Impact of Change Orders on Cost Overruns and Delays in Large-Scale Construction Projects

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ABSTRACT

This study investigates the impact of Change Orders (CO) on construction project performance, focusing on cost overruns and project delays. Partial least square structural equation modeling was used to analyze the relationships between key causal factors, including design changes, planning errors, and project outcomes. Data were collected from 127 construction practitioners involved in large-scale projects managed by PT XYZ, a leading Indonesian contractor. The analysis identifies that design changes contribute to 56.5% of cost overruns and 40% of project delays, while planning errors account for 34.5% of cost overruns and 23.1% of delays. These findings highlight the critical importance of improving project planning accuracy and enhancing design management processes to reduce the adverse effects of CO. Structured protocols for managing CO, better coordination among stakeholders, and adopting advanced technologies are recommended to minimize their effect. These insights are particularly relevant for large-scale projects where CO frequently disrupt budgets and timelines. By addressing these issues, project managers can enhance overall performance and reduce risks associated with cost and time escallations. This research provides practical strategies applicable to various construction contexts, supporting more efficient project delivery and better management of CO.

Keywords-change orders; cost overrun; project delays; PLS-SEM; design changes; planning errors

I. INTRODUCTION

Construction projects are inherently complex and dynamic, frequently undergoing modifications during their lifecycle [1]. One of the most significant challenges in construction projects is managing Change Orders (CO), which involve alterations in design, scope, or other project parameters after the initial contract has been established [2, 3]. CO often result in delays, budget overruns, and quality defects, disrupting planned schedules and resource allocation [4-7]. For PT XYZ, a prominent contractor in Indonesia, CO have notably impacted project efficiency and budget management, raising critical concerns for the industry. Globally, studies have identified several drivers of CO, including design errors, evolving client requirements, planning inaccuracies, and unforeseen site conditions [4-6, 8, 9]. These factors consistently contribute to inefficiencies, rework, and material waste, with rework alone accounting for up to 30% of construction costs [10-12]. Despite such findings, most existing studies focus on qualitative assessments or specific case studies, lacking a robust statistical framework to quantify the causal relationships between CO factors and their impacts.

In Indonesia, and particularly within PT XYZ, CO are often triggered by technical miscalculations, gaps in contract documentation, and coordination issues among stakeholders. These issues lead to substantial cost escalations and extended project timelines [5, 13-15]. However, the understanding of how these factors quantitatively influence project outcomes remains limited, underscoring the need for localized, data-driven research. To address this gap, this study employs a structured dataset comprising six variables (four exogenous variables and two endogenous variables) validated by experts to examine the causes and impacts of COs in PT XYZ's large-scale construction projects. The variables and indicators were derived from a thorough literature review and refined through expert validation to ensure contextual relevance [13, 16, 17]. By leveraging Partial Least Squares Structural Equation Modeling (PLS-SEM), this research offers a novel approach to understanding and mitigating the impacts of CO. The findings aim to contribute actionable recommendations for improving project management practices and reducing inefficiencies caused by CO, particularly in developing countries.

II. RESEARCH METHODOLOGY

A. *Research Design*

This study investigates the impact of CO on project costs and delays in the large-scale construction projects managed by PT XYZ. A structured dataset, derived from prior research and validated by industry experts, evaluates relationships between CO causes and impacts. PLS-SEM was used to analyze these relationships and provide robust statistical insights [3, 13, 18].

B. *Dataset Development and Validation*

The dataset comprises six variables: four exogenous variables (causal factors) and two endogenous variables (impacts), with a total of 17 indicators. These variables were derived from an extensive literature review [3, 14, 18, 19] and validated through structured questionnaires administered to 10 expert practitioners at PT XYZ [5, 26]. This validation ensured the dataset's relevance to large-scale construction projects in Indonesia and its alignment with global best practices [16, 18, 20]. To establish theoretical grounding, key references were linked to each indicator (see Tables II and III). This approach bridges prior research with practical applications in construction project management and supports a robust analysis of CO impacts [13, 21, 22].

C. *Questionnaire Survey*

Data were collected from 127 respondents involved in large-scale construction projects managed by PT XYZ, representing a response rate of 94.78% from the 134 distributed questionnaires [2, 23-25]. The structured questionnaire assessed each indicator's relevance and significance using a 6-point Likert scale, avoiding neutral responses. The scale ranged from "1" (Strongly Disagree) to "6" (Strongly Agree) to ensure respondents leaned towards agreement or disagreement, improving interpretability.

TABLE I. LIKERT SCALE DEFINITION

Scale value	Description	Purpose
1	Strongly Disagree	Respondent completely disagrees with the statement
2	Disagree	Respondent disagrees with the statement
3	Slightly Disagree	Respondent somewhat disagrees with the statement
4	Slightly Agree	Respondent somewhat agrees with the statement
5	Agree	Respondent agrees with the statement
6	Strongly Agree	Respondent completely agrees with the statement

D. *Data Collection*

The sample size adhered to the "10 times rule" of PLS-SEM, requiring at least 10 times the indicators for the most complex construct [27, 28]. With five indicators in the most complex construct, the minimum sample size was 50 [29, 30]. The achieved size of 127 exceeded this requirement, ensuring statistical robustness [7, 31].

E. *Summary of Variables and Indicators*

The variables and indicators are summarized in Tables II and III. Exogenous variables represent CO causes, while endogenous variables capture their impacts. Key references substantiate each variable's theoretical basis.

TABLE II. EXOGENOUS VARIABLES AND INDICATORS

No	Exogenous variables (causes of CO)	Indicators	References
X1	Design Changes	X1.1 Technical specification changes	[1, 4, 18, 32, 33]
		X1.2 Addition/reduction of scope	[3, 5, 14, 15, 18]
		X1.3 Design errors	[18, 32, 34, 35]
		X1.4 Mismatch between design and site conditions	[13, 34-37]
		X1.5 Aesthetic or architectural changes	[3, 18, 32, 34]
X2	Planning Errors	X2.3 Technical miscalculations	[10, 11, 18, 33, 38]
		X2.4 Changes in execution methods	[5, 12, 15, 21, 33]
X4	Project Owner's Needs	X4.1 Additional work requests by owner	[4-6, 39]
		X4.3 Specification changes during execution	[4, 6, 13, 34]
X10	Material Quality and Availability	X10.1 Unavailable materials	[3, 12, 18, 36, 37]
		X10.4 Dependence on imported materials	[12, 18, 32, 36, 39]

TABLE III. ENDOGENOUS VARIABLES AND INDICATORS

No	Endogenous variables (impacts of CO)	Indicators	References
Y1	Increased Total Project Costs	Y1.2 Unexpected cost increases	[3, 14, 15, 18, 40]
		Y1.5 Cost increases due to project delays	[18, 21, 32, 33, 34]
		Y1.7 Cost increases related to redesign	[3, 18, 32, 33, 35]
Y2	Project Completion Delays	Y2.1 Delays due to design revisions	[1, 13, 18, 32, 34]
		Y2.6 Delays due to schedule adjustments	[13, 33, 34, 38, 41]
		Y2.8 Delays due to additional approvals	[18, 21, 34, 40]

F. *Partial Least Squares Structural Equation Modeling*

PLS-SEM analyzed the relationships between CO causes and impacts.

- Measurement Model (Outer Model): Indicators were evaluated using loadings (>0.7), Composite Reliability (CR > 0.7), and Average Variance Extracted (AVE > 0.5) [42-45].
- Structural Model (Inner Model): Path coefficients and R-squared values assessed the relationships between variables [42, 46, 47].

Bootstrapping with 5,000 subsamples tested statistical significance:

- T-Statistic: Values >1.96 indicated significance at 95% confidence [3, 44].
- P-Values: Values below 0.05 confirmed that the relationships were statistically significant [6, 48, 49].

All analyses were conducted using SmartPLS 4.0, ensuring robust, reliable results for understanding CO impacts on project costs and delays [5, 7, 33, 42, 44]. The combination of the

PLS-SEM algorithm and bootstrapping ensured that the results were robust and reliable, providing a comprehensive understanding of how CO influence project costs and delays [5, 6, 34, 37, 50, 51].

III. DATA ANALYSIS AND RESULTS

A. *Data Analysis*

1) *Model Validity and Reliability*

To ensure the validity and reliability of the constructs, Cronbach's Alpha (α), CR, and AVE were analyzed using the PLS-SEM algorithm, which calculates these metrics by estimating the consistency of indicators within a construct and the variance captured relative to the measurement error. This ensures a robust evaluation of construct validity and reliability. These measures confirm the internal consistency and convergent validity of the constructs, adhering to established thresholds [42, 44].

TABLE IV. COMPOSITE RELIABILITY, CRONBACH'S ALPHA, AND AVE

Indicator	α	CR	AVE
X1 (Design Changes)	0.932	0.941	0.652
X2 (Planning Errors)	0.872	0.891	0.659
Y1 (Cost Increase)	0.917	0.926	0.685

High values of α and CR (above 0.7) confirm the strong internal consistency of the constructs, while AVE values exceeding 0.5 validate adequate convergent validity [44]. These findings ensure that the constructs reliably measure the intended variables.

2) *Model Fit*

The goodness of fit was evaluated using the Standardized Root Mean Square Residual (SRMR), calculated through the PLS-SEM algorithm. SRMR was chosen as it effectively measures the discrepancies between observed and predicted data, providing a clear assessment of model fit [42, 44]. An SRMR value below 0.08 is indicative of an acceptable model fit [42].

TABLE V. GOODNESS OF FIT (GOF) INDICATORS

GOF indicator	Saturated model	Estimated model
SRMR	0.058	0.058

The SRMR value of 0.058 confirms a strong fit between the model and the data, validating the structural relationships.

B. *Results*

1) *Significance Testing*

The relationships between exogenous (causal) and endogenous (impact) variables were analyzed using PLS-SEM bootstrapping. This method evaluates path coefficients, T-statistics, and P-values to assess the significance of hypothesized relationships [44].

TABLE VI. PATH COEFFICIENTS AND T-STATISTICS

Path	Original Sample (O)	T-Statistics	P-Values	Conclusion
X1 → Y1	0.565	4.990	0.000	Accepted
X2 → Y1	0.345	5.317	0.000	Accepted
X1 → Y2	0.400	3.439	0.001	Accepted
X2 → Y2	0.231	2.499	0.012	Accepted

The results confirm that design changes (X1) and planning errors (X2) significantly influence cost increases (Y1) and project delays (Y2). Path coefficients above 0.3 indicate substantial relationships, while P-values below 0.05 ensure statistical significance [13, 18, 32].

2) *Structural Model Visualization*

Figures 1-3 provide a graphical representation of the structural model, illustrating the relationships between CO causes and their impacts on cost and delay outcomes.

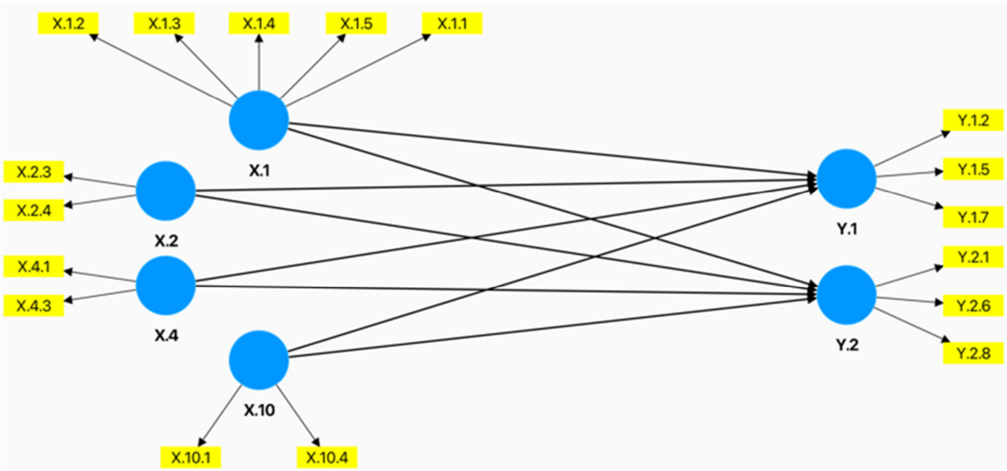

Fig. 1. Initial structural model: CO causes and impacts.

Figure 1 provides a detailed representation of the hypothesized relationships between X1 (Design Changes), X2 (Planning Errors), and their respective impacts on Y1 (Cost Increases) and Y2 (Project Delays). The paths highlight the direction and strength of influence for each causal variable, as determined by the PLS-SEM algorithm. The structural model emphasizes how critical factors like design changes and planning errors contribute to project inefficiencies.

Path coefficients illustrate the magnitude of influence exerted by causal variables (X1 and X2) on impact variables (Y1 and Y2). Outer loadings confirm the validity of individual indicators for each construct. Paths with P-values below 0.05 are highlighted, underscoring statistically significant relationships between variables.

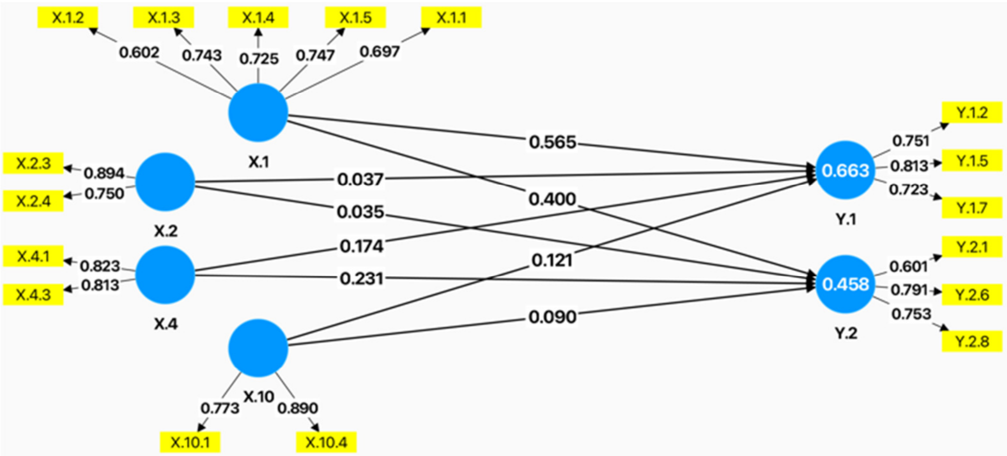

Fig. 2. Path coefficients and outer loadings.

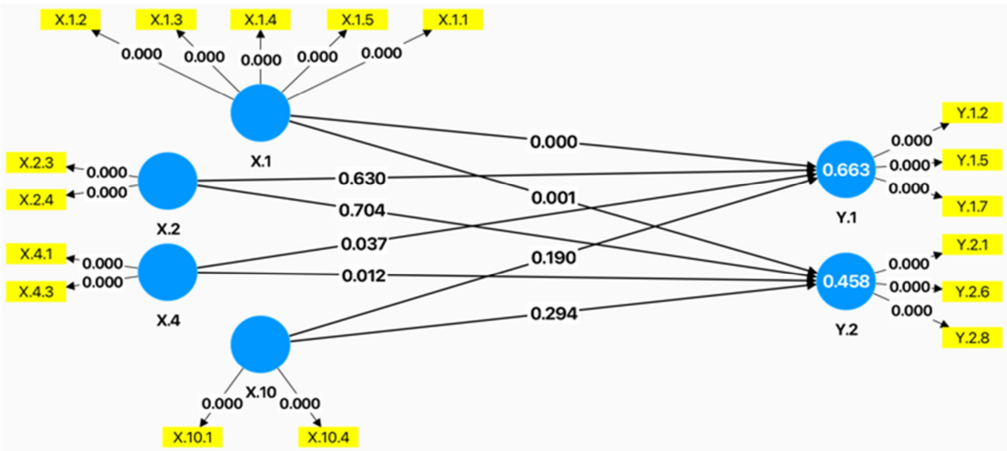

Fig. 3. Significance levels (P-values) in the structural model.

3) Hypothesis Testing Result

The hypotheses tested in this study are summarized in Table VII.

TABLE VII. HYPOTHESIS TESTING RESULTS

Hypothesis	Path Coefficient	T-statistic	P-value	Conclusion
H1: X1 → Y1	0.565	4.990	0.000	Design changes significantly increase project costs.
H2: X1 → Y2	0.400	3.439	0.001	Design changes significantly delay project timelines.
H3: X2 → Y1	0.345	5.317	0.000	Planning errors significantly increase project costs.
H4: X2 → Y2	0.231	2.499	0.012	Planning errors significantly delay project timelines.

All hypotheses are accepted, reinforcing the critical need to address design changes and planning errors to mitigate cost and schedule overruns in large-scale construction projects [18, 44].

IV. DISCUSSION

This study evaluates the impact of CO on cost increases and project delays in construction projects managed by PT XYZ. The relationships between CO causes and their effects on project performance were analysed with PLS-SEM. The findings emphasize the significant roles of design changes and planning errors in driving cost and time overruns.

A. Key Influences on Project Costs and Delays

- Design Changes (X1): The analysis reveals that design changes significantly contribute to cost increases and project delays. The path coefficients (X1 → Y1 = 0.565, X1 → Y2 = 0.400) demonstrate that design modifications often necessitate scope adjustments, rework, additional resources, and extended timelines. These results align with prior studies identifying design alterations as a major cause of project inefficiencies [36, 44, 52]. Within PT XYZ, recurring design mismatches with site conditions further underscore the need for precise initial design assessments and site-specific adaptations [32, 34, 36]. Addressing these mismatches through early-stage validation processes is critical to minimize disruptions.

- Planning Errors (X2): Planning errors also have a substantial impact on project outcomes (X2 → Y1 = 0.345, X2 → Y2 = 0.231). Issues such as insufficient documentation, inaccurate cost estimates, and scheduling inefficiencies exacerbate project disruptions. These findings are consistent with the literature highlighting the importance of robust pre-construction planning [53, 54]. Specifically, in PT XYZ's projects, gaps in planning documentation often result in stakeholder miscommunication, further amplifying delays and cost overruns [55, 56]. Strengthening planning processes could address these challenges effectively.

B. Practical Implications for Project Management

The findings offer actionable insights to enhance project management practices for large-scale construction projects:

- Enhancing Design Review Processes: Implementing rigorous design review and verification procedures during the planning phase is essential to reduce risks associated with design changes. Involving cross-disciplinary teams early in the project lifecycle can help identify inconsistencies and align designs with project goals [13, 36, 57]. This proactive approach reduces costly adjustments later in the project lifecycle, as reflected by the significant path coefficient of X1 → Y1 (0.565) [13, 32, 36].

- Improving Planning Accuracy: Integrating advanced tools such as Building Information Modeling (BIM) can improve planning accuracy by enabling better visualization of project stages and resources [39, 58, 58, 59]. This aligns with the observed path coefficient of X2 → Y1 (0.345), which underscores the critical role of planning accuracy in mitigating cost overruns. Moreover, adopting risk-based planning methodologies allows preparing for potential disruptions through contingency measures [15, 41, 59].

- Strategic Change Order Management: Establishing structured protocols for processing CO is crucial in minimizing disruptions. Introducing CO impact assessment tools within PT XYZ's workflow could streamline evaluations and expedite decision-making processes [3, 18, 15, 60, 61]. Such tools are essential to mitigate the effects of significant CO causes, as evidenced by their impacts on cost and delay outcomes.

C. Broader Impact of Change Orders

The study highlights the multifaceted adverse effects of CO on construction projects:

- Cost Escalation: CO frequently lead to budget overruns, reducing contractor profit margins and imposing additional financial burdens on project owners. These escalations can undermine project feasibility and stakeholder trust [6, 15, 62, 63]. The strong path coefficient of X1 → Y1 (0.565) illustrates the substantial contribution of design changes to these cost increases.

- Quality Compromise: Frequent CO, particularly during later project stages, often compromise quality. Rushed implementations to meet revised deadlines may bypass standard quality controls, resulting in defects [3, 15, 35, 55]. Industry reports suggest up to 15% of quality defects in large-scale projects are caused by CO [14, 32, 50, 64].

- Project Delays: COs significantly extend project timelines, as evidenced by the strong path coefficients between CO causes and delays (e.g., X1 → Y2 = 0.400) [6, 50, 65-67]. Delays not only inflate costs but also disrupt resource allocation and stakeholder satisfaction, compounding inefficiencies [6, 51, 67, 68].

D. Limitations and Future Research Directions

1) Justification for Excluding BIM

Although BIM has shown significant potential in mitigating CO issues, its adoption is still limited in PT XYZ's projects. The focus of this study was to identify key factors contributing to CO impacts within the context of existing project management practices at PT XYZ. Including BIM would require a broader dataset from projects fully utilizing BIM practices, which was not available during this study [58, 69-71]. Future research could explore BIM's role in minimizing CO-related inefficiencies and its impact across various project settings [71, 72].

2) Future Research Directions

Future studies should consider expanding the model to include additional variables, such as:

- Contractor Performance Metrics to better understand how contractor capabilities influence CO occurrences and impacts.

- External Economic Influences to examine the effects of fluctuating market conditions, inflation, and supply chain disruptions on CO dynamics.

Cross-comparative studies involving a diverse range of construction firms and project types would provide more generalizable insights into effective CO management practices. Additionally, exploring the integration of emerging technologies, such as Artificial Intelligence (AI) and Machine Learning (ML), could enhance the prediction and mitigation of CO impacts. These technologies could offer data-driven insights, enabling proactive decision-making and reducing project inefficiencies [3, 53, 73, 74].

V. CONCLUSION

This study examines the impact of Change Orders (CO) on construction project performance, specifically cost overruns and project delays, using Partial Least Squares Structural Equation Modeling (PLS-SEM). By analyzing six variables and 17 indicators, the study provides critical insights into the causes and impacts of CO, particularly in the context of large-scale construction projects in Indonesia.

The results reveal that design changes (X1) are the most influential factor driving cost increases (X1 → Y1 = 0.565) and delays (X1 → Y2 = 0.400). These coefficients highlight how scope adjustments due to design modifications disrupt project execution, necessitating rework, additional resources, and extended timelines. These findings are consistent with prior research emphasizing design issues as a critical source of inefficiency in construction projects [32, 40, 55, 75].

Planning errors (X2) also significantly impact project outcomes, contributing to 34.5% of cost increases (X2 → Y1 = 0.345) and 23.1% of delays (X2 → Y2 = 0.231). Common planning issues, including insufficient documentation, inaccurate cost estimation, and execution inefficiencies, exacerbate project disruptions. Addressing these issues through enhanced planning accuracy and stakeholder coordination is critical to mitigating project inefficiencies [3, 15, 76, 77].

A. Novelty and Contribution

This study pioneers the application of PLS-SEM in analyzing CO impacts in large-scale construction projects within Indonesia, providing a statistically robust framework to establish quantitative relationships between CO causes and their impacts. Unlike prior studies relying on qualitative assessments, this research quantitatively demonstrates the significant roles of design changes and planning errors in driving cost overruns and delays [42, 44, 78, 79]. Additionally, this research bridges a critical gap by offering localized insights into CO impacts, addressing challenges faced by contractors in developing countries [13, 80, 81]. The findings emphasize the importance of:

- Implementing Building Information Modeling (BIM): BIM enhances planning accuracy (aligned with X2 → Y1 = 0.345) and minimizes design changes through improved visualization and simulation [55, 58, 73, 82].
- Strengthening design review processes: Early-stage validation reduces the likelihood of disruptive design changes, which contribute substantially to cost overruns and delays [55, 58, 73, 82].

B. Future Directions

Future research should explore CO dynamics across diverse project types and geographic settings to enhance generalizability. Expanding the model to include additional variables, such as contractor performance, regulatory influences, and external economic conditions, could provide a more comprehensive understanding of CO impacts [39, 83, 84]. Integrating emerging technologies, such as Artificial Intelligence (AI) and Machine Learning (ML), could further improve the prediction and mitigation of CO-related risks. These approaches offer data-driven insights, enabling construction professionals to proactively address inefficiencies and improve project outcomes [3, 53, 73, 74].

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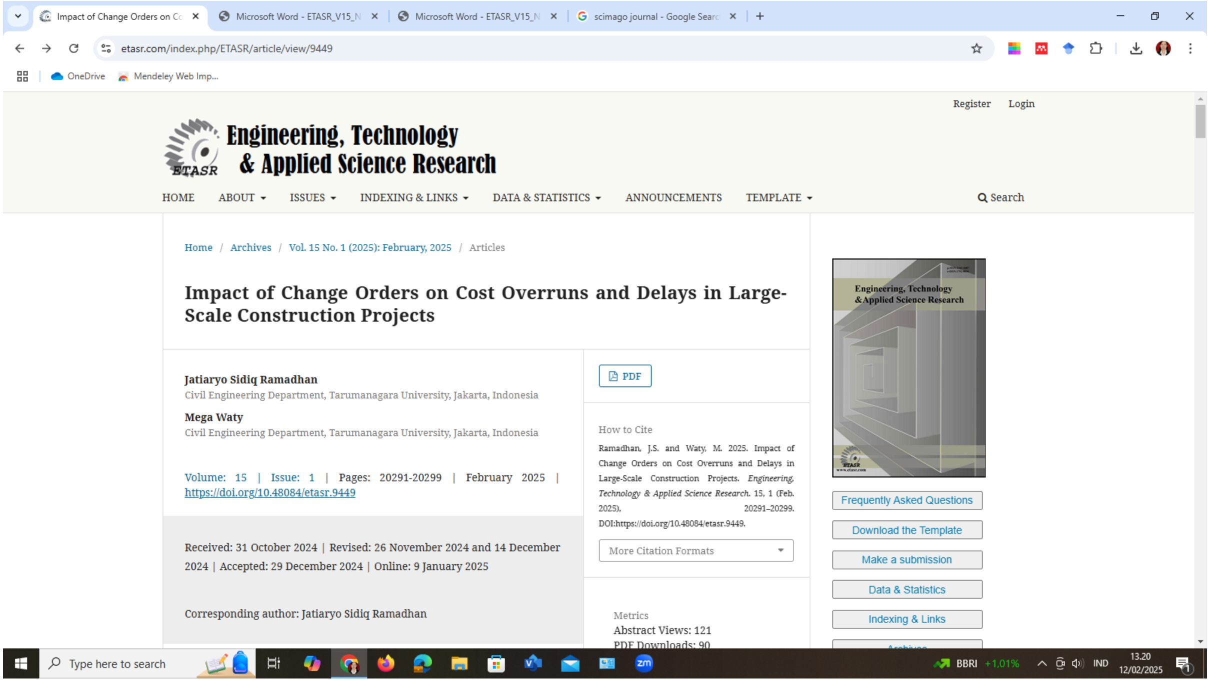

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Impact of Change Orders on Cost Overruns and Delays in Large-Scale Construction Projects

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Abstract

This study investigates the impact of Change Orders (CO) on construction project performance, focusing on cost overruns and project delays. Partial least square structural equation modeling was used to analyze the relationships between key causal factors, including design changes, planning errors, and project outcomes. Data were collected from 127 construction practitioners involved in large-scale projects managed by PT XYZ, a leading Indonesian contractor. The analysis identifies that design changes contribute to 56.5% of cost overruns and 40% of project delays, while planning errors account for 34.5% of cost overruns and 23.1% of delays. These findings highlight the critical importance of improving project planning accuracy and enhancing design management processes to reduce the adverse effects of CO. Structured protocols for managing CO, better coordination among stakeholders, and adopting advanced technologies are recommended to minimize their effect. These insights are particularly relevant for large-scale projects where CO frequently disrupt budgets and timelines. By addressing these issues, project managers can enhance overall performance and reduce risks associated with cost and time escalations. This research provides practical strategies applicable to various construction contexts, supporting more efficient project delivery and better management of CO.

Keywords: change orders, cost overrun, project delays, PLS-SEM, design changes, planning errors

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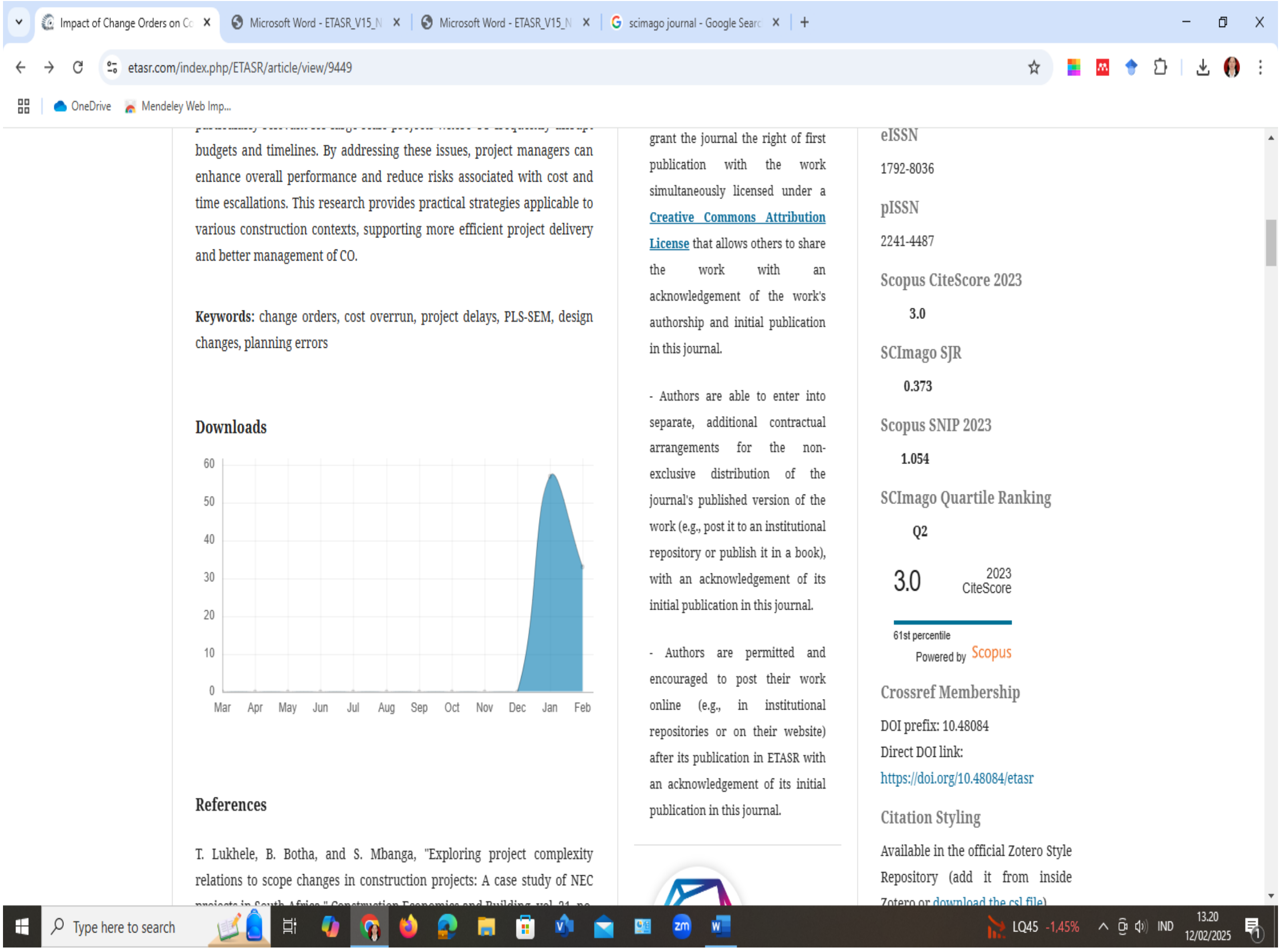

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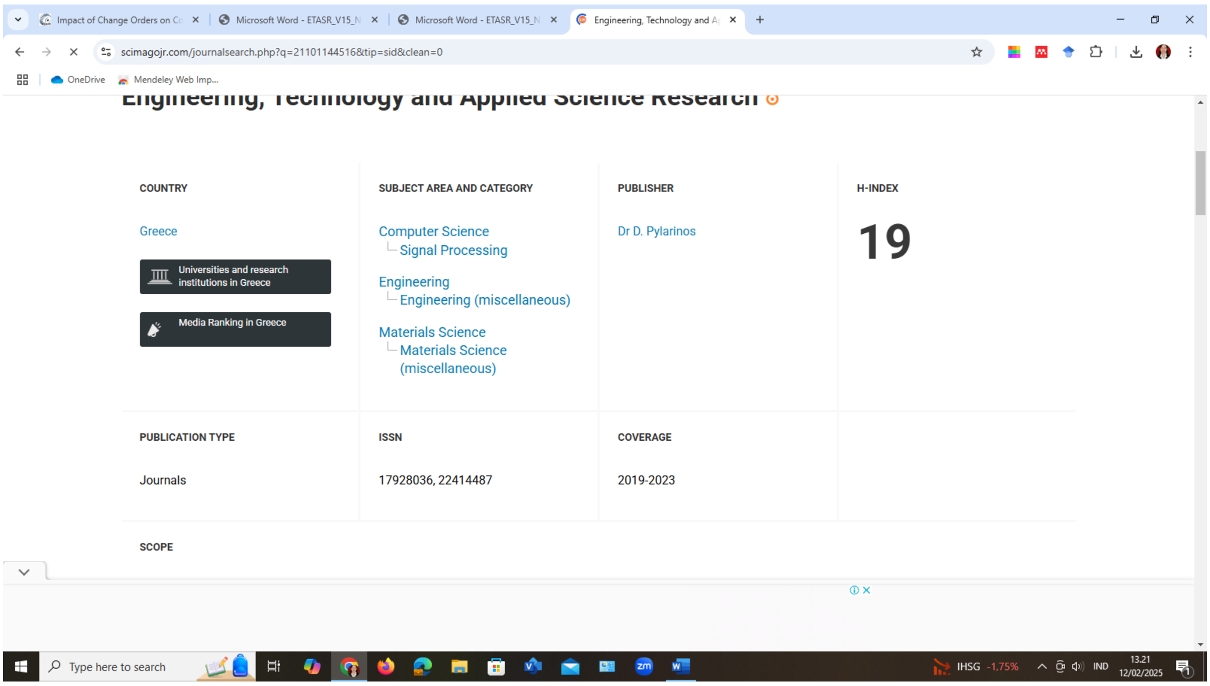

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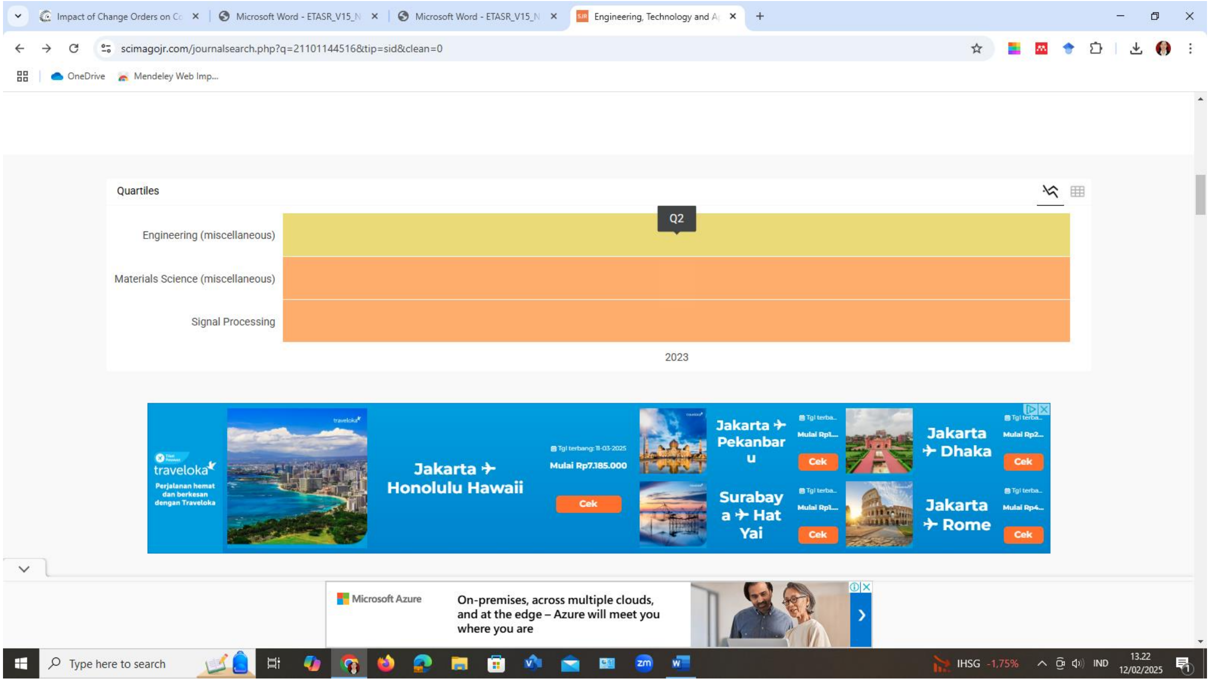
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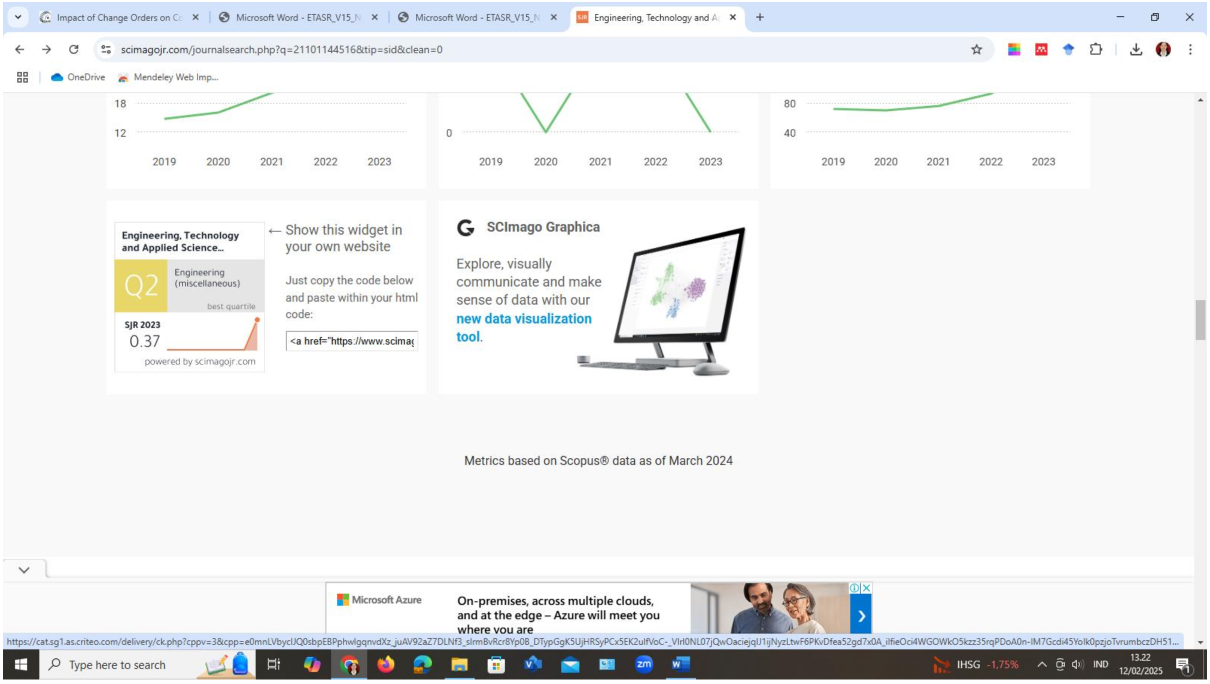
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