

Service Enhancement Opportunity Of Design And Build Project In Trans Papua Project

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KEYWORDS

Analytical Hierarchy Process;
Infrastructure Governance;
Process Chain Network;
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ABSTRACT

This study examines how design-review inefficiencies in a design-and-build infrastructure project can be reduced through process reengineering and digital collaboration, using the Trans Papua Project as an empirical case. A mixed-methods case study was employed by combining quantitative project-control analysis and qualitative process diagnosis. Schedule Performance Index and Schedule Variance were calculated from verified monthly progress reports, while semi-structured interviews with project personnel were analysed using qualitative content analysis. The study then integrated stakeholder analysis, Process Chain Network, value co-creation, DART-PDCA, Building Information Modelling within a Common Data Environment, and Analytical Hierarchy Process to evaluate alternative process-redesign scenarios. The findings show that schedule risk was driven not only by construction productivity constraints but also by technical data misalignment, sequential review routines, and fragmented stakeholder interfaces. Among three PCN alternatives, Alternative 1 was prioritised because it balanced formal design-consultant involvement, contractor-led cost and constructability evaluation, parallel submission of design alternatives, process efficiency, and stakeholder acceptance. Its short-term implementation improved SPI from 1.11 in June 2025 to 1.17 in September 2025. This study contributes to design-and-build infrastructure governance by demonstrating how PCN and BIM-CDE can transform sequential design review into a more collaborative, traceable, and parallel decision-making process in Indonesian public-private infrastructure delivery.

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1. INTRODUCTION

Design-and-build delivery has become an increasingly important procurement approach in infrastructure projects because it integrates design and construction responsibilities within a single contractual arrangement. Compared with the traditional design-bid-build model, this approach is expected to accelerate project delivery, improve constructability, reduce coordination gaps, and strengthen accountability for design implementation (Chan et al., 2002; Hale et al., 2009; Sullivan et al., 2017). These advantages are particularly relevant for public-private infrastructure projects, where delays in technical decisions may affect construction schedules, contractual performance, risk allocation, availability payment arrangements, and long-term service obligations (El-Gohary et al., 2006; Osei-Kyei & Chan, 2015). Recent studies on transport public-private partnerships

also emphasise that stakeholder roles and responsibilities must be reconsidered across project phases because infrastructure outcomes depend on how key actors participate in decision-making, risk management, and project governance (Castelblanco & Guevara, 2024). Therefore, the effectiveness of design-and-build delivery depends not only on contractual integration, but also on the reliability of design information, stakeholder coordination, and the ability of project actors to manage technical uncertainty during execution.

In practice, design-and-build projects remain vulnerable to process inefficiencies when preliminary design assumptions do not match actual field conditions. Infrastructure projects located in geographically complex areas often face uncertainty related to topography, land conditions, access constraints, and technical data reliability. When early project data are incomplete or inconsistent with validated field information, design development may require repeated revisions, additional technical review, cost recalculation, and formal approval from multiple stakeholders. These conditions may weaken the time-efficiency advantage of design-and-build delivery and create schedule risk even when physical construction progress appears favourable. Prior studies have shown that project delivery performance is strongly influenced by design information quality, stakeholder alignment, decision-making speed, and the ability to coordinate technical changes during implementation (Chen et al., 2016; Mok et al., 2015; Yang & Shen, 2015). More recent evidence on construction project management also indicates that digital technologies can improve project performance when they support coordination, information visibility, and more reliable decision-making across project actors (Qadir et al., 202; Seyis & Özkan, 2024).

The Trans Papua Project provides a relevant case for examining this issue in the context of Indonesian public-private infrastructure delivery. The project experienced discrepancies between preliminary topographic data provided during the bidding phase and more detailed LIDAR-based field data obtained by the contractor. These discrepancies affected detailed engineering design development, particularly in relation to earthwork volumes, alignment decisions, structural requirements, and cost implications. Although the project's cumulative Schedule Performance Index remained above the minimum threshold, it declined sharply from 3.47 in December 2024 to 1.07 in April 2025. This trend indicates that favourable aggregate performance may conceal emerging bottlenecks when construction progress depends on the timely approval of final design drawings. Therefore, schedule degradation in this case should not be viewed merely as a construction productivity issue, but also as a symptom of design-data misalignment, sequential review routines, and fragmented stakeholder interfaces.

Existing research has widely examined design-and-build performance, stakeholder management, BIM adoption, Common Data Environment, and project control. Nevertheless, limited attention has been given to how design-review workflows are structurally reorganised when technical data misalignment occurs during project execution. BIM and CDE studies often focus on modelling, clash detection, document management, information integration, and asset management, while their role as

governance interfaces for accelerating multi-stakeholder design approval remains relatively underexplored (Azhar, 2011; Bryde et al., 2013; Love et al., 2014; Patacas et al., 2020). Recent CDE studies show that CDE can function as a single source of truth for project information, but its implementation is challenged by project complexity, multiple platforms, data accountability, transparency, and reliability issues (Jaskula et al., 2024). Similarly, Seyis and Özkan (2024) show that CDE implementation in BIM-based projects can improve productivity, quality, and time-related performance indicators, but its benefits depend on effective organisational adoption and stakeholder use. These findings suggest that BIM-CDE should be examined not merely as a technical platform, but as a digital governance mechanism for improving information traceability, coordination, and decision readiness in infrastructure projects.

In the Indonesian context, the relevance of digital-enabled process improvement is also supported by recent business and governance studies. Sastra et al. (2025) show that digital transformation and innovation capability can strengthen competitive advantage in emerging markets when they are supported by market-oriented organisational capabilities. Yusuf et al. (2025) further emphasise that digital technology can enhance public service efficiency in Indonesia by improving access, transparency, and administrative responsiveness. These insights are relevant to infrastructure project governance because design-review delays often arise not only from technical complexity, but also from fragmented information flows and slow administrative coordination. Therefore, the use of BIM-CDE in a design-and-build project should be positioned as part of a broader digital transformation agenda that improves stakeholder coordination, information transparency, and process efficiency in public infrastructure delivery.

Responding to this gap, this study develops and evaluates a process-reengineering approach to improve the design development and review process in the Trans Papua design-and-build project. The study integrates Schedule Performance Index and Schedule Variance analysis, qualitative content analysis, stakeholder analysis, Process Chain Network, value co-creation, DART-PDCA, BIM-CDE, and Analytical Hierarchy Process. Process Chain Network is used to diagnose existing workflow inefficiencies and redesign stakeholder interaction, while BIM-CDE is positioned as a digital collaboration platform that supports shared information access, document traceability, and parallel evaluation of design alternatives. AHP is applied to select the most feasible process-redesign alternative by balancing compliance, number of design alternatives, required time, process stages, and cost efficiency (Darko et al., 2019; Saaty, 2008). The use of AHP is also consistent with recent HEBR studies showing that AHP can support structured managerial decision-making under multi-criteria constraints in Indonesian organisational settings, including digital payment prioritisation in SMEs and facility optimisation under governance and capital constraints (Sari & Marpaung, 2025; Wibowo & Hermawan, 2026).

The novelty of this study lies in reframing early schedule degradation in a design-and-build infrastructure project as a process-governance problem rather than solely a

construction productivity problem. By integrating PCN and BIM-CDE, this study demonstrates how design-development activities can be redistributed into more collaborative, traceable, and parallel processes. The study contributes theoretically by extending design-and-build and stakeholder-governance literature through a process-reengineering perspective. Methodologically, it combines project-control indicators, qualitative process diagnosis, PCN mapping, BIM-CDE logic, and AHP-based decision analysis. Practically, the study offers a transferable process-redesign model for public-private infrastructure projects in Indonesia and other emerging economies, particularly where technical data uncertainty, multi-stakeholder approval, and digital collaboration capability influence project delivery performance.

2. LITERATURE REVIEW

Design-and-build has become an important project delivery method in infrastructure development because it integrates design and construction responsibilities under one contractual arrangement. This model is expected to reduce fragmentation between designers and contractors, improve constructability, accelerate decision-making, and shorten project delivery compared with the traditional design-bid-build approach (Chan et al., 2002; Hale et al., 2009; Molenaar et al., 1999; Sullivan et al., 2017). However, the performance advantage of design-and-build is not automatic. It depends on the quality of early design information, clarity of design responsibility, contractual risk allocation, stakeholder coordination, and the project team's ability to respond to technical uncertainty during execution (Chen et al., 2016; Molenaar et al., 1999; Yang & Shen, 2015). In public-private infrastructure projects, design delays also affect contractual performance, payment mechanisms, public accountability, and long-term service obligations, making schedule performance not only a technical issue but also a governance issue (El-Gohary et al., 2006; Hueskes et al., 2017; Osei-Kyei & Chan, 2015).

Stakeholder governance is central to design-and-build performance because infrastructure projects involve actors with different interests, authority, risk exposure, and technical responsibilities. Project owners, contractors, design consultants, supervisory consultants, independent quality controllers, and government authorities often participate in sequential design-review and approval processes. Aaltonen (2011) explains that stakeholder analysis helps interpret the project environment and understand how stakeholder interests shape project decisions, while Mok et al. (2015) emphasise that megaproject performance depends on systematic communication and relationship management. More recent studies on public-private infrastructure governance further show that project outcomes are shaped by how stakeholder responsibilities, decision rights, and risk positions evolve across project phases (Castelblanco & Guevara, 2024). When stakeholder review is conducted sequentially, each actor may return feedback to previous stages, creating repeated clarification, redesign, and approval loops. Therefore, stakeholder governance in design-and-build

projects should not only focus on identifying stakeholder power and interest, but also on redesigning how stakeholders interact, exchange information, and make decisions.

Value co-creation provides a useful theoretical lens for understanding stakeholder interaction in infrastructure project delivery. In the value co-creation perspective, value is not produced by a single actor but jointly created through interaction, dialogue, information access, transparency, and risk assessment among stakeholders (Pralhad & Ramaswamy, 2004; Vargo & Lusch, 2008). This perspective is relevant to design-and-build projects because technical decisions require the integration of engineering feasibility, constructability, cost implications, regulatory compliance, and project-owner requirements. The DART framework, which emphasises dialogue, access, risk assessment, and transparency, can support collaborative decision-making by encouraging stakeholders to evaluate design alternatives using shared information and explicit risk considerations (Pralhad & Ramaswamy, 2004). When integrated with the Plan-Do-Check-Action logic, value co-creation can also support continuous process improvement by ensuring that design-review practices are planned, implemented, monitored, and standardised based on performance evidence (Deming, 1986; Moen & Norman, 2010).

Building Information Modelling within a Common Data Environment provides a digital mechanism for supporting collaborative design review and stakeholder governance. BIM enables design visualisation, coordination, quantity calculation, clash detection, and technical validation, while CDE provides a shared platform for storing, accessing, controlling, and tracing design documents, revisions, and approvals (Azhar, 2011; Bryde et al., 2013; Love et al., 2014; Patacas et al., 2020). In design-and-build projects, BIM-CDE can reduce uncertainty by enabling stakeholders to evaluate design alternatives based on the same source of information. This function becomes particularly important when preliminary topographic data differ from validated field data, because digital traceability allows technical discrepancies, cost implications, and design alternatives to be reviewed more transparently. Recent studies show that CDE can improve BIM-based project performance by strengthening information management, workflow coordination, document reliability, and project visibility, although its benefits depend on organisational adoption, stakeholder readiness, data accountability, and platform interoperability (Dolla et al., 2024; Jaskula et al., 2024; Seyis & Özkan, 2024; Seidenschnur et al., 2022).

The role of BIM-CDE should therefore be understood not merely as a digital documentation tool, but as a governance interface for improving design-review efficiency. In infrastructure projects with multiple reviewing authorities, design approval often becomes slow because information is distributed across separate actors, platforms, and decision layers. BIM-CDE can reduce this fragmentation by providing shared access to design alternatives, revision history, technical assumptions, cost implications, and approval status. However, digital platforms do not automatically improve performance when they are used only to automate existing sequential routines. Digital transformation generates organisational value when it redesigns workflows,

improves coordination, and changes how decisions are made (Sastra et al., 2025; Yusuf et al., 2025). This is consistent with recent HEBR evidence showing that digital transformation and innovation capability can strengthen organisational competitiveness in emerging markets, and that digital technology can enhance public service efficiency when it improves transparency, accessibility, and administrative responsiveness (Sastra et al., 2025; Yusuf et al., 2025).

Process Chain Network provides a process lens for analysing how stakeholder activities are connected in design development and review. Sampson (2012) introduced PCN analysis as a visual framework for examining processes and interactions involving networks of entities. The framework distinguishes activities based on the degree of interaction among actors, allowing analysts to identify which activities can be conducted independently, which require surrogate interaction through shared information, and which require direct interaction among stakeholders (Sampson, 2012). In a fragmented design-review process, design development, cost evaluation, technical review, constructability assessment, and formal approval may form a long sequential chain that increases cycle time. PCN helps identify whether these activities can be redistributed into more efficient interaction patterns, such as parallel review, simultaneous evaluation of design alternatives, or earlier involvement of key decision-makers. Therefore, PCN is suitable for diagnosing whether schedule risk emerges from technical complexity alone or from the structure of stakeholder interaction.

When combined with BIM-CDE, PCN-based process redesign can support a more collaborative and traceable design-review process. PCN provides the process architecture by mapping how activities and stakeholders are connected, while BIM-CDE provides the digital infrastructure for sharing information and tracing decisions. This combination is relevant for design-and-build projects because the contractor, consultant, project owner, supervisory consultant, independent quality controller, and government authority must evaluate not only whether a design is technically feasible, but also whether it complies with contractual requirements, cost limits, availability payment implications, and construction constraints. By enabling parallel submission and review of several design alternatives, PCN and BIM-CDE can reduce repetitive feedback loops and improve decision readiness. This integrated perspective responds to the limitation of studies that examine BIM-CDE primarily as an information-management system without sufficiently explaining how it can restructure stakeholder interaction and approval workflows.

The selection of the most feasible process-redesign alternative requires a structured multi-criteria decision-making method. Analytical Hierarchy Process is appropriate because it decomposes complex decisions into criteria and alternatives, then applies pairwise comparison to determine priority weights (Saaty, 2008). AHP has been widely used in construction management to evaluate alternatives and support decision-making under uncertainty, particularly when technical, financial, managerial, and stakeholder considerations must be assessed simultaneously (Darko et al., 2019). In this study, AHP is used to assess process alternatives based on compliance, number of

design alternatives, required time, number of process stages, and cost efficiency. The use of AHP is also consistent with recent HEBR studies that apply structured decision-making methods in Indonesian organisational settings, such as prioritising cashless payment alternatives in SMEs and optimising oil-field facilities under governance and capital constraints (Sari & Marpaung, 2025; Wibowo & Hermawan, 2026). These studies support the relevance of AHP for managerial decision-making in contexts where alternatives must be evaluated under multiple constraints.

Based on this literature, this study conceptualises design-review inefficiency as the result of technical data misalignment, sequential stakeholder interfaces, fragmented information flows, and limited digital integration. Design-and-build procurement provides contractual integration, but it does not automatically eliminate process fragmentation when design assumptions change during execution. Stakeholder governance explains why approval delays emerge from multiple authority structures and different risk positions. Value co-creation and DART-PDCA explain how stakeholders can jointly evaluate alternatives through dialogue, access, risk assessment, transparency, and continuous improvement. BIM-CDE provides the digital infrastructure for shared and traceable information, while PCN provides the process structure for redesigning stakeholder interaction. AHP then supports the selection of the most feasible alternative by balancing compliance, time, cost, process stages, and design options. This integrated perspective frames the Trans Papua Project as a case of digital-enabled process reengineering in public-private infrastructure governance.

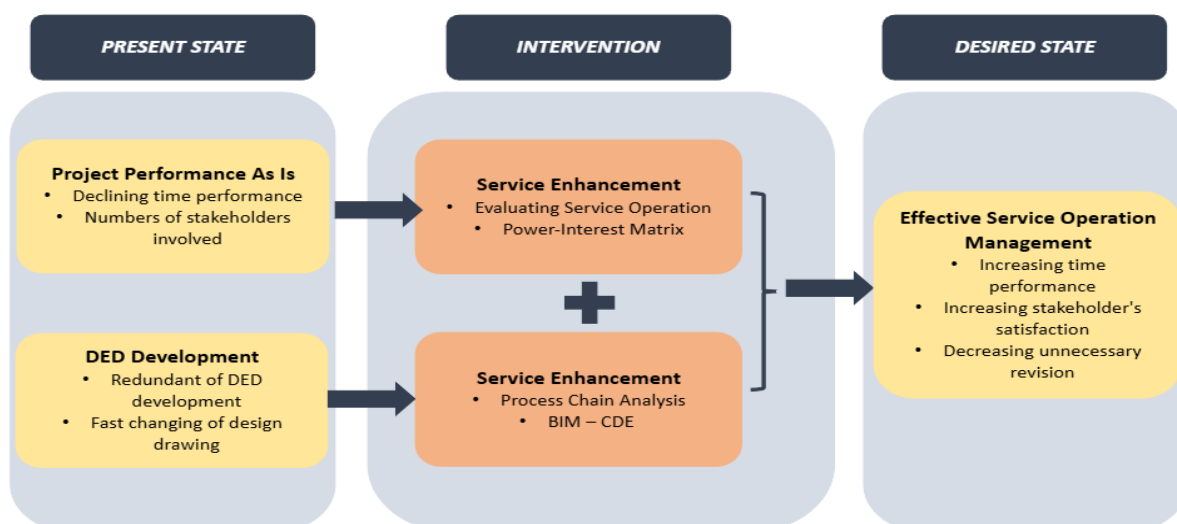


Figure 1. Conceptual Framework (Author)

3. METHODOLOGY

This study employed a mixed-methods case study design to examine design-review inefficiencies and develop process improvement alternatives in the Trans Papua design-and-build project. This approach was selected because the study needed to capture both measurable schedule-performance trends and the underlying process, stakeholder, and

technical causes of repeated design-review cycles. Quantitative analysis was used to evaluate project schedule performance, while qualitative analysis was used to diagnose workflow inefficiencies and stakeholder coordination problems.

Quantitative data were obtained from verified monthly progress reports covering November 2024 to September 2025. The reports had been reviewed by the contractor, project owner, and supervisory consultant. Two project-control indicators were used: Schedule Performance Index (SPI) and Schedule Variance (VS). SPI measures the ratio between performed work and scheduled work, while VS measures the difference between performed work and scheduled work in monetary terms. The formulas are expressed as follows:

$$SPI = BCWP / BCWS \quad (1)$$

$$VS = BCWP - BCWS \quad (2)$$

where BCWP refers to Budgeted Cost of Work Performed and BCWS refers to Budgeted Cost of Work Scheduled. An SPI value above 1.00 indicates that actual progress is ahead of schedule, while an SPI value below 1.00 indicates schedule delay. The SPI values were interpreted using the project performance classification adapted from the Project Management Institute (2021).

Qualitative data were collected through semi-structured interviews with five project personnel involved in design development, technical review, field coordination, and project control. Respondents were selected purposively because they had direct knowledge of the design-and-build process and the LIDAR-based topographic data discrepancies affecting detailed engineering design. The interview data were analysed using qualitative content analysis supported by ATLAS.ti. The coding process was grouped into five categories: scope of work, stakeholder, process, bottleneck, and improvisation. These categories were used to identify the root causes of design-review inefficiency and explain the schedule-performance trend found in the quantitative analysis.

Stakeholder analysis was then conducted to clarify the roles, interests, and authority of the contractor, design consultant, supervisory consultant, independent quality controller, project owner, and government authority. Process Chain Network analysis was used to map the existing design-review workflow, identify repeated review loops, and develop three alternative process-redesign scenarios. The alternatives were developed by integrating value co-creation, DART-PDCA, BIM-CDE, and PCN principles. BIM-CDE was positioned as the digital platform for shared access, document traceability, and parallel assessment of design alternatives.

The Analytical Hierarchy Process was applied to select the most feasible process-redesign alternative. The evaluation criteria consisted of compliance, number of design alternatives, required time, number of process stages, and cost efficiency. Pairwise comparisons were conducted using Saaty's 1–9 scale by seven project management and

engineering personnel. The average judgment scores were used to calculate priority weights and rank the alternatives. Consistency Index and Consistency Ratio were calculated to ensure judgment consistency, with a Consistency Ratio of 0.10 or below considered acceptable (Saaty, 2008; Darko et al., 2019).

Overall, the integration of SPI and VS analysis, qualitative content analysis, stakeholder analysis, PCN mapping, BIM-CDE-based redesign, DART-PDCA logic, and AHP provided methodological triangulation. This design enabled the study to connect schedule-performance evidence with process diagnosis and structured decision-making to identify a feasible process improvement model for design-and-build infrastructure projects.

4. RESULTS

4.1 Root Causes of Design-Review Inefficiency

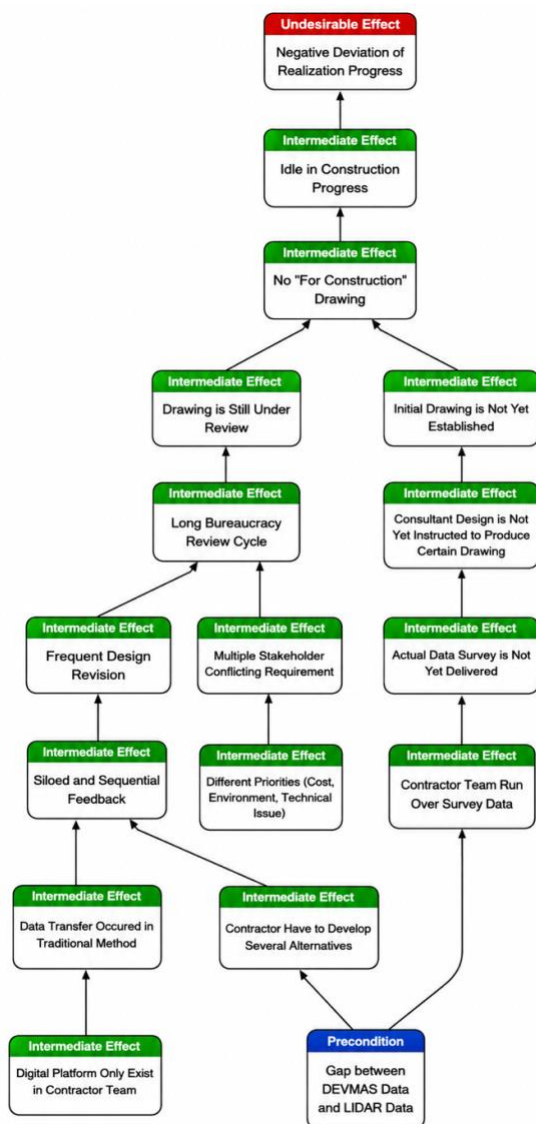


Figure 2. Root Cause Analysis (Data Analysis)
Source: Data analysis

The analysis shows that the main source of schedule risk in the Trans Papua design-and-build project was not merely construction productivity, but the misalignment between preliminary topographic assumptions and validated field data. The discrepancy between bidding-stage topographic data and contractor-acquired LIDAR data affected earthwork volumes, alignment decisions, structural requirements, and cost estimates. As a result, the initial design could not be directly implemented without further technical review, cost recalculation, and stakeholder approval.

The qualitative content analysis supports this diagnosis. Interview coding identified five dominant categories: scope of work, stakeholder, process, bottleneck, and improvisation. These categories show that design-review inefficiency emerged from three interrelated causes: data inconsistency, repeated design-revision cycles, and fragmented stakeholder interfaces. The repeated review process occurred because each stakeholder evaluated the design from different perspectives, including technical feasibility, cost control, contractual compliance, quality assurance, and regulatory approval.

The existing Process Chain Network confirms that the design-review workflow followed a sequential structure. The design consultant, contractor, supervisory consultant, independent quality controller, project owner, and government authority reviewed the design in separate stages. Although this structure supported formal accountability, it increased the probability of repeated feedback loops and prolonged approval time. Therefore, the existing workflow created a process bottleneck when technical data discrepancies required rapid design adjustment.

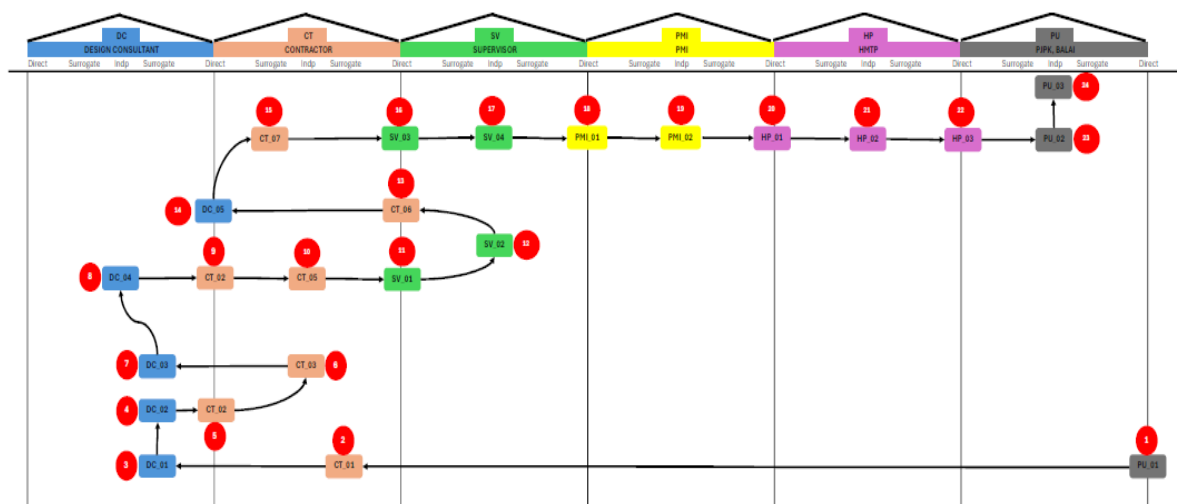


Figure 3. Existing Process Chain Analysis

Stakeholder analysis further shows that several actors had both high power and high interest in the design approval process. The contractor and project owner were strongly affected by cost and schedule implications, while the supervisory consultant, independent quality controller, and government authority influenced technical and regulatory acceptance. This indicates that design-review inefficiency was not only a technical issue, but also a stakeholder-governance issue.



Figure 4. Power Interest Matrix

4.2 Schedule-Performance Evidence

The quantitative analysis confirms that the project experienced a weakening schedule-performance trend during the early construction phase. Although the cumulative Schedule Performance Index remained above 1.00, the SPI declined sharply from 3.47 in December 2024 to 1.07 in April 2025. This indicates that the project was still ahead of schedule in aggregate terms, but its early schedule buffer was eroding. The decline suggests that favourable cumulative progress may conceal emerging process bottlenecks when construction activities depend on the timely approval of revised design drawings.

Table 1. Calculation of Schedule Performance Index (SPI) and Variance of Schedule (Vs)

No.	Month	Progress per Month			Progress Up to This Month		BCWP (in Rp million)	BCWS (in Rp million)	SPI	Vs (in million)
		Master Schedule	Realization	Deviation	Master Schedule	Realization				
1	Nov 2024	0.200%	0.650%	0.450%	0.200%	0.650%	19.372	5.960	3,25	13.411
2	Dec 2024	0.231%	0.844%	0.613%	0.431%	1,494%	44.526	12.845	3,47	31.680
3	Jan 2025	0.602%	0.520%	-0.082%	1,033%	2,014%	60.023	30.786	1,95	29.237
4	Feb 2025	0.946%	0.755%	-0.191%	1,979%	2,769%	82.525	58.980	1,40	23.544
5	Mar 2025	1,185%	1,223%	0.038%	3,164%	3,992%	118.974	94.297	1,26	24.677
6	Apr 2025	3,380%	3,020%	-0.360%	6,544%	7,012%	208.980	19.032	1,07	13.947
7	May 2025	5,443%	6,287%	0.844%	11,987%	13,299%	396.353	357.251	1,11	39.101

Although SPI values remained above 1.00, the decline from 3.47 in December 2024 to 1.07 in April 2025 indicates a weakening schedule buffer. This pattern suggests that early physical progress had not yet translated into stable schedule resilience because design-dependent construction activities still relied on the approval of revised design drawings. The SPI trend therefore served as an early warning signal that design-review bottlenecks could later constrain construction progress.

The risk analysis also confirms that design changes due to actual site conditions created schedule and cost exposure. The identified risk event was construction delay caused by design changes. The potential impacts included the extension of Construction

All Risk insurance, additional fixed costs, and increased design consultant fees. This risk profile indicates that design-review inefficiency had direct contractual and financial consequences.

Table 2. Design-Change Risk Mapping

Risk Event	Root Cause	Impact	Impact Score	Probability Scale
Delay of construction work.	Design change issue due to site conditions.	1. Elongation of CAR insurance 2. Increase in fixed cost and design consultant's fee.	4	4

Taken together, the SPI trend, risk mapping, interview findings, and process diagnosis indicate that the project required managerial intervention before the design-review issue developed into a more severe construction delay. The declining SPI functioned as an early warning signal of deeper workflow and stakeholder coordination problems.

4.3 Development of PCN-Based Process Alternatives

Based on the root cause, PCN, stakeholder, and schedule-performance analyses, three process alternatives were developed. These alternatives were designed to reduce repeated design-review loops, improve the transparency of design alternatives, and accelerate stakeholder decision-making. The alternatives were developed using value co-creation, DART-PDCA, BIM-CDE, and PCN principles. The objective was not only to shorten design production time, but also to redesign stakeholder interaction so that technical, financial, and regulatory considerations could be evaluated more efficiently.

Alternative 1 allows the design consultant to prepare the initial alternative, which is then evaluated and expanded by the contractor into several technically and financially justified design alternatives. These alternatives are submitted simultaneously to the relevant stakeholders for review. This structure preserves the role of the design consultant while enabling the contractor to contribute cost, constructability, and BIM-based evaluation.

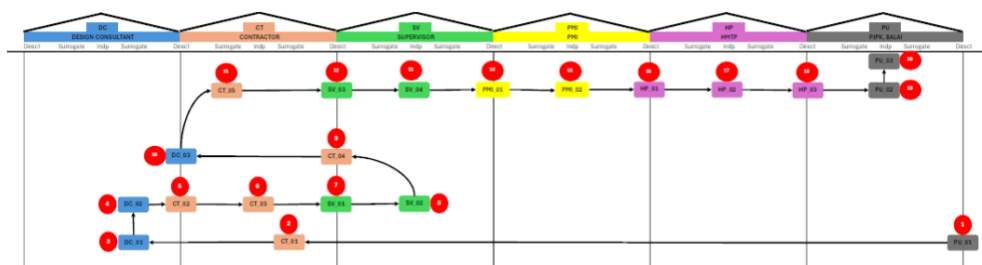


Figure 5. Process Chain Network Analysis of Alternative 1

Alternative 2 assigns broader responsibility to the design consultant to prepare multiple design alternatives before contractor evaluation. This alternative strengthens consultant involvement, but it requires more process stages and longer review time because design alternatives must still be checked by the contractor before being submitted to other stakeholders.

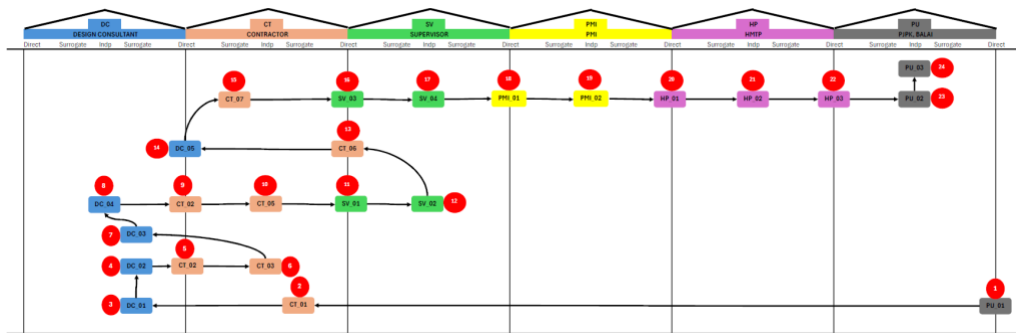


Figure 6. Process Chain Network Analysis of Alternative 2

Alternative 3 shifts the development of design alternatives to the contractor’s internal engineering department. This alternative has fewer stages and may offer faster coordination within the contractor’s organization. However, it creates potential compliance concerns because the formal role of the design consultant becomes less prominent.

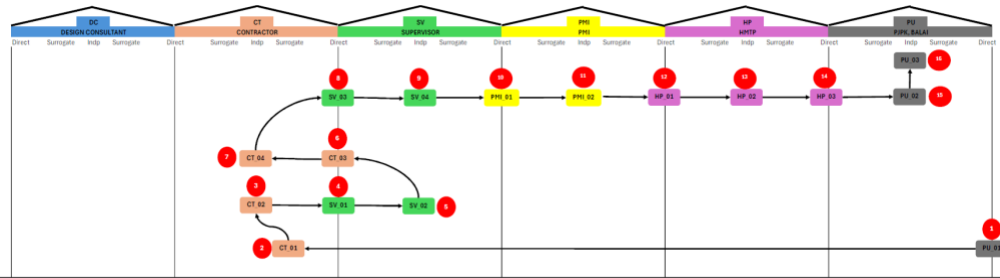


Figure 7. Process Chain Network Analysis of Alternative 3

The comparison of process alternatives is summarised in Table 3. This table replaces the long procedural table by focusing on the analytical differences among alternatives.

Table 3. Summary of PCN-Based Business Process Alternatives

Aspect	PCN Alternative 1	PCN Alternative 2	PCN Alternative 3
Main process logic	Consultant prepares the initial alternative; contractor expands it into several alternatives through BIM-supported cost and constructability evaluation	Consultant prepares multiple alternatives before contractor review	Contractor’s internal engineering department develops the alternatives
Design alternatives	Five alternatives	Six alternatives	Three alternatives
Required time	Less than 4.5 months	6–7.5 months	Less than 4.5 months
Process stages	20 stages	24 stages	16 stages
Compliance position	Strong because consultant involvement is retained	Strong but slower because the consultant leads more stages	Weaker because consultant involvement is reduced
Cost implication	86.94% efficient against COGS	86.94% efficient against COGS	Equal to COGS

Main implication	Balanced option between compliance, cost, time, and stakeholder acceptance	Consultant-oriented but longer	Faster internally but less favourable for compliance and cost
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The selected process alternative also required a clearer stakeholder responsibility structure. Each actor remained involved, but their roles were reorganised to support earlier evaluation, shared information access, and parallel decision-making.

Table 4. Stakeholder Roles in the Selected PCN Alternative

Stakeholder	Role in the Selected Process
Contractor	Compares secondary and field-validated data, evaluates technical feasibility, develops additional design alternatives, and aligns options with budget and availability payment constraints
Design consultant	Prepares the initial design alternative and provides the technical basis for further development
Supervisory consultant	Reviews the proposed alternatives to ensure consistency with technical criteria and design standards
Independent quality controller	Evaluates design completeness, technical justification, and readiness for formal approval
Project owner	Reviews design alternatives based on technical feasibility, budget constraints, and availability payment implications
Government authority	Provides initial design reference, conducts final review, and determines the approved design for construction

Source: Data analysis

4.4 AHP-Based Selection of the Preferred Alternative

The Analytical Hierarchy Process was used to determine the most feasible process-redesign alternative. The evaluation criteria consisted of compliance, number of design alternatives, required time, number of process stages, and cost efficiency. These criteria were developed from project requirements and stakeholder interview findings.

The criteria-weight results show that cost was the most influential criterion, followed by the number of process stages and required time. This indicates that stakeholders prioritised alternatives that could reduce financial exposure and workflow complexity while still maintaining acceptable compliance.

Table 5. AHP Criteria Weights

Criteria	Priority Weight	Interpretation
Compliance	0.03	Minimum requirement but not the dominant differentiator
Design alternatives	0.07	Relevant for comparison, but less influential than cost and time-related criteria
Required time	0.14	Important for reducing approval cycle time
Process stages	0.26	Highly important because repeated stages increase delay risk
Cost	0.50	Most influential criterion due to direct financial and contractual implications

The consistency test shows that all pairwise comparison matrices met the accepted threshold. The Consistency Ratio values were equal to or below 0.10, indicating that respondent judgments were sufficiently consistent for decision analysis.

Table 6. AHP Consistency Results

Matrix	Consistency Index (CI)	Random Consistency Index (RI)	Consistency Ratio (CR)
Compliance	0.09	1.12	0.08
Design Number	0.02	1.12	0.02
Required Time	0.09	1.12	0.08
Stages Amount	0.11	1.12	0.10
Cost	0.03	1.12	0.03

Source: Data analysis

The final AHP ranking confirms that PCN Alternative 1 was the preferred solution. It obtained the highest total score because it provided the best balance among cost efficiency, process-stage reduction, time efficiency, design alternatives, and compliance acceptability.

Table 7. Final Ranking of PCN Alternatives

Alternative	Compliance	Design Alternatives	Required Time	Process Stages	Cost	Total Score	Rank
PCN Alternative 1	0.01751	0.03397	0.06755	0.07746	0.13976	0.33625	1
PCN Alternative 2	0.00468	0.00521	0.01805	0.11297	0.13976	0.28067	2
PCN Alternative 3	0.00236	0.01751	0.06755	0.07746	0.03292	0.19781	3

Source: Data analysis

These results indicate that the preferred process alternative was not simply the fastest or shortest alternative. Instead, the most feasible option was the alternative that balanced process efficiency with compliance, stakeholder acceptance, and cost control. This finding is important because design-and-build process improvement cannot be achieved only by reducing stages; it must also preserve technical accountability and decision legitimacy.

4.5 Implementation Outcome and Performance Validation

The short-term implementation of PCN Alternative 1 showed improvement in project schedule performance. After implementation began, SPI increased from 1.11 in June 2025 to 1.13 in July 2025, 1.16 in August 2025, and 1.17 in September 2025. This indicates that the declining trend observed in the early phase was reversed after the design-review process was reorganised.

Table 8. Schedule Index Performance Rating After Short Implementation

Month (up to)	SPI	Condition	Rating
November 2024	3.25	A	Outstanding Performance
December 2024	3.47	A	Outstanding Performance
January 2025	1.95	A	Outstanding Performance
February 2025	1.40	A	Outstanding Performance
March 2025	1.26	A	Outstanding Performance
April 2025	1.07	B	Exceeds Target
May 2025	1.11	B	Exceeds Target
June 2025	1.11	B	Exceeds Target
July 2025	1.13	B	Exceeds Target
August 2025	1.16	A	Outstanding Performance
September 2025	1.17	A	Outstanding Performance

Source: Data analysis

The schedule-monitoring results show that actual progress remained above the master schedule during the post-implementation period. More importantly, the gap between planned and actual progress widened after the process intervention, suggesting that the redesigned workflow helped reduce constraints on construction progress.

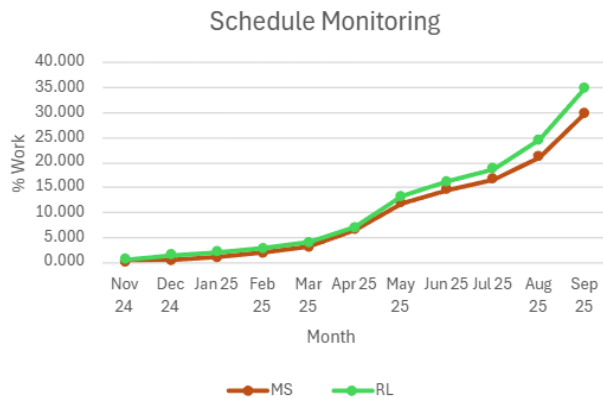


Figure 8. Schedule Monitoring

The SPI graph further shows that the declining trend observed earlier was reversed after the implementation of Alternative 1. Although schedule improvement may also have been influenced by other operational factors, the timing of the improvement indicates that the parallel submission and review of design alternatives contributed to restoring schedule performance.

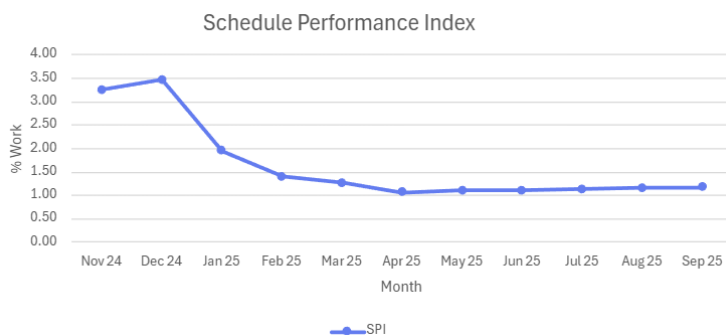


Figure 9. Schedule Performance Index

Although the improvement in SPI may also have been influenced by operational factors, the timing of the improvement indicates that the parallel submission and review of design alternatives contributed to restoring schedule performance. The implementation outcome demonstrates that process reengineering can produce measurable project benefits when it directly addresses the root causes of schedule risk. In this case, the main root cause was not only design complexity, but the sequential structure of stakeholder review and the absence of an integrated digital collaboration mechanism.

4.6 Institutionalisation through Management of Change

The selected process alternative should not be treated only as a temporary solution for the Trans Papua Project. Similar data discrepancies and design-review bottlenecks may occur in other design-and-build infrastructure projects. Therefore, the redesigned process needs to be institutionalised through Management of Change and continuous PDCA-based improvement.

The proposed institutionalisation process consists of change identification, investigation and plan evaluation, implementation, monitoring, and evaluation. Senior management involvement is required during change investigation and implementation because process redesign requires formal approval, resource allocation, and cross-unit coordination. At the project level, the project manager and operational management are responsible for monitoring lead time, SPI, and Schedule Variance to ensure that the new workflow produces measurable performance improvements.

Table 9. Management of Change Framework

No.	Description	Stakeholder Involved	Output
1	Change identification	Identify design-management issues and process inefficiencies	Project team and operational management
2	Investigation and plan evaluation	Review proposed change and assess feasibility	Construction department, risk management, and executive management
3	Change implementation	Apply redesigned process and align stakeholder roles	Operational management, construction department, and executive management
4	Monitoring and evaluation	Monitor implementation constraints and performance outcomes	Project manager and operational management

Source: Data analysis

The PDCA cycle provides the mechanism for sustaining the redesigned design-review process. The Plan stage identifies design-management problems and prepares the change plan. The Do stage implements the redesigned workflow using BIM-CDE and coordinated stakeholder engagement. The Check stage monitors lead time, SPI, and Schedule Variance. The Action stage standardises improved practices and refines the process based on implementation evidence.

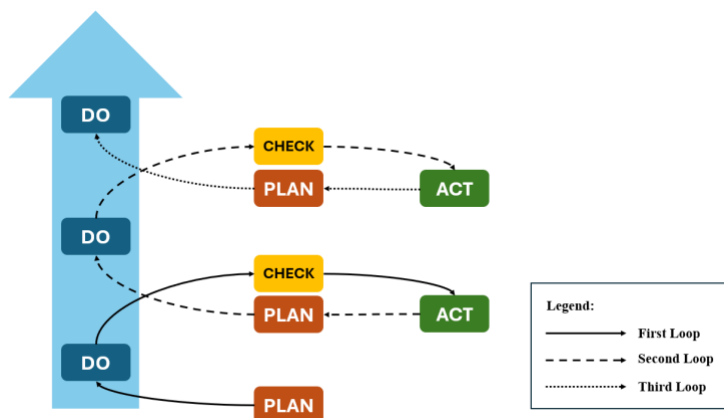


Figure 10. Continuous Cycle of PDCA Design Management (Data Analysis)

Long-term implementation also requires knowledge transfer to external stakeholders, especially project owners and public-sector reviewers. Since BIM-CDE changes the way design information is accessed, reviewed, and approved, stakeholder readiness becomes a critical success factor. Without sufficient understanding and adoption by external actors, the process may return to conventional sequential review routines. Therefore, digital readiness, stakeholder learning, and formal process standardisation are essential for sustaining the benefits of PCN-based process reengineering.

5. DISCUSSION

The findings show that schedule risk in the Trans Papua design-and-build project was not caused solely by field productivity constraints, but by technical data misalignment, sequential design-review routines, and fragmented stakeholder interfaces. Although design-and-build delivery is expected to improve cost, schedule, and coordination performance through integrated design and construction responsibility, this case demonstrates that contractual integration alone is insufficient when preliminary design assumptions differ from validated field conditions (Chan et al., 2002; Hale et al., 2009; Sullivan et al., 2017). The discrepancy between bidding-stage topographic data and contractor-acquired LIDAR data created repeated design adjustments, cost recalculations, and approval loops. The decline in SPI from 3.47 in December 2024 to 1.07 in April 2025 further indicates that favourable cumulative progress may conceal emerging process bottlenecks when construction progress depends on unresolved design approvals.

The results reinforce the importance of stakeholder governance in public-private infrastructure projects. The design-review process involved multiple actors with different authority, interests, and technical responsibilities, including the contractor, design consultant, supervisory consultant, independent quality controller, project owner, and government authority. Sequential review increased the possibility of repeated feedback because each stakeholder assessed the design from different perspectives, such as technical feasibility, cost implications, contractual compliance, quality assurance, and regulatory acceptance. This supports prior studies showing that infrastructure project performance depends on stakeholder alignment, communication quality, decision rights, and risk coordination (Aaltonen, 2011; El-Gohary et al., 2006; Mok et al., 2015; Osei-Kyei & Chan, 2015). Therefore, stakeholder management should move beyond mapping power and interest toward redesigning interaction structures that reduce unnecessary review loops.

The selection of PCN Alternative 1 demonstrates that process improvement requires structural reconfiguration rather than simple administrative acceleration. Alternative 1 was preferred because it maintained the formal role of the design consultant, enabled contractor-led cost and constructability evaluation, and allowed multiple design alternatives to be submitted for parallel stakeholder review. This reflects

the logic of value co-creation, where project value is produced through dialogue, access, risk assessment, and transparency among stakeholders (Prahalad & Ramaswamy, 2004; Vargo & Lusch, 2008). PCN supported this redesign by identifying which activities could be conducted independently, which required shared information, and which required direct stakeholder interaction (Sampson, 2012). In this study, PCN helped transform design review from a sequential process into a more collaborative and parallel workflow.

BIM-CDE strengthened the selected process alternative by functioning as a governance interface, not merely as a modelling or documentation tool. Through shared information access, document traceability, revision history, and transparent comparison of design alternatives, BIM-CDE improved stakeholder readiness to make technical and managerial decisions. This is consistent with studies showing that BIM and CDE can improve coordination, workflow visibility, and information reliability when supported by organisational adoption and stakeholder readiness (Azhar, 2011; Bryde et al., 2013; Love et al., 2014; Patacas et al., 2020; Jaskula et al., 2024; Seyis & Özkan, 2024). The findings suggest that BIM-CDE creates value when integrated with process redesign, rather than when used only to automate existing sequential routines.

The AHP results show that stakeholders prioritised cost efficiency, process stages, and required time in selecting the preferred alternative. Alternative 1 achieved the highest score because it balanced compliance, cost efficiency, stakeholder acceptance, and process speed. This confirms the relevance of AHP for construction decision-making where alternatives must be assessed under technical, financial, organisational, and governance constraints (Darko et al., 2019; Saaty, 2008). The short-term implementation outcome also supports the effectiveness of the selected alternative. After implementation, SPI improved from 1.11 in June 2025 to 1.17 in September 2025, indicating that parallel submission and review of design alternatives contributed to restoring schedule performance. Although other operational factors may also have influenced this improvement, the timing of the performance recovery suggests that PCN-based process reengineering and BIM-CDE-supported coordination helped reduce design-review constraints.

This study contributes to design-and-build and infrastructure governance literature by reframing schedule degradation as a process-governance problem rather than merely a construction productivity issue. Methodologically, it demonstrates the usefulness of combining SPI and Schedule Variance analysis, qualitative content analysis, stakeholder mapping, PCN, BIM-CDE, DART-PDCA, and AHP to connect performance symptoms with process causes and decision-support mechanisms. Practically, the findings suggest that field-validated data such as LIDAR should be integrated earlier into design development, while BIM-CDE should be institutionalised as a collaborative governance platform for shared review, traceable decisions, and parallel evaluation of design alternatives. To sustain the improvement, Management of Change and PDCA should be applied so that the redesigned process becomes part of organisational routines rather than a temporary project-level solution.

6. CONCLUSION

This study examined design-review inefficiency in the Trans Papua design-and-build project and found that early schedule degradation was mainly driven by technical data misalignment, sequential stakeholder review, and fragmented approval interfaces. The discrepancy between preliminary topographic data and contractor-validated LIDAR data created repeated design adjustments related to earthwork volume, alignment decisions, structural requirements, and cost feasibility. Although the project's cumulative Schedule Performance Index remained above the minimum threshold, its decline from 3.47 in December 2024 to 1.07 in April 2025 indicated an emerging schedule risk. By integrating SPI and Schedule Variance analysis, qualitative content analysis, stakeholder mapping, Process Chain Network, BIM-CDE, DART-PDCA, and Analytical Hierarchy Process, this study identified PCN Alternative 1 as the most feasible process-redesign solution.

The selected alternative balanced formal design-consultant involvement, contractor-led cost and constructability evaluation, parallel submission of design alternatives, process efficiency, and stakeholder acceptance. Its short-term implementation improved SPI from 1.11 in June 2025 to 1.17 in September 2025, indicating that process reengineering can support schedule recovery when it directly addresses the root causes of design-review bottlenecks. Theoretically, this study contributes to design-and-build and infrastructure governance literature by reframing schedule degradation as a process-governance problem rather than merely a construction productivity issue. Methodologically, it demonstrates the usefulness of combining project-control indicators, qualitative diagnosis, PCN, BIM-CDE, DART-PDCA, and AHP to connect performance symptoms with process causes and decision-support mechanisms. Practically, the findings suggest that field-validated data should be integrated earlier into design development, while BIM-CDE should be institutionalised as a collaborative governance platform for shared information access, traceable decisions, and parallel evaluation of design alternatives.

This study is limited by its single-case design, the relatively small number of interview respondents, and its focus on SPI and Schedule Variance as the main performance indicators. Therefore, the findings should be interpreted as context-specific evidence from an Indonesian public-private infrastructure project rather than as a universal model for all design-and-build projects. Future research should test the proposed process-reengineering model across multiple infrastructure projects and examine broader outcomes, such as stakeholder satisfaction, lifecycle cost, claim reduction, environmental impact, public service value, and long-term BIM-CDE adoption. Further studies may also explore how organisational readiness, digital capability, and stakeholder behaviour influence the sustainability of process redesign in infrastructure governance.

Author Contributions

F.P.P: Conceptualization; Data Curation; Formal Analysis; Investigation; Methodology; Project Administration; Resources; Software; Writing – Original Draft Preparation.
A.A.U: Supervision; Writing – Review.

Disclosure Statement

No potential conflict of interest has been reported by the author.

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