J. Wang, "Understanding the Key Risks in Construction Projects in China," *Int. J. Proj. Manag.*, vol. 25, no. 6, pp. 601–614, Aug. 2007. doi: 10.1016/j.ijproman.2007.03.001.

[20] J. I. T. Buertey, E. Abeere-Inga, and T. A. Kumi, "The Financial Impact of Risk Factors Affecting Project Cost Contingency: Evidential Reasoning Method," *J. Eng. Proj. Prod. Manag.*, vol. 3, no. 2, pp. 65–73, Jul. 2013. doi: 10.32738/jeppm.201307.0003.

[21] R. S. Abdulrahman, A. D. Ibrahim, and P. G. Chindo, "Assessment of Risk Management Maturity of Construction Organisations in Joint Venture Projects," *J. Eng. Proj. Prod. Manag.*, Jan. 2019. doi:10.2478/jeppm-2019-0004.

[22] A. A. Shash, M. Al-Salti, A. Alshibani, and L. Hadidi, "Predicting Cost Contingency Using Analytical Hierarchy Process and Multi Attribute Utility Theory," *J. Eng. Proj. Prod. Manag.*, Sep. 2021. doi:10.2478/jeppm-2021-0022.

[23] S. Mak and D. Picken, "Using Risk Analysis to Determine Construction Project Contingencies," *J. Constr. Eng. Manag.*, vol. 126, no. 2, pp. 130–136, Mar. 2000. doi: 10.1061/(asce)0733-9364(2000)126:2(130).

[24] 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.

[25] M. S. Islam, M. P. Nepal, M. S. Alam, and M. Arifuzzaman, "Cost Contingency Modelling for Construction Projects: Insight from the Literature," in *2019 Int. Conf. Innov. Intell. Inform. Comput. Technol. (3ICT)*, Sep. 2019, pp. 1–5. doi: 10.1109/3ict.2019.8910317.

[26] O. Akinradewo, L. Ngwenya, C. Aigbavboa, W. Thwala, and L. Mphela, "Improving the Efficacy of Cost Contingency Plans for Construction Projects in South Africa," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 640, no. 1, p. 012030, Nov. 2019. doi: 10.1088/1757-899x/640/1/012030.

[27] A. Söderholm, "Project Management of Unexpected Events," *Int. J. Proj. Manag.*, vol. 26, no. 1, pp. 80–86, Jan. 2008. doi:10.1016/j.ijproman.2007.08.016.

[28] M. Wied, J. Oehmen, T. Welo, and E. Pikas, "Wrong, but Not Failed? A Study of Unexpected Events and Project Performance in 21 Engineering Projects," *Int. J. Manag. Proj. Bus.*, vol. 14, no. 6, pp. 1290–1313, May 2021. doi: 10.1108/ijmpb-08-2020-0270.

[29] G. G. Micah and I. K. Ogona, "Contingency Leadership Approach: An Antidote to Organizational Conflict," in *2nd Int. Conf. Institutional Leadership Capacity Building Africa*, 2022, p. 457.

[30] D. Howell, C. Windahl, and R. Seidel, "A Project Contingency Framework Based on Uncertainty and Its Consequences," *Int. J. Proj. Manag.*, vol. 28, no. 3, pp. 256–264, Apr. 2010. doi:10.1016/j.ijproman.2009.06.002.

[31] R. C. Walke, V. M. Topkar, and N. U. Matekar, "An Approach to Risk Quantification in Construction Projects Using EMV Analysis," *Int. J. Eng. Sci. Technol.*, vol. 3, no. 9, pp. 6847–6855, 2011.

[32] F. Farjam, P. Shojaei, and K. Askarifar, "A Conceptual Model for Open Innovation Risk Management Based on the Capabilities of SMEs: A Multi-Level Fuzzy MADM Approach," *Technovation*, vol. 127, p. 102844, Sep. 2023. doi: 10.1016/j.technovation.2023.102844.

[33] A. S. Dorokhov, Y. V. Kataev, I. A. Tishaninov, and E. A. Gradov, "The Use of Digital Intelligent Technologies in Predicting Failures of Automotive and Tractor Equipment," *J. Phys. Conf. Ser.*, vol. 2373, no. 7, p. 072008, Dec. 2022. doi: 10.1088/1742-6596/2373/7/072008.

[34] P. A. Mahendra, J. R. Pitroda, and J. J. Bhavsar, "A Study of Risk Management Techniques for Construction Projects in Developing Countries," *Int. J. Innov. Technol. Explor. Eng.*, vol. 3, no. 5, pp. 139–142, 2013.

[35] H. E. Hosny, A. H. Ibrahim, and R. F. Fraig, "Risk Management Framework for Continuous Flight Auger Piles Construction in Egypt," *Alex. Eng. J.*, vol. 57, no. 4, pp. 2667–2677, Dec. 2018. doi:10.1016/j.aej.2017.10.003.

[36] X. Lai, Z. Li, and J. Li, "Modeling Risks and Uncertainties in Residents' License Choice Behaviors Under a Vehicle Restriction Policy," *Transp. Plan. Technol.*, vol. 41, no. 5, pp. 497–518, Apr. 2018. doi: 10.1080/03081060.2018.1468973.

[37] D. Curto, F. Acebes, J. González-Varona, and D. Poza, "Impact of Aleatoric, Stochastic and Epistemic Uncertainties on Project Cost Contingency Reserves," *Int. J. Prod. Econ.*, vol. 253, p. 108626, Nov. 2022. doi: 10.1016/j.ijpe.2022.108626.

[38] J. Yuan et al., "Social Network Analysis for Social Risks of Construction Projects in High-Density Urban Areas in China," *J. Clean. Prod.*, vol. 198, pp. 940–961, Oct. 2018. doi:10.1016/j.jclepro.2018.07.109.

[39] L. Yousefi-Rizi, J.-D. Baek, N. Blumenfeld, and C. Stoskopf, "Impact of Housing Instability and Social Risk Factors on Food Insecurity Among Vulnerable Residents in San Diego County," *J. Community Health*, vol. 46, no. 6, pp. 1107–1114, May 2021. doi:10.1007/s10900-021-00999-w.

[40] D. C. Montgomery, E. A. Peck, and G. G. Vining, *Introduction to Linear Regression Analysis*. John Wiley & Sons, 2021.

[41] A. Kamel and M. R. Abonazel, "A Simple Introduction to Regression Modeling using R," *Comput. J. Math. Stat. Sci.*, vol. 2, no. 1, pp. 52–79, Apr. 2023. doi: 10.21608/cjmss.2023.189834.1002.

[42] S. Ekung, A. Lashinde, and E. Adu, "Critical Risks to Construction Cost Estimation," *J. Eng. Proj. Prod. Manag.*, Jan. 2021. doi:10.2478/jeppm-2021-0003.

[43] T. Ammar, M. Abdel-Monem, and K. El-Dash, "Appropriate Budget Contingency Determination for Construction Projects: State-of-the-Art," *Alex. Eng. J.*, vol. 78, pp. 88–103, Sep. 2023. doi:10.1016/j.aej.2023.07.035.

[44] A. Sablis, D. Smite, and N. Moe, "Team-External Coordination in Large-Scale Software Development Projects," *J. Softw. Evol. Process*, vol. 33, no. 3, Jun. 2020. doi: 10.1002/smr.2297.

[45] H. Qin, "Decision-Making Under Uncertainty for Buildings Exposed to Environmental Hazards," *J. Saf. Sci. Resil.*, vol. 3, no. 1, pp. 1–14, Mar. 2022. doi: 10.1016/j.jnlssr.2021.11.002.

[46] J. Bae, "Supervised Learning to Covering Cost Risk Through Post-Construction Evaluation of Transportation Projects by Project Delivery Methods," *Eng. Constr. Archit. Manag.*, vol. 32, no. 9, pp. 5863–5884, Jun. 2024. doi: 10.1108/ecam-01-2024-0136.

[47] I. A. Eldosouky, A. H. Ibrahim, and H. E.-D. Mohammed, "Management of Construction Cost Contingency Covering Upside and Downside Risks," *Alex. Eng. J.*, vol. 53, no. 4, pp. 863–881, Dec. 2014. doi: 10.1016/j.aej.2014.09.008.

[48] E. Zaneldin and W. Ahmed, "A Generic Framework for Managing Schedule and Cost Risks of Construction Activities Using PERT and the EV Technique," *Buildings*, vol. 14, no. 7, p. 1918, Jun. 2024. doi:10.3390/buildings14071918.

[49] A. De Marco, T. Narbaev, F. M. Ottaviani, and M. Vanhoucke, "Influence of Cost Contingency Management on Project Estimates at Completion," *Int. J. Constr. Manag.*, vol. 24, no. 9, pp. 935–945, Aug. 2023. doi: 10.1080/15623599.2023.2239487.

[50] R. E. Adaurhere, I. Musonda, and C. S. Okoro, "Construction Contingency Determination: A Review of Processes and Techniques," in *Advances in Science, Technology & Innovation*, Springer International Publishing, 2020, pp. 271–277. doi: 10.1007/978-3-030-48465-1_45.