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Project Delay Analysis and Improvement Strategy for the Mataloko Geothermal Infrastructure Project

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Abstract
Indonesia's energy transition requires the timely delivery of geothermal infrastructure; however, project delays continue to threaten investment efficiency and renewable energy targets. This study aimed to identify and measure the factors affecting delays in the Mataloko Geothermal Infrastructure Project and formulate appropriate improvement strategies. A quantitative research design was employed using data from 74 respondents representing PT PLN (Persero), construction supervision consultants, contractors, and subcontractors. Data were collected through a five-point Likert-scale questionnaire and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM), predictive assessment, and Importance–Performance Map Analysis (IPMA). Project documents and focus group discussions were also used to support the interpretation of findings. The model explained 59.5% of the variance in project delay impacts. Financial factors had the strongest significant effect ($\beta = 0.409$), followed by project resource management ($\beta = 0.394$) and external factors ($\beta = 0.391$). Contractor cash-flow difficulties, delayed supplier payments, low labor productivity, material shortages, manpower limitations, and community-related issues emerged as the main priorities for improvement. Planning, design, contractor-related, and owner-related factors did not have significant direct effects. The study concluded that integrated cash-flow control, resource-loaded look-ahead planning, stakeholder readiness, and accelerated owner decision-making were essential to reduce delays and improve the delivery of future geothermal infrastructure projects in Indonesia.

INTRODUCTION

Climate change pressures and commitments under the Paris Agreement and COP26 have accelerated the global shift toward low-carbon energy systems, requiring countries to translate policy commitments into concrete financing mechanisms and infrastructure programs. Geothermal energy plays a distinctive role in this transition because it is sustainable, has low carbon emissions, and can provide stable baseload electricity, unlike intermittent sources such as solar and wind. These characteristics are highly relevant for Indonesia, an archipelagic nation that requires equitable and reliable electricity access while integrating variable renewable energy sources into its power system (Ali et al., 2025; Langer et al., 2021; Pratama et al., 2017; Syauqi et al., 2021; Zublie et al., 2023).

Indonesia has targeted net-zero emissions by 2060 and, through the 2025–2034 Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik [RUPTL]), aims to add 69.5 GW of generation and storage capacity, with 76% expected to come from renewable energy and storage, including 5.2 GW of additional geothermal capacity. Indonesia has the second-largest geothermal potential in the world; however, utilization remains limited. Installed geothermal capacity reached only approximately 2.6–2.7 GW by 2024–2025, representing roughly 9% of total potential, which remains significantly lower than the Philippines' 44% utilization rate despite its smaller resource base. This gap indicates that the main constraint on geothermal development is not resource availability but rather the ability to convert resources into financeable and executable projects amid substantial capital requirements, geological uncertainty, land constraints, environmental licensing obligations, and specialized labor and technology requirements (Ingason & Fridgeirsson, 2026; Sanane, 2026).

Accordingly, this study addressed four research questions: (1) What were the main factors causing delays in the Mataloko Geothermal Power Plant infrastructure project? (2) To what extent did these factors affect project delays? (3) Which factors were most critical in contributing to project delay accumulation? and (4) What strategies and improvements should be recommended for the future project-management system? (Gunawan et al., 2025; Ariyanto & Armono, 2024). The corresponding research objectives were to identify and categorize delay factors, measure their level of influence using Partial Least Squares Structural Equation Modeling (PLS-SEM), determine the most critical factors, and formulate improvement strategies and a project-enhancement framework applicable to future geothermal infrastructure projects (Hair et al., 2021). The study was limited to the scope of the Mataloko contract package, excluding drilling, steam-field, and geothermal power plant Engineering, Procurement, and Construction (EPC) works, and used quantitative survey data collected from PLN, consultants, and contractors directly involved in the project between 2023 and 2026 (Rachmawati et al., 2023; Buyung & Irawan, 2026).

Project management theory under the Project Management Body of Knowledge (PMBOK) framework emphasizes that project success depends on the effective integration of processes such as scope, schedule, risk, and integration management. When this integration is inadequate, such as through unrealistic schedule baselines, unclear scope definitions, or insufficient risk management, projects are more likely to experience delays. Studies of large EPC projects have shown that delay risks increase with the complexity of technical planning, geological conditions, and social dynamics. Even when PMBOK-based standards are applied, schedule performance may still deteriorate due to insufficient initial design preparation, land-acquisition uncertainty, and prolonged approval processes. The literature broadly classifies delay causes into five categories: design, contractor, materials and logistics, equipment, and external factors, with project complexity acting as an amplifying condition across these categories.

Recent research has applied Structural Equation Modeling (SEM) to clarify relationships among latent delay factors rather than merely ranking individual causes. Memon et al. (2023) applied Partial Least Squares Structural Equation Modeling (PLS-SEM) and demonstrated that contractor, resource, financial, and managerial conditions collectively influenced construction-delay outcomes. Rady et al. (2023) found that owner-related constraints, contractor capability, resource availability, and project-management practices significantly affected building-project performance in Egypt. Aljarallah et al. (2023) similarly used PLS-SEM to demonstrate that organizational, technical, and resource factors influenced infrastructure-project quality and performance in Saudi Arabia. In Indonesia's upstream oil and gas sector, Permadi and Wiguna (2025) examined 186 project practitioners and found that material shortages had the strongest influence on delays, followed by planning and design problems, while contractor performance mediated several labor, financial, and external effects. These studies support the use of PLS-SEM because project delay is a latent and multidimensional phenomenon involving multiple simultaneous relationships that cannot be adequately explained through descriptive rankings alone.

Despite these contributions, several research gaps remain. First, most previous studies have examined general building, road, housing, or oil and gas projects, whereas empirical research specifically focusing on enabling infrastructure for geothermal development in Indonesia remains limited. The financial, geological, logistical, environmental, and social characteristics of geothermal projects differ from those of conventional construction projects, limiting the direct applicability of generic delay models. Second, many studies rely on frequency indices or mean-score rankings that identify perceived causes but do not estimate their direct effects after controlling for other constructs simultaneously. Third, previous studies have often emphasized planning, design, and contractor capability without sufficiently integrating owner governance, contractor financial conditions, project-resource management, and external stakeholder factors into a single predictive model. Fourth, studies applying PLS-SEM frequently stop at hypothesis testing and provide only general recommendations, without combining structural-model results with effect-size analysis, predictive assessment, Importance–Performance Map Analysis (IPMA), project records, and managerial frameworks. Therefore, an evidence-based model connecting statistical findings with implementable improvement priorities remains necessary.

Addressing this gap is urgent because prolonged delays in geothermal-enabling infrastructure may create consequences beyond the performance of an individual contract. Delays in well pads and access roads can postpone exploratory or production drilling, while delays in water-supply facilities can disrupt drilling preparation and testing activities. These disruptions may increase financing costs, extend equipment and personnel commitments, generate contractual claims, and reduce confidence among lenders and development partners. The urgency is greater for projects supported by international cooperation, such as the Mataloko project, because persistent schedule deviations may affect institutional credibility and the perceived bankability of future renewable energy investments. The International Energy Agency (IEA) estimates that geothermal investment could reach USD 1 trillion by 2035 if project risks, permitting barriers, and bankability constraints are successfully addressed (IEA, 2024). Therefore, improving schedule reliability in geothermal infrastructure projects is not merely a contractor-level concern but a prerequisite for mobilizing investment, maintaining stakeholder confidence, and accelerating Indonesia's transition toward a more secure and sustainable electricity system.

The novelty of this research lies in its integrated empirical and managerial approach to examining a severely delayed geothermal-enabling infrastructure project. The study developed a model comprising seven potential determinants—planning process, design-related factors, project-resource management, contractor-related factors, external-related factors, owner-related factors, and financial-related factors—and evaluated their effects on project delay impacts. Unlike studies that only rank delay indicators, this research used PLS-SEM to estimate the unique direct effects of each construct while accounting for the simultaneous influence of other factors. The analysis was strengthened through measurement-model evaluation, effect-size assessment, predictive analysis using PLSpredict and the Cross-Validated Predictive Ability Test (CVPAT), and IPMA to distinguish factors with high managerial importance and high observed severity.

Based on this background, the present research aimed to identify and categorize the principal factors causing delays in the Mataloko Geothermal Power Plant Infrastructure Development Project, measure the magnitude and significance of their effects, determine the most critical constructs and indicators, and formulate appropriate project-management improvement strategies. More specifically, the study examined whether planning processes, design-related factors, project-resource management, contractor-related factors, external-related factors, owner-related factors, and financial-related factors significantly influenced project delay impacts. Data were obtained from PLN personnel, construction-supervision consultants, contractors, and subcontractors with direct knowledge of the project. By focusing on stakeholders with relevant operational and managerial experience, the research provided a contextual explanation of how financial, resource, external, and governance conditions interact within a remote geothermal infrastructure environment.

Theoretically, this study contributes to project-management and geothermal-infrastructure literature by extending multidimensional construction-delay models to an enabling-infrastructure package within Indonesia's renewable energy sector. Methodologically, it demonstrated how PLS-SEM, predictive assessment, IPMA, focus-group evidence, and project documentation could be integrated to produce more robust and actionable conclusions. Practically, the findings are expected to assist PLN, contractors, consultants, lenders, and government institutions in prioritizing interventions based on factors with the greatest statistical influence and operational severity. The proposed strategies may support stronger contractor cash-flow controls, more reliable supplier-payment mechanisms, improved alignment between resources and short-term work plans, earlier management of permits and community concerns, and faster owner decisions regarding changes and contractual amendments. Ultimately, the study is expected to reduce the risk of repeated delays in future geothermal projects, strengthen organizational learning, improve renewable energy investment efficiency, and support the timely achievement of Indonesia's RUPTL 2025–2034 targets and net-zero-emission commitments.

METHOD

Research Design and Data Collection

This study applied a quantitative research design using a questionnaire survey analyzed with PLS-SEM to identify, measure, and prioritize the factors causing delays in the Mataloko Geothermal Power Plant infrastructure project. Respondents were selected through purposive sampling based on their direct expertise and involvement in the project, comprising the Owner (PLN, 63.5%), Construction Supervision Consultants (16.2%), and Contractors/Subcontractors (20.3%), for a total of 74 respondents. The questionnaire used a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) and was distributed online. Primary data from focus group discussions and secondary data from monthly progress reports, S-curve records, and previous literature were used to strengthen and triangulate the research findings. Following Hair (2019), a sample size of fewer than 100 respondents was considered adequate for PLS-SEM, particularly in business-to-business contexts with inherently limited target populations.

Seven exogenous constructs and one endogenous construct were operationalized into 33 reflective indicators, as summarized in Table 2. These constructs included Planning Process (P1–P4), Design-Related Factors (D1–D4), Project Resource Management (R1–R6), Contractor-Related Factors (C1–C5), External-Related Factors (E1–E4), Owner-Related Factors (O1–O3), Financial-Related Factors (F1–F3), and Impact of Project Delay (PD1–PD4).

Table 2. Research Constructs and Indicators

Construct	Indicators (code)	Representative Item
Planning Process	P1-P4	Adequacy of pre-construction planning, realism of contract duration, accuracy of site investigation, land-acquisition readiness.
Design-Related Factors	D1-D4	Timeliness of drawing approval, frequency of design change, design errors, completeness of tender design.

Construct	Indicators (code)	Representative Item
Project Resources Management	R1-R6	Availability of skilled personnel/manpower, labour productivity, equipment breakdown/shortage, material shortage or late delivery.
Contractor-Related Factors	C1-C5	Project monitoring/scheduling effectiveness, site supervision, contractor and subcontractor competence, execution errors.
External-Related Factors	E1-E4	Regulatory/policy change, community and social issues, unforeseen geological and climatic conditions.
Owner-Related Factors	O1-O3	Timeliness of environmental-permit and financing approval, speed of decisions/amendments, owner-initiated scope change.
Financial-Related Factors	F1-F3	Contractor cash-flow difficulty, delay in owner progress payment, delay in payment to suppliers/subcontractors.
Impact of Project Delay	PD1-PD4	Cost overrun, contractual disputes/claims, reputational impact, risk of project failure.

Data Analysis Method

Data were processed using SmartPLS 4 following the two-stage PLS-SEM evaluation procedure. The measurement (outer) model was first assessed for internal consistency reliability (Cronbach's alpha and composite reliability, threshold >= 0.70), convergent validity (Average Variance Extracted/AVE >= 0.50 and outer loading >= 0.708, with loadings of 0.40-0.70 considered for retention if they improve composite reliability), and discriminant validity (Fornell-Larcker criterion, cross-loading and the Heterotrait-Monotrait ratio/HTMT, threshold < 0.85-0.90). The structural (inner) model was then evaluated through collinearity assessment (VIF < 5), the coefficient of determination (R^2; 0.25 = weak, 0.50 = moderate, 0.75 = substantial), effect size (f^2; 0.02/0.15/0.35 = small/medium/large), path-coefficient significance via bootstrapping with 10,000 subsamples (two-tailed, t > 1.96 or p < 0.05), and predictive relevance using PLSpredict (Q^2 > 0) and the Cross-Validated Predictive Ability Test (CVPAT). Findings were further interpreted through Importance-Performance Map Analysis (IPMA) to translate statistical results into managerial priorities, and were triangulated against project evidence and the PMBOK performance domains (Governance, Stakeholders, Scope, Resources, Schedule, Risk and Finance) to formulate improvement strategies.

RESULTS AND DISCUSSION

Respondent Profile

Of the 74 respondents, 94.6% (70 persons) were male and 5.4% (4 persons) were female. The dominant age group was 31-40 years (66.2%), followed by 41-50 years (21.6%), together accounting for 87.8% of respondents. Regarding educational background, 73.0% held a Bachelor's degree and 17.6% held a Master's degree (90.6% combined). Work experience was substantial: 43.2% had 11-15 years of experience and 31.1% had more than 15 years, so 74.3% of respondents had over ten years of relevant experience. By project role, 63.5% of respondents were from the Owner (PLN, spanning corporate, procurement, implementation-unit, land/licensing and communications functions), while the remaining 36.5% comprised Construction Supervision Consultants (16.2%) and Contractors/Subcontractors (20.3%). Table 3 summarises these characteristics, which indicate a respondent base with sufficient seniority, technical/managerial literacy and direct project exposure to provide informed judgements on delay factors.

Table 3. Respondent Characteristics (n = 74)

Characteristic	Category	n	%
Gender	Male	70	94.6
	Female	4	5.4
Age	31-40 years	49	66.2
	41-50 years	16	21.6
	Other age groups	9	12.2
Education	Bachelor's degree	54	73.0
	Master's degree	13	17.6
	Other	7	9.4
Work experience	11-15 years	32	43.2
	>15 years	23	31.1
	<=10 years	19	25.7
Project role	Owner (PLN)	47	63.5
	Contractor/Subcontractor	15	20.3
	Construction Supervision Consultant	12	16.2

Measurement Model Evaluation

The initial model comprised seven exogenous constructs and 33 indicators. Iterative refinement removed five indicators with outer loadings that impaired construct reliability and validity: F2 (loading 0.116), E4 (0.229), E3 (0.201 after E4 removal), P4 (0.496) and O1 (0.648). Each removal was evaluated jointly against its effect on AVE, composite reliability and Cronbach's alpha rather than on loading value alone, and indicators were retained where removal would have eroded conceptual coverage without a meaningful gain in model quality (for example C5 and R4, retained despite loadings below 0.70). The final model retained 28 indicators across the eight constructs. Table 4 summarises the final measurement-model results.

Table 4. Final Measurement Model Evaluation

Construct	Retained Indicators	Cronbach's Alpha	Composite Reliability (rho_c)	AVE
Contractor-Related Factors	C1-C5	0.812	0.864	0.561
Design-Related Factors	D1-D4	0.787	0.850	0.588
External-Related Factors	E1, E2	0.464*	0.722	0.594
Financial-Related Factors	F1, F3	0.780	0.901	0.819
Impact of Project Delay	PD1-PD4	0.859	0.904	0.702
Owner-Related Factors	O2, O3	0.763	0.894	0.808
Planning Process	P1-P3	0.756	0.850	0.657

Construct	Retained Indicators	Cronbach's Alpha	Composite Reliability (rho_c)	AVE
Project Resources Management	R1-R6	0.870	0.902	0.608

*The External construct met AVE and composite-reliability thresholds but its Cronbach's alpha (0.464) remained below 0.70 because only two indicators were retained; the construct was carried forward with this measurement caveat.

Discriminant validity was confirmed through the Fornell-Larcker criterion (the square root of AVE for every construct exceeded its correlation with other constructs), cross-loading (each indicator loaded highest on its own construct) and HTMT ratios (all below 0.90). Two construct pairs required closer inspection: Contractor-Related Factors and Project Resources Management (HTMT = 0.862; 95% CI 0.767-0.929), reflecting the conceptual overlap between contractor capability and resource deployment, and External-Related Factors with Impact of Project Delay (HTMT = 0.655; 95% CI 0.248-0.949), consistent with the External construct's reduced indicator set. Both pairs were retained as theoretically and empirically distinct constructs but interpreted with caution.

Structural Model Evaluation and Hypothesis Testing

All inner-model VIF values ranged from 1.232 to 2.509, below the conservative threshold of 3, indicating no critical multicollinearity. The structural model explained 59.5% of the variance in the Impact of Project Delay (R^2 = 0.595; adjusted R^2 = 0.552), a moderate level of explanatory power. Bootstrapping with 10,000 subsamples produced the path coefficients, effect sizes and hypothesis-test results summarised in Table 5.

Table 5. Path Coefficients, Effect Size and Hypothesis Testing Summary

Hyp.	Path	β	t-statistic	p-value	f^2	Result
H1	Planning Process → Impact of Project Delay	0.043	0.454	0.650	0.003 (none)	Not supported
H2	Design-Related Factors → Impact of Project Delay	-0.097	0.890	0.374	0.013 (none)	Not supported
H3	External-Related Factors → Impact of Project Delay	0.391	3.345	0.001	0.307 (medium)	Supported*
H4	Financial-Related Factors → Impact of Project Delay	0.409	4.551	0.000	0.276 (medium)	Supported
H5	Contractor-Related Factors → Impact of Project Delay	-0.267	1.927	0.054	0.074 (small)	Not supported
H6	Owner-Related Factors → Impact of Project Delay	0.132	1.231	0.218	0.031 (small)	Not supported
H7	Project Resources Management → Impact of Project Delay	0.394	2.923	0.003	0.153 (medium)	Supported

*Supported with measurement qualification (see Section 4.2 regarding the External construct's reliability caveat). Threshold: $t > 1.96$ or $p < 0.05$ (two-tailed).

Predictive assessment using PLSpredict showed positive Q^2predict values for all four indicators of Impact of Project Delay (0.235-0.375), and PLS-SEM RMSE values were lower than the Linear Model benchmark for every indicator, indicating adequate out-of-sample predictive relevance. The Cross-Validated Predictive Ability Test (CVPAT) confirmed that the

PLS-SEM model produced a lower prediction loss than the Linear Model benchmark (average loss difference = -0.205; t = 5.141; p < 0.001), while the comparison against the Indicator Average was directionally favourable but not yet statistically significant (difference = -0.200; p = 0.135). Overall, three constructs -- Financial-Related Factors, Project Resources Management and External-Related Factors -- were confirmed as significant, positive direct drivers of the Impact of Project Delay, while Planning, Design, Contractor and Owner-Related Factors did not show a significant unique direct effect once the other constructs were accounted for simultaneously. Figure 2 presents the final structural model with its path coefficients and R^2 value.

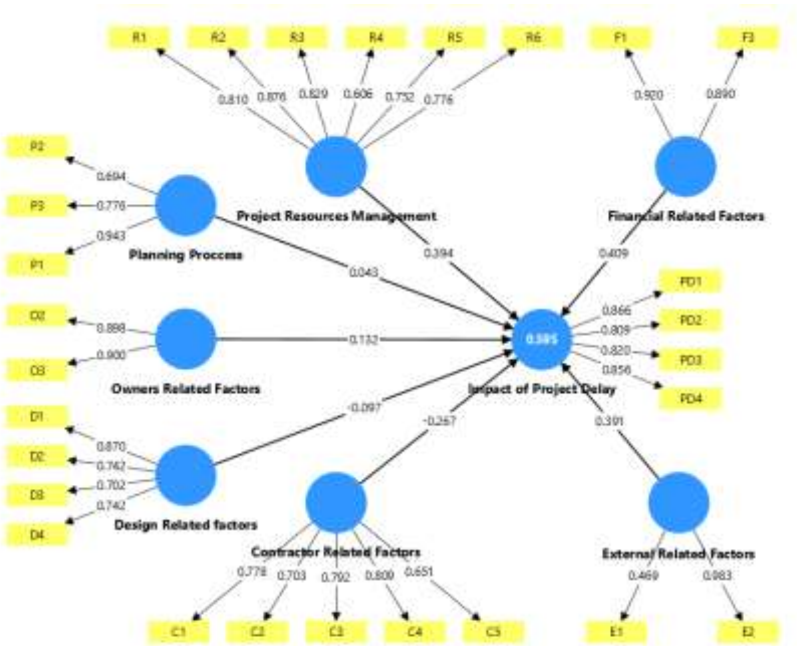

Figure 2. Final Structural Model (Path Coefficients and R² = 0.595)

Importance-Performance Map Analysis (IPMA)

Because the study's indicators are formulated as problem statements, IPMA 'performance' scores are interpreted as observed severity or exposure rather than as a positive attainment: a higher score indicates a more intense manifestation of the problem. At the construct level (Figure 3), Financial-Related Factors recorded the highest importance-severity combination (importance 0.409, severity 73.929), followed by Project Resources Management (0.394; 68.076) and External-Related Factors (0.391; 80.092) -- all falling in the 'high importance-high severity' quadrant that requires immediate managerial attention. Owner-Related Factors and Planning Process showed lower importance (0.132 and 0.043 respectively), while Contractor and Design-Related Factors returned negative importance values, consistent with their non-significant structural paths.

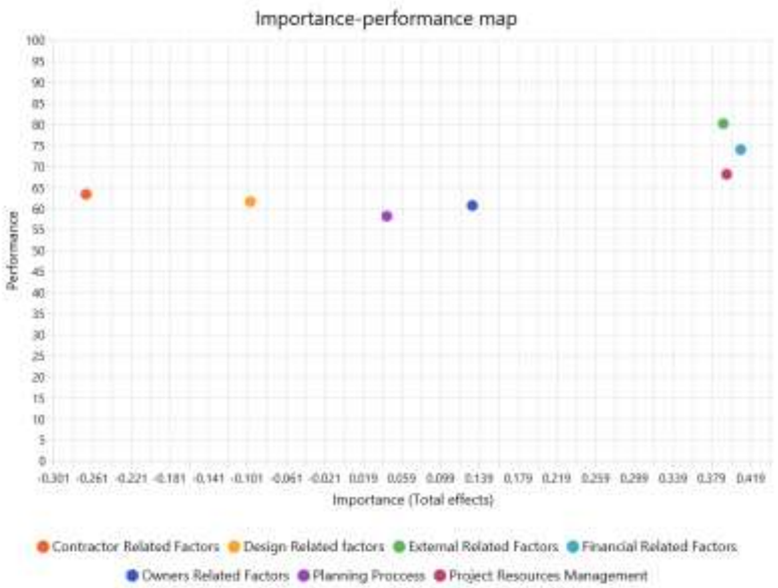

Figure 3. Importance-Performance Map at the Construct Level

At the indicator level, Table 6 lists the highest-priority indicators. Community and social issues (E2) recorded both the highest importance (0.362) and severity (83.446) of any indicator, followed by contractor cash-flow difficulty (F1: 0.243; 76.689) and delayed payment to suppliers/subcontractors (F3: 0.209; 70.946). Several resource indicators -- low labour productivity (R3), material shortage/late delivery (R6), manpower shortage (R2), lack of skilled personnel (R1) and equipment shortage (R5) -- also fall above the average importance line. Notably, although the Owner construct was not statistically significant, its indicators for owner-initiated scope change (O3: 0.074; 63.514) and slow decision-making/contract amendment (O2: 0.073; 57.432) both exceed the average indicator importance of 0.046, signalling practical managerial relevance despite the absence of a significant direct statistical effect.

Table 6. Priority Indicators from IPMA at the Indicator Level

Code	Construct	Indicator	Importance	Severity
E2	External	Community and social issues	0.362	83.446
F1	Financial	Contractor cash-flow and financial difficulty	0.243	76.689
F3	Financial	Delay in payment to suppliers/subcontractors	0.209	70.946
R3	Resources	Low labour productivity	0.101	73.311
R6	Resources	Material shortage and late delivery	0.095	71.284
R2	Resources	Shortage of manpower	0.095	65.878
R1	Resources	Lack of skilled personnel	0.087	67.905
R5	Resources	Equipment shortage	0.075	64.189
O3	Owner	Owner-initiated scope change	0.074	63.514
E1	External	Regulatory/policy change	0.074	58.108

Code	Construct	Indicator	Importance	Severity
O2	Owner	Slow decision-making / contract amendment	0.073	57.432

Discussion of Findings

Financial-Related Factors. Financial difficulty was confirmed as the strongest driver of project delay ($\beta = 0.409$; $f^2 = 0.276$; medium effect), consistent with the highest IPMA severity among significant constructs. Project evidence shows that contractor cash-flow constraints and delayed payment to subcontractors triggered material withholding and idle heavy equipment at Wellpad A and Wellpad C. This aligns with prior evidence that supply-chain cash flow is functionally linked to project stability and that liquidity weakness directly produces implementation delay, late-payment penalties and lost business opportunities (Chen, 2011; Purnus & Bodea, 2016). On the Owner's side, payments tied to 80% of installed work value with no Material-on-Site provision create a structural timing mismatch between physical progress, Owner disbursement and downstream payment obligations.

Project Resources Management. Resource issues ($\beta = 0.394$; $f^2 = 0.153$; medium effect) were driven mainly by low labour productivity, manpower and material shortages, and limited equipment and skilled-personnel availability. Cumulative progress deviation at Mataloko widened from -1.67% to -30.56%, reflecting that resource additions alone did not translate into progress where productivity, predecessor readiness and material synchronisation remained unresolved -- consistent with Last Planner System theory, which holds that Critical Path Method scheduling alone often overlooks workflow continuity and workfront-readiness prerequisites (Hamzeh et al., 2016).

External-Related Factors. External exposure ($\beta = 0.391$; $f^2 = 0.307$, the largest medium effect size among the significant constructs) was dominated by community and social issues (E2), consistent with delayed SIPA permitting, road blockades, land-lease disputes and incomplete public communication regarding the sabodam works, which halted physical activity at Wellpad A and B. This is consistent with the view that infrastructure development inherently disrupts local communities, and that unresolved land objections reflect legitimate community concerns rather than purely technical obstacles; excluding affected groups from early communication and decision-making tends to escalate informal resistance and idle time (Di Maddaloni & Davis, 2017).

Owner and Contractor Governance. Owner-Related Factors did not reach significance at the construct level ($\beta = 0.132$; $p = 0.218$), yet IPMA indicates practical relevance in owner-initiated scope changes and slow decision-making/amendments. Twelve contract amendments were processed during the project, averaging 57 days each, underscoring the Owner's governance role as an enabling mechanism that determines how quickly the project can respond to financial, resource and external disruptions, consistent with the 'strong owner' and owner-project-capability literature (Shenoy & Mahanty, 2024; Winch & Leiringer, 2016). Contractor-Related Factors also did not reach significance ($\beta = -0.267$; $p = 0.054$) once other constructs were controlled for, and showed high empirical proximity to the Resources construct (HTMT = 0.862), suggesting that contractor performance is expressed through resource deployment rather than as an independent driver. Planning and Design-Related Factors likewise showed no significant direct effect ($p = 0.650$ and 0.374 respectively), indicating that, within this sample, front-end planning and design issues functioned as enabling rather than direct delay drivers.

4.6 Strategy Formulation

Guided by the significant structural paths, the IPMA priorities and the PMBOK performance domains, four complementary strategies were formulated to address the empirically confirmed drivers of delay while positioning Owner governance as the mechanism that enables their execution. Table 7 summarises the empirical basis and core recommendation of each strategy; detailed 5W+1H implementation plans and an implementation roadmap linking each strategy to PMBOK process groups and lessons learned are set out in the full study report.

Table 7. Summary of Recommended Improvement Strategies

Strategy	Empirical Basis	Core Recommendation	Expected Outcome
1. Project Cash-Flow Continuity and Contractual Payment Alignment	$\beta = 0.409$; $p < 0.001$; $f^2 = 0.276$ (largest driver); IPMA importance 0.409, severity 73.929	Establish a rolling project cash-flow forecast and a critical supplier/subcontractor payment register; evaluate the progress-payment percentage and introduce Material-on-Site payment provisions for future contracts.	Early visibility of financing gaps; continuity of material, equipment and subcontractor supply; reduced risk of late downstream payment.
2. Resource-Loaded Lookahead Planning and Production Reliability	$\beta = 0.394$; $p = 0.003$; $f^2 = 0.153$; IPMA importance 0.394, severity 68.076	Implement a 3-6 week resource-loaded lookahead schedule, a Make-Ready constraint register, and capacity-to-load/productivity matching before weekly work commitments.	Improved workfront readiness, productivity and resource utilisation; reduced idle resources and reactive mobilisation.
3. External Stakeholder Readiness and Social Licence Assurance	$\beta = 0.391$; $p = 0.001$; $f^2 = 0.307$; IPMA importance 0.391, severity 80.092 (E2 highest indicator exposure)	Establish a Stakeholder and External Readiness Register linked to the schedule, periodic external-readiness lookahead reviews, and a Grievance Redress Mechanism as an early-warning system.	Earlier visibility of external exposure; stronger social licence; higher executability of technically ready workfronts.
4. Owner Governance and Decision Acceleration	Owner $\beta = 0.132$ (not significant at construct level) but O2/O3 above average IPMA importance; 12 amendments averaging 57 days	Establish an Integrated Decision and Action Register, a Decision Authority (RACI) Matrix, and a Service-Level Agreement for amendment approval (target 35 days), with verified closure control.	Shorter decision cycles, clearer accountability, and a governance backbone enabling timely execution of Strategies 1-3.

CONCLUSION

This study identified and measured the factors driving delays in the Mataloko Geothermal Infrastructure Project using PLS-SEM with data from 74 respondents, supported by effect-size analysis, predictive assessment (PLSpredict/CVPAT), Importance–Performance Map Analysis (IPMA), project evidence, and PMBOK-based diagnosis. Of the seven hypothesized constructs, Financial-Related Factors ($\beta = 0.409$), Project Resource Management ($\beta = 0.394$), and External-Related Factors ($\beta = 0.391$) showed significant positive direct effects on the Impact of Project Delay, with the full model explaining 59.5% of its variance ($R^2 = 0.595$). Meanwhile, Planning, Design, Contractor-Related, and Owner-Related Factors did not show significant unique direct effects; however, owner governance and contractor execution remained embedded within the financial, resource, and external pathways. IPMA confirmed that contractor cash-flow difficulties, delayed supplier payments, low labor productivity, material shortages, manpower limitations, and community/social issues were the highest-priority indicators, while owner-initiated scope changes and slow decision-making, although statistically insignificant, represented managerial areas requiring attention.

Four complementary strategies were formulated: a Project Cash-Flow Continuity and Contractual Payment Alignment Framework; a Resource-Loaded Look-Ahead Planning and Production Reliability Framework; an External Stakeholder Readiness and Social License Assurance Framework; and an Owner Governance and Decision Acceleration Framework, which served as the governance backbone for the first three strategies. For the Mataloko project, outstanding financial, resource, and stakeholder issues should be resolved through an integrated closure register before final handover. At the institutional level, PLN is advised to standardize cash-flow continuity controls and Material-on-Site payment provisions, institutionalize resource-loaded look-ahead planning as a standard construction-control practice, strengthen owner decision-making Service Level Agreements (SLAs) for contract amendments, and incorporate Mataloko's lessons learned into its knowledge-management system for future geothermal enabling-infrastructure packages. Future research should test the model on comparable projects, such as Ulumbu or Atadei, refine the measurement of External-Related Factors using more homogeneous indicators, and employ larger samples with Multi-Group Analysis across stakeholder groups.

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