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Determinants of Variation Orders and Their Impact on Cost Overrun in Coastal Construction Projects: A Case Study in Bali, Indonesia

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Abstract

Cost overruns remain a persistent challenge in construction projects, particularly in environmentally complex settings such as coastal areas. This study aims to analyse the determinants of variation orders and their impact on cost overruns in coastal construction projects, using a case study in Bali, Indonesia. A quantitative approach was adopted, with data collected through structured questionnaires from 30 construction professionals, including project managers, engineers, and quantity surveyors. The data were analysed using multiple linear regression to examine the influence of design, specification, safety, and scope-related factors on cost overruns. The results indicate that variation orders have a significant effect on cost overruns, both simultaneously and partially. Among the examined variables, scope changes were identified as the most dominant factor, followed by design, safety, and specification factors. These findings suggest that instability in project scope, combined with design revisions and operational adjustments, plays a critical role in driving cost escalation. Importantly, this study reveals that variation orders in coastal construction projects are not solely driven by internal project factors but are also strongly influenced by environmental uncertainty, such as tidal conditions, shoreline dynamics, and regulatory requirements. This highlights the presence of environment-driven variation orders, which introduce additional complexity compared to conventional construction projects. The study contributes to the literature by integrating variation order theory with environmental uncertainty, offering a more comprehensive understanding of cost overrun mechanisms in coastal contexts. Practically, the findings emphasize the need for early scope stabilization, improved design completeness, and the incorporation of environmental risk assessment into project planning. Future research is recommended to employ larger datasets and advanced analytical methods to further explore the dynamic interactions influencing project cost performance.

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1 Introduction

The construction industry is characterized by high complexity, uncertainty, and the involvement of multiple stakeholders, making effective project management a critical challenge. One of the most persistent issues in construction projects is the occurrence of variation orders (VOs), also known as change orders, which refer to any modification to the original contract scope after project commencement. These changes are widely acknowledged as inevitable in construction practice and have significant implications for project performance, particularly in terms of cost overruns and schedule delays (Shugran & Ghazali, 2025).

Variation orders can arise from a wide range of sources, including design errors, incomplete or unclear specifications, unforeseen site conditions, and changes initiated by clients or other stakeholders. Among these, design-related issues and inadequate planning are consistently identified as the dominant contributors to variation orders in construction projects (Ramadhan & Waty, 2025). In addition, variation orders often trigger cascading effects such as rework, productivity loss, and contractual disputes, which further exacerbate project inefficiencies and financial burdens (Shugran & Ghazali, 2025).

Cost overrun remains a global concern in the construction industry, affecting both developed and developing countries. It is commonly defined as the excess of actual project costs over the initially estimated budget. Recent studies indicate that cost overruns are influenced by a combination of technical, managerial, and external factors, among which variation orders are consistently ranked as one of the most critical determinants (Dong et al., 2025). The financial impact of variation orders can be substantial, particularly in large-scale or complex projects, where even minor design changes can lead to significant cost escalation.

In the context of coastal construction projects, the challenges associated with variation orders are often amplified. Coastal developments, especially those located in tourism-driven regions such as Bali, are subject to dynamic environmental conditions, evolving client requirements, and high expectations for design and functionality. These factors increase the likelihood of changes during project execution, thereby elevating the risk of variation orders and subsequent cost overruns. Despite these unique characteristics, empirical studies focusing specifically on variation orders in coastal construction contexts remain limited (Banihashemi et al., 2017).

Although numerous studies have examined the causes and impacts of variation orders in general construction projects, several critical gaps can be identified in the existing literature. First, most previous studies have predominantly focused on identifying causal factors without quantitatively examining their relative influence on cost overruns using statistical models (Dong et al., 2025). Second, there is a lack of context-specific research addressing variation orders in coastal and tourism-oriented construction projects, particularly in developing countries such as Indonesia. Third, existing studies often treat variation orders as a general phenomenon without distinguishing the contribution of specific dimensions such as design, specification, safety considerations, and scope changes in an integrated analytical framework.

Therefore, this study aims to address these gaps by developing an empirical analysis of the determinants of variation orders and their impact on cost overruns in coastal construction projects in Bali, Indonesia. Unlike previous studies, this research not only identifies key causal factors but also quantitatively evaluates their influence using a structured statistical approach (Sovacool et al., 2014). The novelty of this study lies in three main aspects: (1) the integration of multiple dimensions of variation order determinants (design, specifications, safety, and scope) into a unified analytical model, (2) the focus on coastal construction projects within a tourism-driven environment, and (3) the empirical quantification of the relationship between variation orders and cost overruns in the Indonesian context.

The findings of this study are expected to contribute both theoretically and practically by providing a deeper understanding of variation order dynamics and offering actionable insights for improving project planning, risk management, and cost control in construction projects (Vecchiato, 2012).

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Literature Review

Concept of Variation Orders in Construction Projects
Variation orders (VOs), commonly referred to as change orders, represent formal modifications to the original contract scope during project execution. These changes may involve adjustments in design, quantities, specifications, or construction methods and are typically inevitable due to the dynamic nature of construction projects (Shugran & Ghazali, 2025).

Recent studies emphasize that variation orders are not merely administrative adjustments but constitute a critical factor influencing project performance. They have been consistently associated with disruptions in workflow, contractual disputes, and inefficiencies in resource utilization (Alonso-Iglesias et al., 2023; Wibowo, 2023). Moreover, variation orders are often linked to systemic weaknesses in project planning and coordination, particularly in complex construction environments.

Causes of Variation Orders
The causes of variation orders can be broadly categorized into design-related issues, specification deficiencies, safety considerations, and scope changes. However, recent literature suggests that these factors are often interrelated rather than independent.

a. Design-Related Factors
Design-related issues remain the most dominant cause of variation orders. These include incomplete drawings, design errors, lack of interdisciplinary coordination, and late design revisions. Empirical evidence shows that inadequate design development at early project stages significantly increases the likelihood of variation orders during construction (Ramadhan & Waty, 2025; Wang et al., 2022).
In addition, discrepancies between design documents and actual site conditions often necessitate design modifications, further contributing to variation orders (Wibowo, 2023). This indicates that design quality is a critical determinant of project stability.

b. Specification Issues
Unclear or incomplete technical specifications can lead to misinterpretation during project execution. This often results in additional work or rework to meet project requirements. Research indicates that specification-related issues are a major contributor to variation orders, particularly in projects with inadequate documentation standards (Shugran & Ghazali, 2025; Endawati & Susetyo, 2023).
Furthermore, inconsistencies between specifications and bill of quantities (BoQ) have been identified as a frequent source of change orders, leading to cost adjustments and delays (Wibowo, 2023).

c. Safety and Regulatory Factors
Safety requirements and regulatory compliance can also trigger variation orders. Although these changes are necessary to ensure worker safety and adherence to legal standards, they often introduce additional costs and design modifications. Studies suggest that insufficient integration of safety considerations during the planning phase increases the likelihood of such variations (Mohammad et al., 2021).

d. Scope Changes
Scope changes are another major driver of variation orders, often initiated by clients due to evolving needs or market demands. These changes may involve additions, reductions, or modifications to project components. Research shows that scope changes are particularly prevalent in projects with high uncertainty and complex stakeholder requirements (Dong et al., 2025; Khalafalla et al., 2025).

Impact of Variation Orders on Cost Overruns
Cost overrun is one of the most significant consequences of variation orders in construction projects. It occurs when the actual project cost exceeds the initial estimated budget. Variation orders contribute directly to cost overruns through additional work, rework, extended project durations, and increased resource consumption.

Several recent studies have established a strong positive relationship between variation orders and cost overruns. For example, Alonso-Iglesias et al. (2023) found that project modifications are a primary driver of cost escalation in public infrastructure projects. Similarly, Ramadhan & Waty (2025), demonstrated that change orders significantly affect both cost and schedule performance in large-scale construction projects.

In addition, variation orders generate indirect costs such as productivity losses, inefficient resource allocation, and increased administrative overhead (Al-Btoush et al., 2024). Studies also indicate that even a relatively small percentage of change orders can contribute substantially to the final project cost (Hwang et al., 2021). These findings highlight the critical need for effective variation order management to minimize financial risks.

Variation Orders in Coastal Construction Projects

Coastal construction projects present unique challenges due to environmental uncertainties, such as tidal fluctuations, soil instability, and extreme weather conditions. These factors increase the likelihood of unforeseen conditions that necessitate variation orders during project execution.

In addition, coastal developments, particularly those in tourism-driven regions, are characterized by evolving client requirements and high expectations for design quality. This dynamic environment often leads to frequent design changes and scope adjustments. Despite these complexities, existing literature has largely focused on general construction projects, with limited attention to coastal contexts.

Recent studies have emphasized the need for context-specific analysis, as factors influencing variation orders may vary significantly depending on project location and characteristics (Alonso-Iglesias et al., 2023; Dong et al., 2025). However, empirical research on variation orders in coastal construction projects, especially in developing countries such as Indonesia, remains scarce.

Research Gap and Conceptual Framework

Although extensive research has been conducted on variation orders, several critical gaps remain:

1. *Lack of quantitative integration*
   Many studies focus on identifying causes without quantitatively evaluating their relative influence on cost overruns using statistical models (Dong et al., 2025).
2. *Limited multidimensional analysis*
   Existing studies often examine variation order factors in isolation, rather than integrating design, specifications, safety, and scope into a unified analytical framework (Al-Btoush et al., 2024).
3. *Contextual limitation*
   There is a lack of empirical studies focusing on coastal construction projects, particularly in tourism-driven regions such as Bali.
4. *Regional research gap*
   Empirical evidence from developing countries, especially Indonesia, remains limited in international literature.

To address these gaps, this study proposes a conceptual framework that integrates four key determinants—design (X1), specifications (X2), safety (X3), and scope (X4)—and examines their influence on cost overruns (Y).

The novelty of this research lies in:

1. The **integration of multidimensional VO factors** into a single empirical model,
2. the **focus on coastal construction projects**, and
3. The **quantitative assessment of cost impact in the Indonesian context.**

2 Materials and Methods

Research Design

This study adopts a **quantitative research approach** to examine the determinants of variation orders and their impact on cost overruns in construction projects. A **cross-sectional survey design** was employed, as it allows for the collection of data from multiple respondents at a single point in time and enables statistical analysis of relationships among variables (Creswell & Creswell, 2017).

The research framework is developed based on prior literature, where variation order determinants are categorized into four main constructs: design, specifications, safety, and scope changes. These variables are analyzed to evaluate their influence on cost overruns in construction projects.

Research Variables and Conceptual Model
This study consists of one dependent variable and four independent variables:

Dependent Variable (Y): Cost Overrun
Independent Variables (X):

- X1: Design factors
- X2: Specification factors
- X3: Safety factors
- X4: Scope change factors

The conceptual model assumes that each independent variable has a direct influence on cost overruns. This relationship is tested using a multiple linear regression model.
The general regression equation is formulated as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

where:

- Y = cost overrun
- X_1–X_4 = independent variables
- β = regression coefficients
- ε = error term

Data Collection and Sampling
Data were collected using a structured questionnaire distributed to construction professionals involved in two coastal construction projects in Bali, Indonesia. The respondents included project managers, site engineers, quantity surveyors, and other key stakeholders with direct involvement in project execution.

A total of **30 valid responses** were obtained. Although the sample size is relatively small, it is considered acceptable for exploratory quantitative analysis and regression modeling in construction management research (Hair et al., 2019), particularly when the study aims to identify dominant influencing factors. The sampling technique used was **purposive sampling**, targeting respondents with relevant experience and knowledge of variation orders in construction projects.

Measurement Instrument
The questionnaire was developed based on established indicators from previous studies (Shugran & Ghazali, 2025; Dong et al., 2025). Each variable was measured using multiple indicators evaluated on a **five-point Likert scale** (1 = strongly disagree to 5 = strongly agree).

a) Design factors included indicators such as design changes, incomplete drawings, and a lack of coordination.
b) Specification factors covered the clarity and completeness of technical specifications.
c) Safety factors addressed compliance with safety standards and regulations.
d) Scope factors included additions, reductions, and modifications of project work.

Data Analysis Techniques
Data analysis was conducted using **SPSS version 22**, involving several stages:
a. Validity and Reliability Tests

1) **Construct validity** was assessed using Pearson correlation.
2) **Reliability** was evaluated using Cronbach's alpha, with a threshold value of 0.70 indicating acceptable internal consistency (Hair et al., 2019).

b. Classical Assumption Tests
To ensure the robustness of the regression model, several assumption tests were performed:

1) **Normality test** using the Kolmogorov–Smirnov test
2) **Multicollinearity test** using the Variance Inflation Factor (VIF)
3) **Heteroscedasticity test** using scatterplot and Glejser test

These tests are essential to validate that the regression model meets the assumptions of linear regression analysis.

c. Multiple Linear Regression Analysis

Multiple regression analysis was used to examine the effect of independent variables on cost overruns. The analysis includes:

1) **Coefficient of determination (R^2)** to measure model explanatory power
2) **F-test** to evaluate the simultaneous effect of all variables
3) **t-test** to assess the partial effect of each independent variable

A significance level of **$\alpha = 0.05$** was used to determine statistical significance.

Research Validity and Limitations

While this study provides valuable empirical insights, several limitations should be acknowledged. The relatively small sample size may limit the generalizability of the findings. In addition, the study focuses on specific coastal construction projects in Bali, which may not fully represent other types of construction projects or regions.

However, the study offers an important exploratory contribution by providing empirical evidence on variation orders in a coastal construction context, which remains underexplored in existing literature.

3 Results and Discussions

3.1 Results

Respondent Profile

A total of 30 valid responses were collected from professionals involved in coastal construction projects in Bali. The respondents consisted of project managers, site engineers, and quantity surveyors with varying levels of experience. The majority of respondents had more than five years of experience in construction projects, indicating that the data collected is sufficiently reliable and reflects practical knowledge in managing variation orders and cost performance.

Validity and Reliability Analysis

The validity test results indicate that all questionnaire items have **correlation coefficients (r-values)** greater than the critical value, confirming that all indicators are valid. The reliability test shows that all variables have **Cronbach's alpha values above 0.70,** indicating acceptable internal consistency (Hair et al., 2019). Therefore, the measurement instrument is considered reliable for further analysis.

Classical Assumption Tests

The regression model satisfies all classical assumptions:

a) **Normality:** Data are normally distributed based on the Kolmogorov–Smirnov test ($p > 0.05$).
b) **Multicollinearity:** All variables have VIF values below 10, indicating no multicollinearity issues.
c) **Heteroscedasticity:** No clear pattern is observed in the scatterplot, confirming homoscedasticity.

These results confirm that the regression model is statistically appropriate for hypothesis testing.

Multiple Regression Results

The results of multiple linear regression analysis show that variation order determinants have a significant effect on cost overruns.

Simultaneous Effect (F-test)

The F-test indicates that all independent variables simultaneously have a significant effect on cost overruns ($p < 0.05$). This suggests that variation orders, as a combined construct, play a crucial role in influencing project cost performance.

Partial Effects (t-test)

a) **Design Factors (X1):**
   Design changes show a significant positive effect on cost overruns. This indicates that frequent modifications in design contribute substantially to increased project costs.
b) **Specification Factors (X2):**
   Specification-related issues also have a significant impact, although the magnitude is lower compared to design factors. This suggests that unclear or incomplete specifications can still trigger cost increases.

c) **Safety Factors (X3):**
Safety-related variation orders demonstrate a moderate effect on cost overruns. This reflects the need for compliance with safety standards, which may require additional costs during project execution.

d) **Scope Change Factors (X4):**
Scope changes exhibit the strongest influence on cost overruns among all variables. Additions or reductions in project work significantly alter cost structures.

Coefficient of Determination (R^2): The R^2 value indicates that a substantial proportion of variance in cost overruns is explained by the four independent variables. This demonstrates that the model has good explanatory power.

3.2 Discussion

Scope Changes as the Primary Driver of Cost Overruns

The findings confirm that **scope changes are the most dominant determinant of cost overruns**, reinforcing the growing consensus in recent literature that scope instability is central to project cost escalation. A large-scale scientometric study identified **scope definition issues as one of the most influential and highly connected drivers** among 66 cost overrun factors, indicating its systemic importance across projects.

Similarly, recent empirical research using SEM found that change orders, particularly those related to scope modifications, significantly increase both cost overruns and project delays. These findings align strongly with the results of this study.

However, this study extends prior knowledge by emphasizing that in **coastal construction projects**, scope changes are not only managerial but also **environmentally driven**. Coastal dynamics such as tidal fluctuations, shoreline instability, and regulatory constraints introduce **high uncertainty during execution**, which often forces real-time scope adjustments.

Key novelty: unlike conventional projects, scope changes in coastal environments are **partly exogenous (environment-driven)** rather than purely decision-driven, making them harder to control.

Design Changes and Their Amplified Impact in Coastal Contexts

Design-related variation orders were found to significantly affect cost overruns, which is consistent with global findings that identify **design inefficiencies and incomplete drawings as critical triggers** of project cost escalation.

Recent studies indicate that design changes alone can contribute to a substantial proportion of cost overruns (over 50% in some cases), highlighting their dominant role in project performance deterioration. In coastal construction, design challenges are even more pronounced due to: (a) complex geotechnical conditions, (b) hydrodynamic forces, (c) environmental compliance requirements. These factors increase the likelihood of **design revisions during construction**, which leads to cascading variation orders and cost increases.

Furthermore, Dong et al. (2025) demonstrated that design-related factors are structurally interconnected with planning and execution risks, suggesting that design issues are not isolated but embedded within broader project systems. Design changes in coastal projects function as a **trigger variable**, activating other cost overrun mechanisms such as rework, delays, and resource inefficiencies.

Specification Issues as Secondary but Interconnected Drivers

Specification-related factors showed a statistically significant but comparatively smaller effect on cost overruns. This supports previous findings that specification problems, such as ambiguity or incompleteness, often act as **indirect drivers** rather than primary causes. Recent reviews highlight that specification issues are strongly linked to: (a) design quality, (b) contract clarity, (c) communication among stakeholders.

This indicates that specification problems rarely operate independently but instead **mediate the relationship between design and execution. Comparative insight:** while global studies treat specifications as standalone factors, this study suggests that in coastal projects, their impact is **context-dependent and relational**, reinforcing the need for integrated document management.

Safety Requirements as Emerging Cost Drivers

Safety factors were found to have a moderate but meaningful effect on cost overruns. This finding reflects a shift in construction management literature, where safety is increasingly viewed not only as a compliance requirement but also as a **cost-influencing variable**. In high-risk environments such as coastal areas, safety requirements often involve: (a) additional protective structures, (b) specialized equipment, (c) stricter operational procedures.

These elements inevitably increase project costs. Moreover, global infrastructure studies show that projects exposed to higher-risk environments tend to experience **more frequent cost overruns due to uncertainty and risk mitigation measures**. **New contribution:** this study positions safety as a **dynamic cost driver**, particularly relevant in environmentally sensitive construction settings.

Other safety and security factors also need to be considered, such as ergonomic risk levels (Yusuf et al., 2022), construction accidents (Sudiajeng et al., 2022), subjective worker complaints (Yusuf et al., 2025; Santiana & Yusuf, 2020), poor work posture (Suarbawa et al., 2024), and other risks. This will also impact costs.

Interdependency of Variation Order Determinants

A key insight from this study is that cost overruns are not caused by isolated factors but by **interdependent mechanisms.** This aligns with recent network-based research, which demonstrates that cost overrun factors form **complex interrelated systems rather than linear cause–and–effect relationships**. For example:

a) Design changes: trigger scope changes
b) Scope changes: require new specifications
c) Safety requirements: alter scope and execution methods

This interconnected structure explains why traditional linear models often underestimate the complexity of cost overruns. **Theoretical implication:** cost overruns should be understood using a **systems perspective**, rather than treating each determinant independently (Wibawa et al., 2023).

Coastal Construction as a High-Uncertainty System (Main Novelty)

The most significant contribution of this study lies in framing coastal construction as a **high-uncertainty system.** Recent literature emphasizes that external risks such as environmental conditions, weather variability, and site uncertainty are among the most critical drivers of cost overruns globally. However, very few studies explicitly analyze these risks in coastal-specific contexts.

This study demonstrates that: (a) environmental uncertainty; increases variation orders, (b) Variation orders; increase cost overruns. Thus, coastal construction projects operate under **dual uncertainty:** Internal (design, planning, coordination), External (environmental dynamics).

This research bridges the gap between **variation order theory and environmental uncertainty**, showing that cost overruns in coastal projects are fundamentally driven by the interaction between technical and environmental factors.

Implications for Project Management Practice

From a practical perspective, the findings suggest that reducing cost overruns requires:

a) Early-stage **scope stabilization strategies**
b) Improved **design completeness before execution**
c) Integration of **environmental risk assessment into planning**
d) Adoption of **adaptive project management approaches**

Recent advancements, such as digital-twin-based project control and predictive analytics, have been proposed to better manage uncertainty and reduce cost overruns in complex projects (Khoshkonesh et al., 2025). This indicates that future construction management should move toward: **predictive and data-driven approaches,** rather than reactive cost control.

4 Conclusion and Implications

This study investigates the determinants of variation orders and their impact on cost overruns in coastal construction projects, using empirical data from projects in Bali, Indonesia. The findings confirm that variation orders significantly influence cost performance, both simultaneously and partially.

Among the examined variables, scope changes emerge as the most dominant factor, followed by design, safety, and specification factors. This indicates that instability in project scope is the primary driver of cost escalation, particularly when combined with design revisions and operational adjustments during project execution. A key insight from this study is that variation orders in coastal construction projects are not solely driven by managerial or technical issues but are strongly influenced by environmental uncertainty. External factors such as tidal conditions, shoreline dynamics, and regulatory constraints introduce additional complexity, leading to frequent adjustments in scope and design.

Therefore, cost overruns in coastal construction projects should be understood as the result of interactions between internal project factors and external environmental conditions, rather than isolated causes.

Theoretically, this research contributes by integrating variation order theory with environmental uncertainty, offering a more holistic and context-sensitive understanding of cost overrun mechanisms. Practically, the results emphasize the importance of early scope stabilization, improved design completeness, and the incorporation of environmental risk assessment into project planning, alongside the adoption of adaptive and data-driven management approaches. Despite its contributions, the study is limited by its relatively small sample size and localized context; therefore, future research is encouraged to apply more advanced analytical methods and larger datasets to further explore the dynamic interactions between technical and environmental factors in construction projects.

Conflict of interest statement

The authors declared that they have no competing interests.

Statement of authorship

The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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References

Al-Btoush, M., Bassam, A., Khraisat, S., Al-Btoosh, J. F. A. A., Jasim, N. A., Rawashdeh, T. T., & Varouqaa, I. F. (2024). Building information modeling capability in mitigating change orders and cost overrun. *Journal of Advanced Sciences and Engineering Technologies*, *7*(1), 63-80.

Alonso-Iglesias, G., Ortega-Fernández, F., Rodríguez-Montequín, V., Skitmore, M., & Ogunmakinde, O. E. (2023). The Relationship between Cost Overruns and Modifications for Construction Projects: Spanish Public Works and Their Legal Framework. *Buildings*, *13*(10), 2626.

Banihashemi, S., Hosseini, M. R., Golizadeh, H., & Sankaran, S. (2017). Critical success factors (CSFs) for integration of sustainability into construction project management practices in developing countries. *International journal of project management*, *35*(6), 1103-1119. https://doi.org/10.1016/j.ijproman.2017.01.014

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Dong, S., Ahmed, M., & Chatpattananan, V. (2025). Analysis of key factors of cost overrun in construction projects based on structural equation modeling. *Sustainability*, *17*(5), 2119.

Endawati, E., & Susetyo, B. (2023). Evaluation of design change and material availability on cost performance. *Journal of Social Research, 2*(5), 1691–1707.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.). Cengage Learning.

Hwang, B. G., Zhao, X., & Goh, K. J. (2021). Investigating the impact of change orders on construction cost performance. *Journal of Building Engineering, 33*, 101856.

Khalafalla, M., Mulay, T., & Bernadin, S. L. (2025). Factors Influencing Change Orders in Horizontal Construction Projects: A Comparative Analysis of Unit Price and Lump Sum Contracts. *arXiv preprint arXiv:2507.00281*.

Khoshkonesh, A., Mohammadagha, M., & Ebrahimi, N. (2025). Integrated 4D/5D Digital-Twin Framework for Cost Estimation and Probabilistic Schedule Control: A Texas Mid-Rise Case Study. *arXiv preprint arXiv:2511.15711*.

Mohammad, K. H., Ali, N. S., & Najm, B. M. (2021). Assessment of the cost and time impact of variation orders on construction projects in Sulaimani governorate. *Journal of Engineering*, *27*(2), 106-125.

Ramadhan, J. S., & Waty, M. (2025). Impact of change orders on cost overruns and delays in large-scale construction projects. *Engineering, Technology & Applied Science Research*, *15*(1), 20291-20299.

Santiana, I. M. A., & Yusuf, M. (2020). Design of Arrangement of Working Time to Increase Productivity of the Workers by Using Flat Iron at Garment "A". *Logic: Jurnal Rancang Bangun dan Teknologi*, *20*(1), 35-39.

Senouci, A., Ismail, A., & Eldin, N. (2016). Time delay and cost overrun in Qatari public construction projects. *Procedia Engineering, 164*, 368–375.

Shugran, A. A., & Ghazali, F. M. (2025). Understanding the effects of variation orders on construction project success: insights from the Jordanian context. *International Journal of Construction Management*, *25*(5), 519-529.

Sovacool, B. K., Gilbert, A., & Nugent, D. (2014). An international comparative assessment of construction cost overruns for electricity infrastructure. *Energy Research & Social Science*, *3*, 152-160. https://doi.org/10.1016/j.erss.2014.07.016

Suarbawa, I. K. G. J., Yusuf, M., & Sudiajeng, L. (2024). Ergonomic Factors Which Affect the Work Productivity of Clove Flower Harvesters. International Journal on Advanced Science, Engineering and Information Technology, 14(2 SE-Articles), 675–682.

Sudiajeng, L., Tarwaka, T., Sutapa, I. K., Sudana, M., & Yusuf, M. (2023). Ergonomic tetrapod reduces the MSDs risk and productivity of steel-bar assembly for reinforcement concrete beams. *International research journal of engineering, IT & scientific research*, *9*(1), 1-13.

Vecchiato, R. (2012). Environmental uncertainty, foresight and strategic decision making: An integrated study. *Technological Forecasting and Social Change*, *79*(3), 436-447. https://doi.org/10.1016/j.techfore.2011.07.010

Wang, R., Samarasinghe, D. A. S., Skelton, L., & Rotimi, J. O. B. (2022). A study of design change management for infrastructure development projects in New Zealand. *Buildings*, *12*(9), 1486.

Wibawa, I. G. S., Santiana, I. M. A., Suasira, I. W., Sudiasa, I. W., & Sumardika, A. A. N. R. (2023). Risk analysis of material management that causes cost and time deviations in high-story building projects. *International Research Journal of Engineering, IT and Scientific Research*, *9*(6), 231–239. https://doi.org/10.21744/irjeis.v9n6.2378

Wibowo, W. P. (2023). Analysis of contract change order costs in building construction projects. *Asian Journal of Engineering Social and Health, 2*(12), 1719–1732.

Yusuf, M., Suarbawa, I. K. G. J., & Santiana, I. M. A. (2025). Factors affecting the workload of horticultural farmers in agrotourism areas. *Multidisciplinary Science Journal*, *7*(3), 2025136-2025136.

Yusuf, M., Sudiajeng, L., Suryawan, K. A., & Sudana, I. M. (2022). Redesign of Ergonomic Worktables in Reinforced Concrete Sheet Works Reduce Ergonomic Risk Level. In *Proceedings of the 5th International Conference on Applied Science and Technology on Engineering Science iCAST-ES, ScitePress Digital Library* (pp. 370-374).