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Risk-Based Contingency Cost Analysis Using the Expected Monetary Value Method

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contingency cost; risk management; Probability Impact Matrix; Expected Monetary Value; Work Breakdown Structure; Risk Breakdown Structure.

Abstract
Construction projects are characterized by high levels of uncertainty that may affect project cost, quality, and schedule performance. Effective risk management is therefore essential to determine contingency costs that adequately reflect project risks. This study aims to identify dominant construction work packages based on risk exposure and estimate risk-based contingency costs for the Main Building Construction Project of the Gianyar Regency Government Center. Project risks were identified through a literature review and Work Breakdown Structure (WBS), validated by experts, and compiled into a risk register. The Probability Impact Matrix (PIM) was used to identify dominant risks, while the Expected Monetary Value (EMV) method was applied to estimate contingency costs for cost (EMVc), quality (EMVq), and schedule (EMVt) aspects. These three aspects were then integrated to determine the overall contingency cost. The results identified ten high-risk work packages, including concrete, reinforcement, steel roof trusses, masonry, sanitary, signage, roof covering, plumbing, road, and softscape works. The EMV analysis produced contingency values of 6.22% (EMVc), 5.95% (EMVq), and 0.70% (EMVt), resulting in an integrated contingency cost of IDR 28.92 billion, equivalent to 12.87% of the project contract value. The findings indicate that contingency cost requirements are primarily influenced by cost and quality risks, providing a more objective basis for contingency reserve allocation during project execution.

INTRODUCTION

The rapid development of infrastructure has increased the complexity of construction projects in terms of technical execution, coordination, and resource management. This complexity has led to greater uncertainty, which may adversely affect the achievement of project cost, quality, and schedule objectives (Project Management Institute, 2017; Shahroz et al., 2021). Previous studies have reported that projects with high levels of risk may experience cost overruns ranging from 5% to 40%, primarily due to inadequate risk identification and analysis during the planning phase, resulting in initial cost estimates that fail to adequately account for uncertainties encountered during project execution (Bohórquez-Castellanos & Mejía, 2021; Johnson & Babu, 2020; Purba et al., 2021).

To address these uncertainties, construction projects allocate contingency costs as financial reserves for potential risks (Alhashedi et al., 2026; Hammad, 2018). However, in practice, contingency costs are still commonly determined using a deterministic approach based on a fixed percentage of approximately 10–15% of the total project value, relying largely on professional experience and historical data (Ammar et al., 2023; Shrestha & Shrestha, 2016; Sutikno & Arif Rohman, 2022). This approach has significant limitations because it does not explicitly consider the probability and impact of individual risks, despite the fact that contingency requirements may vary considerably, ranging from 3% to 30%, depending on the characteristics of each project (Stachoń et al., 2025). Therefore, a risk-based approach is required to produce contingency cost estimates that more accurately reflect actual project conditions (Nguyen et al., 2021; Ortiz et al., 2018).

One of the most widely adopted methods for quantitative risk analysis is the Expected Monetary Value (EMV) method, which integrates the probability of risk occurrence with its potential financial impact to estimate contingency costs in monetary terms. The EMV method is recommended by the Project Management Institute (2017) as part of quantitative risk analysis and is considered more systematic, transparent, and appropriate for projects with limited historical data (Ammar et al., 2023; Cruz & Lima, 2021).

Several studies have demonstrated the effectiveness of the EMV method in estimating contingency costs for construction projects. Walke (2010) reported contingency cost requirements ranging from 6% to 10% for ready-mix concrete plant projects, while Astana et al., (2025) estimated a contingency cost of 9.61% by integrating cost, schedule, and quality risks in a road construction project. Nevertheless, the application of the EMV method to government building projects implementing Green Building principles remains relatively limited, highlighting the need for further investigation (D. Zhang et al., 2024).

This study was conducted on the Main Building Package of the Gianyar Regency Government Center Project, which has a contract value of IDR 225,024,648,648.65. According to the regulations of the Indonesian Ministry of Public Works and Housing, this project is classified as a complex construction project because it incorporates Green Building and Clean and Green Construction principles, including the use of certified construction materials, energy-efficient building systems, and compliance with green building certification requirements. These characteristics increase both project complexity and uncertainty, making the project an appropriate case study for the application of the EMV method (Li, Xu, Sun, & Ding, 2020; Zhang et al., 2019).

Although the EMV method has been widely applied in construction risk analysis, most previous studies have focused primarily on cost-related risks or specific project types. Research integrating cost, quality, and schedule risks simultaneously for contingency cost estimation in building construction projects remains limited. Consequently, further investigation is needed to develop a more comprehensive risk-based contingency estimation approach that reflects the multidimensional nature of construction project risks. This study aims to identify the dominant construction work packages based on risk exposure in terms of cost, quality, and time, as well as to estimate risk-based contingency costs using the Expected Monetary Value (EMV) method in the Main Building Construction Project of the Gianyar Regency Government Center.

Although the EMV method has been widely applied in construction risk analysis, most previous studies have focused primarily on cost-related risks or specific project types, such as road and bridge infrastructure (Astana et al., 2025; Sutikno & Rohman, 2022). Research integrating cost, quality, and schedule risks simultaneously for contingency cost estimation in government building projects implementing Green Building principles remains limited. This study addresses this gap by integrating WBS and RBS for comprehensive risk identification, considering cost, quality, and time aspects simultaneously, and applying the method to a complex green building project. The novelty lies in the integration of three risk dimensions and the context of sustainable building construction, which has distinct risk characteristics compared to conventional projects.

This research aims to identify dominant construction work packages based on risk exposure and to estimate risk-based contingency costs using the EMV method. Theoretically, this research contributes to construction project management literature by providing empirical evidence on risk-based contingency estimation in green building projects. Practically, the findings offer input for project owners and construction practitioners in objectively determining contingency budgets, thereby improving cost certainty and project performance in complex government construction projects.

METHOD

Study design, case context, and data sources

This research aims to analyze risk-based contingency costs in construction projects using the Expected Monetary Value (EMV) method by considering cost, quality, and time aspects. The research was conducted using a quantitative descriptive approach to systematically and objectively assess risk characteristics and estimate the required contingency cost during the construction phase. The case study was conducted on the Main Building Package of the Gianyar Regency Government Center Development Project, located in Gianyar, Bali, Indonesia. The project owner is the Gianyar Regency Public Works and Spatial Planning Agency. The analysis was limited to the construction phase, focusing on risks affecting cost, quality, and time. The project has a total budget of IDR 225,024,648,648.65 with an implementation duration of 330 calendar days.

Research workflow

The research workflow is presented in Figure X. The study began with a literature review to identify potential construction risks and establish the theoretical framework. Risk identification was conducted by integrating the Work Breakdown Structure (*WBS*) and Risk Breakdown Structure (*RBS*) to develop a risk register relevant to the construction phase. The identified risks were subsequently validated by experts to ensure their relevance to the research object. Data collection was performed through risk assessment questionnaires to obtain probability and impact values. The collected data were analyzed using the Probability Impact Matrix (*PIM*) to determine risk levels and identify dominant risks. Furthermore, the Expected Monetary Value (*EMV*) method was applied to quantify the potential financial impact of identified risks and estimate the required risk-based contingency cost. The final stage involved analyzing the contingency cost allocation based on cost, quality, and time risk aspects.

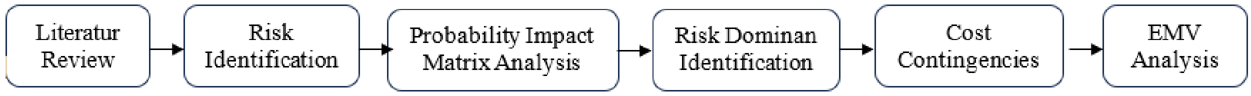

Figure 1. Research Workflow
Source: Authors' Conceptual Framework (2025)

RESULTS AND DISCUSSION

Risk Dominant Identification

Potential project risks were initially identified through a literature review and mapped using the integration of the Work Breakdown Structure (WBS) and Risk Breakdown Structure (RBS). The identified risks were subsequently validated through expert judgment involving construction professionals with relevant expertise and experience in construction project management and building project implementation. The selected experts held Level 8 (Intermediate Expert) and Level 9 (Principal Expert) professional qualifications. Based on the identification and validation process, a total of 106 relevant risk items were obtained and used for further analysis. These identified risks were subsequently assessed using the Probability Impact Matrix (PIM) method to determine the risk level associated with each work package. The risk classification was determined based on the criteria presented in Table 1.

Table 1. Risk classification

Classification	Range
Low	0.05 – 0.07
Moderate	0.08 – 0.20
High	0.24 – 0.72

Source: Adapted from Project Management Institute (2017)

Based on the PIM classification criteria, each identified risk was categorized according three level low, moderate and high based on PIM matrix. The distribution of risk levels for each work package is presented in Table 2.

Table 2. Risk classification

No	Risk	Aspect			PI ctq
		Cost (*PIc*)	Time (*PIt*)	Quality (*PIq*)	
1	Preliminary Works	Moderate	Moderate	Moderate	Moderate
2	Structural Works				
2.1	Earthworks, Excavation and Foundation Works	Moderate	Moderate	Moderate	Moderate
2.2	Concrete Works	Moderate	Moderate	High	High
2.3	Reinforcement Works	Moderate	High	Moderate	High
2.4	Formwork Works	Moderate	Moderate	Moderate	Moderate
2.5	Structural Steel Roof Truss Works	Moderate	Moderate	High	High
3	Architectural Works				
3.1	Wall Construction Works	Moderate	High	Moderate	High
3.2	Ceiling Works	Low	Moderate	Moderate	Moderate
3.3	Floor and Wall Finishing Works	Moderate	Moderate	Moderate	Moderate
3.4	Door and Window Works	Moderate	High	Moderate	High
3.5	Painting and Waterproofing Works	Moderate	Moderate	Moderate	Moderate
3.6	Sanitary Fixture Works	Moderate	High	High	High
3.7	Signage Works	Moderate	Moderate	High	High

No	Risk	Aspect			PI ctq
		Cost (*PIc*)	Time (*PIt*)	Quality (*PIq*)	
3.8	Roof Covering Works	Moderate	Moderate	Moderate	Moderate
4	Mechanical, Electrical and Plumbing (MEP) Works				
4.1	Electrical Works	Moderate	High	Moderate	High
4.2	Plumbing Works	Moderate	Moderate	Moderate	Moderate
4.3	Fire Hydrant and Sprinkler System Works	Moderate	Moderate	Moderate	Moderate
4.4	Electronic Systems Works	Moderate	Moderate	Moderate	Moderate
4.5	Vertical Transportation Works	Moderate	Moderate	Moderate	Moderate
5	Interior Works	Moderate	Moderate	Moderate	Moderate
6	Road Works	Moderate	Low	High	High
7	Softscape Works	Moderate	High	Moderate	High

Source: Primary Data Processed (2025)

The dominant risk level for each work package was determined by considering the highest classification among the cost, quality, and schedule risk aspects. This approach was applied to represent the most critical risk exposure associated with each work package. The results indicated that 12 work packages were categorized as moderate risks, while 10 work packages were identified as high-risk work packages.

Integrate Expected Monetary Value at Cost, Time and Quality Aspect

The duration, probability values, and contract value of each work package served as the primary input data for the risk-based contingency cost analysis using the Expected Monetary Value (EMV) method. Each data set was utilized in the EMV calculations to estimate the contingency cost.

Table 3. Probability value, duration, and contract rate

No.	Risk	Pc	Pt	Pq	D	Contract Rate (IDR)
1	Preliminary Works	0.7	0.5	0.5	35	192,633,987.67
2	Structural Works					
2.1	Earthworks, Excavation and Foundation Works	0.3	0.5	0.7	49	9,674,753,023.33
2.2	Concrete Works	0.3	0.7	0.5	84	12,961,773,595.20
2.3	Reinforcement Works	0.3	0.5	0.5	84	33,028,984,496.66
2.4	Formwork Works	0.5	0.7	0.5	84	14,607,023,496.04
2.5	Structural Steel Roof Truss Works	0.3	0.5	0.7	56	6,126,367,326.01
3	Architectural Works	-	-	-		
3.1	Wall Construction Works	0.5	0.7	0.5	70	6,026,408,074.71
3.2	Ceiling Works	0.5	0.5	0.5	154	9,343,699,738.80
3.3	Floor and Wall Finishing Works	0.5	0.7	0.3	217	25,264,094,442.21
3.4	Door and Window Works	0.5	0.5	0.5	182	22,254,393,189.72
3.5	Painting and Waterproofing Works	0.5	0.5	0.7	161	3,289,865,882.55
3.6	Sanitary Fixture Works	0.3	0.7	0.7	21	1,154,447,937.43

No.	Risk	Pc	Pt	Pq	D	Contract Rate (IDR)
3.7	Signage Works	0.3	0.5	0.3	21	490,005,914.80
3.8	Roof Covering Works	0.3	0.7	0.7	35	2,221,937,405.20
4	Mechanical, Electrical and Plumbing (MEP) Works		-	-		
4.1	Electrical Works	0.5	0.5	0.5	140	23,740,524,383.56
4.2	Plumbing Works	0.5	0.5	0.5	91	2,708,361,429.07
4.3	Fire Hydrant and Sprinkler System Works	0.3	0.5	0.5	126	2,607,975,099.29
4.4	Electronic Systems Works	0.5	0.5	0.5	112	33,565,350,295.09
4.5	Vertical Transportation Works	0.3	0.3	0.7	140	4,026,000,000.00
5	Interior Works	0.5	0.5	0.5	42	2,387,436,000.00
6	Road Works	0.3	0.5	0.7	28	520,199,834.84
7	Softscape Works	0.5	0.7	0.5	70	8,503,972,784.31
					Amount	224,696,208,336.50

Source: Primary Data Processed (2025)

Based on the duration, probability values, and contract value of each work package, the Expected Monetary Value (EMV) was calculated for each project objective, namely cost, time, and quality. The resulting EMV values for each objective were then integrated to estimate the overall risk-based contingency cost for the project.

Table 4. EMV analysis for cost, time, and quality aspect

No	Risk	EMV c (IDR)	EMV t (IDR)	EMV q (IDR)	EMV ctq (IDR)
1	Preliminary Works	20,226,569	252,832	10,874,189	31,353,589
2	Structural Works				
2.1	Earthworks, Excavation and Foundation Works	435,363,886	17,777,359	764,595,731	1,217,736,976
2.2	Concrete Works	583,279,812	57,161,422	1,086,844,716	1,727,285,949
2.3	Reinforcement Works	1,486,304,302	208,082,602	1,864,486,175	3,558,873,080
2.4	Formwork Works	1,095,526,762	64,416,974	824,566,476	1,984,510,212
2.5	Structural Steel Roof Truss Works	275,686,530	12,865,371	719,174,260	1,007,726,161
3	Architectural Works				
3.1	Wall Construction Works	451,980,606	44,294,099	340,190,736	836,465,441
3.2	Ceiling Works	N/A	53,959,866	527,451,850	581,411,716
3.3	Floor and Wall Finishing Works	1,894,807,083	287,821,196	855,694,879	3,038,323,158
3.4	Door and Window Works	1,669,079,489	303,772,467	1,256,260,496	3,229,112,452
3.5	Painting and Waterproofing Works	246,739,941	19,862,565	259,998,101	526,600,607
3.6	Sanitary Fixture Works	51,950,157	2,545,558	135,520,643	190,016,358
3.7	Signage Works	22,050,266	385,880	24,652,198	47,088,343
3.8	Roof Covering Works	99,987,183	4,082,810	175,599,713	279,669,706

No	Risk	EMV c (IDR)	EMV t (IDR)	EMV q (IDR)	EMV ctq (IDR)
4	Mechanical, Electrical and Plumbing (MEP) Works				
4.1	Electrical Works	1,780,539,329	249,275,506	1,340,152,601	3,369,967,436
4.2	Plumbing Works	203,127,107	9,242,283	152,887,003	365,256,393
4.3	Fire Hydrant and Sprinkler System Works	117,358,879	12,322,682	147,220,194	276,901,756
4.4	Electronic Systems Works	2,517,401,272	140,974,471	1,894,764,024	4,553,139,768
4.5	Vertical Transportation Works	181,170,000	12,681,900	318,174,780	512,026,680
5	Interior Works	179,057,700	3,760,212	134,770,762	317,588,674
6	Road Works	23,408,993	N/A	61,066,259	84,475,251
7	Softscape Works	637,797,959	62,504,200	480,049,264	1,180,351,422
	Amount	13,972,843,825	1,568,042,255	13,374,995,050	28,915,881,131
	Percentage	6.22%	0.70%	5.95%	12.87%

Source: Primary Data Processed (2025)

The contingency cost estimated in this study was primarily influenced by the dominance of risks associated with several work packages that exhibited the highest EMVctq values, namely electronic systems installation (IDR 4,553,139,767.53), reinforcement works (IDR 3,558,873,079.52), electrical works (IDR 3,369,967,436.25), doors and windows installation (IDR 3,229,112,451.83), and floor and wall finishes (IDR 3,038,323,157.86). These work packages are characterized by a high level of complexity, require extensive multidisciplinary coordination, and have strong interdependencies with the project objectives of cost, quality, and time.

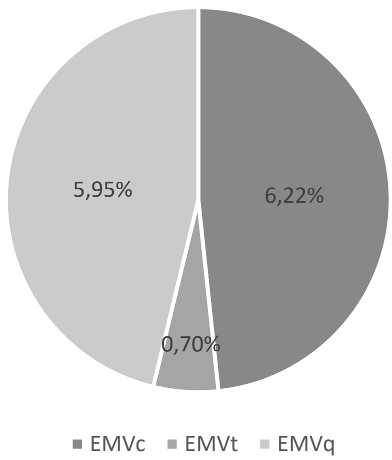

Figure 2. Distribution of Contingency Cost Contribution Based on Risk Aspects
Source: Adapted from Astana et al. (2025)

Any deviation occurring in these work packages may result not only in increased direct costs but also in rework, schedule delays, material replacement, and other corrective actions. Previous studies have identified rework as one of the primary factors contributing to cost overruns and project delays in construction projects, arising from execution errors, inadequate coordination, design or scope changes, and non-compliance with technical specifications.

Discussion in relation to previous studies

Based on the contribution of each risk aspect, the EMVc value of 6.22% contributed the largest proportion to the project's contingency cost requirement, followed by EMVq at 5.95%, while EMVt contributed only 0.70%. These results indicate that the project's risk exposure was influenced more significantly by the cost and quality aspects than by the time aspect. This finding suggests that the risks identified during the project execution phase were more likely to result in cost increases due to additional work, material adjustments, and quality improvement measures rather than schedule delays. The relatively high contribution of the quality aspect, which was comparable to that of the cost aspect, further indicates that construction quality plays a critical role in determining contingency cost requirements, as quality failures may lead to financial consequences through rework and corrective actions.

The substantial contribution of quality-related risks in this study is associated with the project's characteristics, which were designed in accordance with green building principles and implemented using the clean and green construction approach. Sustainable construction projects generally involve more complex technical requirements than conventional projects, particularly regarding material selection, building system integration, energy efficiency, and compliance with sustainability standards. Previous studies have shown that green building projects are exposed to additional risks related to design complexity, technology adoption, material selection, multidisciplinary coordination, and compliance with building performance requirements (Issa et al., 2025; Mohandes et al., 2025). Consequently, specification non-compliance or coordination failures among building systems, particularly within Mechanical, Electrical, and Plumbing (MEP) works such as electrical and electronic systems, may increase project costs due to rework and necessary design or construction modifications.

In addition to technical factors, contingency cost requirements are also affected by external uncertainties during project execution, including fluctuations in material prices, procurement cost variability, and supply chain disruptions. These conditions may increase the likelihood of cost escalation, particularly for work packages that rely heavily on specialized materials and technical specifications. The risk identification conducted in this study also revealed potential risks associated with material delivery delays and uncertainty in material costs, both of which may adversely affect project performance. Therefore, allocating an adequate contingency budget is essential to maintain project cost stability under changing conditions throughout the execution phase. In this study, the integration of the cost, time, and quality aspects in the EMVctq calculation demonstrates that project risks originate not only from the potential for direct cost increases but also from schedule delays and quality deficiencies that may indirectly generate additional costs during construction execution.

CONCLUSION

Based on the Probability Impact Matrix (PIM) analysis, dominant risks were identified from the moderate and high-risk categories. Moderate risks were found across all work packages, while high risks were identified in ten work packages, namely concrete works, reinforcement works, steel roof truss works, wall masonry works, doors and windows installation, sanitary works, signage works, electrical works, road works, and softscape works, indicating that these activities require priority attention for risk mitigation and contingency planning. Furthermore, the Expected Monetary Value (EMV) analysis estimated a risk-based contingency cost of IDR 28,915,881,130.60, equivalent to 12.87% of the analyzed work value. This estimate was derived from the integrated assessment of cost, time, and quality risks EMVctq, with the largest contribution from cost-related risks (6.22%), followed by quality-related risks (5.95%) and time-related risks (0.70%), indicating that the project's contingency requirement was driven primarily by cost and quality risks rather than schedule risks.

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