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Research Paper

Probability-Based Time and Cost Comparison of Precast and Conventional Methods for Drainage Construction in East Kalimantan, Indonesia

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ABSTRACT : *Drainage construction in high-rainfall regions requires a method that can control schedule risk without creating excessive cost. This study compares precast and conventional cast-in-situ methods for drainage-channel projects along the Samarinda Seberang-Sanga Sanga corridor in East Kalimantan, Indonesia. A quantitative comparative case-study design was applied to 86 project records, comprising 45 conventional and 41 precast observations. Project documents, field observations, interviews, and rainfall records were analyzed using independent-samples t-tests, classical regression diagnostics, multiple linear regression, and model-based method classification. The methods differed significantly in duration ($t = 4.150$; $p < 0.001$), while their costs were statistically comparable ($t = 0.440$; $p = 0.661$). All four regression models were significant ($F = 5.606$-23.800; $p <= 0.001$). Conventional duration was influenced by logistics access and segment length, whereas conventional cost was influenced by rainfall, logistics access, contractor experience, and segment length. Precast duration was influenced by rainfall, logistics access, and labor productivity; precast cost was influenced by productivity and contractor experience. Model application recommended a precast or time-priority precast strategy for 72 of 86 cases (83.7%), while 14 cases favored conventional construction under a cost-priority criterion. The findings indicate that precast construction is generally preferable when completion time is critical, but its benefits depend on transport readiness, lifting and installation productivity, weather planning, and contractor competence.*

KEYWORDS: *Construction cost, construction time, drainage channel, precast concrete, regression model.*

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I. INTRODUCTION

East Kalimantan has an intensive road and drainage development agenda because mobility corridors must remain functional under high rainfall and recurrent surface-water pressure. Samarinda climate records show pronounced monthly variability; October 2024 recorded 324.7 mm of rainfall across 31 rainy days, illustrating the exposure of roadside works to hydrometeorological disruption [1]. Weather affects excavation stability, concrete placement, haulage, worker productivity, and the availability of safe work windows. A systematic review of weather-related construction delay similarly identifies precipitation and related climate effects as recurring sources of schedule uncertainty [2].

Roadside drainage can be built using cast-in-situ concrete or precast components. Conventional construction provides flexibility when dimensions, utilities, soil conditions, and access change during execution, because reinforcement, formwork, and concrete placement can be adjusted directly in the field. Its disadvantages include longer on-site cycles, weather exposure, variable workmanship, and intensive supervision. Precast construction transfers much of the production process to a controlled environment and can shorten installation time, improve consistency, and reduce field labor; however, its success depends on fabrication capacity, transport routes, cranes, storage space, dimensional coordination, and installation planning [3-5].

Previous studies generally report a time advantage for precast systems, but cost results vary. The balance depends on project scale, repetition, hauling distance, lifting requirements, local labor conditions, and the cost of temporary works. A Samarinda case study of a macro-drainage channel found that method selection affected time, cost, and quality simultaneously [4]. Research in developing construction markets also shows that logistics limitations, weak communication, and shortages of specialist contractors can reduce the benefits of precast adoption [5]. Comparative project evidence therefore should not treat precast as universally superior; it should identify the circumstances under which each method performs effectively.

The research gap addressed in this study is the limited quantitative evidence linking construction method, rainfall, logistics, productivity, contractor experience, and drainage-segment characteristics to both time and cost outcomes in East Kalimantan. The study has three objectives: (1) to test whether conventional and precast methods differ in duration and cost; (2) to develop method-specific regression models for duration and cost; and (3) to translate the models into a practical method recommendation. The contribution is an evidence-based decision structure for drainage projects operating under rainfall and logistics constraints.

Table 1. Comparative characteristics of conventional and precast drainage construction

Dimension	Conventional Cast-In-Situ	Precast/Off-Site	Expected Management Implication
Production location	Most production occurs at the project site	Components are produced before delivery	Precast reduces on-site cycle time but shifts risk to supply and transport
Field flexibility	High; dimensions and details can be modified in situ	Lower; geometry and connections require early definition	Conventional is advantageous where site conditions are uncertain
Weather exposure	High during formwork, reinforcement, and concreting	Lower during fabrication but installation remains exposed	Rainfall planning is important for both methods
Logistics and equipment	Material deliveries and ordinary equipment	Heavy transport, lifting equipment, storage, and access	Precast requires route, crane, and delivery coordination
Quality control	Highly dependent on field supervision	More controlled production conditions	Precast can improve consistency when installation tolerances are managed
Primary decision criterion	Adaptability and local resource availability	Speed, repetition, and controlled production	Method selection should integrate time and cost priorities

II. LITERATURE REVIEW

2.1. Time-Cost Performance of Precast and Conventional Methods

Precast technology improves productivity by enabling parallel activities: site preparation can proceed while structural elements are manufactured. Controlled casting and curing can also reduce rework and variability [3]. Comparative studies report substantial schedule savings, although the magnitude depends on the building or infrastructure type and the maturity of the supply chain [6]. For drainage systems, repetitive elements such as box culverts and standardized channel units are particularly suitable for off-site production, while irregular outlets, utility crossings, and changing levels may still require cast-in-situ work.

The cost effect is less predictable. Precast can reduce labor, formwork, and site overhead, but it adds mold investment, factory handling, transport, lifting, storage, and connection costs. Yard layout and component handling must balance safety and operational efficiency [7]. In complex projects, logistics should be treated as a core management function rather than a secondary delivery activity because dependencies among suppliers, transporters, contractors, and site access directly affect production continuity [8].

2.2. Determinants of Duration and Cost

Rainfall can stop excavation, destabilize subgrade, reduce concrete productivity, and create dewatering or traffic-management requirements. Logistics access affects the movement of aggregates, ready-mix concrete, precast units, cranes, fuel, and workers. Poor access may be more disruptive to precast installation because delivery and lifting must be synchronized, yet it also raises conventional costs through repeated material hauling and idle labor.

Labor productivity represents the conversion of time and resources into installed work. Reviews of construction productivity identify workforce competence, supervision, planning, material availability, equipment, and environmental conditions as critical factors [9,10]. Contractor experience is expected to improve sequencing, temporary works, risk response, and cost control. Segment length captures work volume and repetition: longer segments may increase total duration and cost, but they can also create economies of repetition, particularly for standardized precast units.

Construction risk management requires the simultaneous consideration of time, cost, resource, and environmental uncertainty [11]. Time-cost optimization research emphasizes that a technically faster option is not automatically the most economical option under every constraint [12]. Consequently, this study estimates separate duration and cost models for each method rather than imposing one combined model.

2.3. Analytical Framework

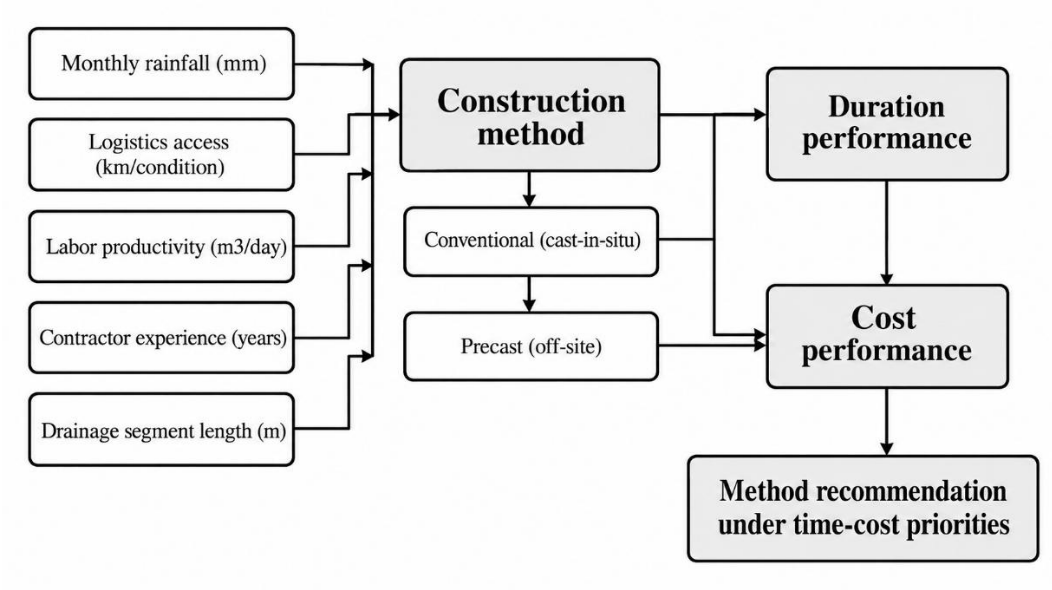

Figure 1. Analytical framework for method-specific duration and cost modeling

Figure 1 positions rainfall, logistics access, labor productivity, contractor experience, and segment length as predictors of duration and cost. The relationships are estimated separately for conventional and precast projects. The fitted results are subsequently used to identify the method that best supports time- or cost-priority decisions.

III. RESEARCH METHOD

3.1. Research Design and Study Area

The research used a quantitative comparative case-study design. The study area was the Samarinda Seberang-Sanga Sanga Road corridor in East Kalimantan, a strategic route characterized by high rainfall, drainage pressure, utility conflicts, and varying site access. Data covered project implementation during 2024-2025. The study combined statistical comparison with method-specific predictive modeling.

The analytical dataset contained 86 drainage-project records: 45 using conventional cast-in-situ construction and 41 using precast construction. The records were compiled from project budgets, schedules, daily and weekly reports, progress documentation, rainfall information, site observations, and semi-structured interviews with contractor and supervision personnel. Cross-checking between documents and field information was used to improve consistency.

3.2. Variables and Measurement

Table 2. Variables used in the comparative and regression analysis

Variable	Role	Unit/Measurement	Operational Interpretation
Construction duration	Dependent	Days or deviation from planned duration	Time required to complete the drainage work
Actual construction cost	Dependent	Indonesian rupiah or deviation from budget	Recorded expenditure for labor, material, equipment, and disruption
Rainfall	Predictor	mm/month	Hydrometeorological exposure during execution
Logistics access	Predictor	km and access condition	Distance and difficulty of transporting resources to the site
Labor productivity	Predictor	m^3/day	Installed work volume per working day
Contractor experience	Predictor	Years	Experience relevant to the selected construction method

Variable	Role	Unit/Measurement	Operational Interpretation
Segment length	Predictor	m	Length of the drainage section under construction
Construction method	Grouping	Conventional or precast	Basis for the comparative test and separate regression models

3.3. Statistical Analysis

An independent-samples t-test compared duration and actual cost between the two method groups. Multiple linear regression was then estimated separately for conventional duration, conventional cost, precast duration, and precast cost. The general model was $Y = b0 + b1R + b2L + b3P + b4E + b5S + e$, where R is rainfall, L is logistics access, P is productivity, E is contractor experience, and S is segment length.

Model diagnostics included Kolmogorov-Smirnov normality tests, variance inflation factors (VIF), Durbin-Watson statistics, and Glejser tests. Overall model significance was evaluated using the F-test, and individual effects were interpreted from t-statistics and p-values. Regression coefficients were interpreted at the 5% significance level. The thesis applied a 1% criterion to its Glejser tests; this diagnostic choice is reported explicitly because one precast-duration rainfall test had $p = 0.024$ and would require additional examination under a 5% criterion. Statistical procedures followed standard applied-statistics and econometric guidance [13-15].

Finally, fitted duration and cost models were applied to classify each observation according to the method providing the more favorable predicted outcome. Recommendations were separated into direct precast, time-priority precast, and cost-priority conventional categories so that the trade-off remained visible rather than being reduced to a single universal rule.

IV. RESULT AND DISCUSSION

4.1. Observed Project Outcomes

Across the 86 records, schedule performance was more problematic than cost performance. Sixty-seven projects were delayed and only 19 were completed on time. Cost outcomes were almost balanced: 41 records showed cost overrun and 45 showed savings. This pattern indicates that the central management challenge in the dataset was completion time rather than an across-the-board inability to control cost.

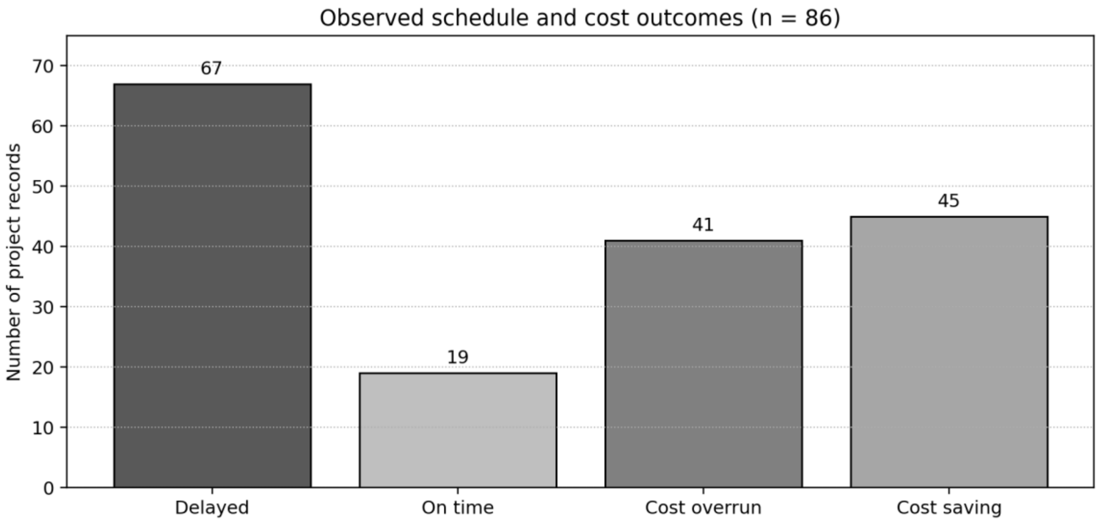

Figure 2. Frequency of schedule and cost outcomes in the analyzed records

Field documentation from the corridor supports this interpretation. Drainage work was affected by heavy rainfall, utility interference, and the need to reschedule or extend working hours. The case package combined cast-in-situ channel work with precast box-culvert elements and ultimately reached full physical completion, demonstrating that hybrid application can be effective when field irregularities and standardized units coexist.

4.2. Comparison of Duration and Cost

Table 3. Independent-samples t-test for conventional and precast methods

Performance Criterion	t	p-value	df	Interpretation
Duration	4.150	< 0.001	84	Significant difference between methods

Performance Criterion	t	p-value	df	Interpretation
Actual cost	0.440	0.661	84	No statistically significant difference

The significant duration result confirms that construction method is associated with different completion-time performance. Project-level interpretation in the thesis identifies the precast method as the faster alternative because fabrication is partly transferred away from the work front and field installation is shorter. By contrast, the cost test shows that the two methods were statistically comparable. Thus, the time advantage of precast was not accompanied by a significant average cost penalty or saving in this dataset.

The cost equivalence is practically important. Savings from reduced on-site cycles and formwork may be offset by fabrication, transport, lifting, handling, and storage. Conversely, conventional work can avoid heavy component transport but may incur longer overhead, weather exposure, and field labor. The result therefore supports a context-dependent decision rather than a cost-only preference.

4.3. Regression Diagnostics and Model Significance

Table 4. Summary of classical regression diagnostics

Diagnostic	Conventional Duration	Conventional Cost	Precast Duration	Precast Cost	Decision
Normality p-value	> 0.200	0.170	0.105	> 0.200	Residual normality supported
VIF range	1.017-1.695	1.017-1.695	1.038-1.077	1.038-1.077	No material multicollinearity
Durbin-Watson	1.938	2.055	2.134	2.167	No autocorrelation under reported ranges
Glejser p-value range	0.307-0.590	0.075-0.956	0.024-0.905	0.214-0.649	No significance at alpha = 0.01

The normality, VIF, and Durbin-Watson results support the use of linear regression. VIF values were low, indicating that rainfall, logistics, productivity, experience, and segment length contributed sufficiently distinct information. The heteroscedasticity diagnostics were acceptable under the 1% criterion applied in the thesis, although the $p = 0.024$ result for rainfall in the precast-duration model should be rechecked in future validation using robust standard errors or additional residual plots.

Table 5. Overall significance of the four regression models

Construction Method	Dependent Variable	F-statistic	p-value	Overall Result
Conventional	Duration	15.305	< 0.001	Significant
Conventional	Cost	23.800	< 0.001	Significant
Precast	Duration	5.606	0.001	Significant
Precast	Cost	11.604	< 0.001	Significant

All four models were significant, demonstrating that the selected predictors jointly explained meaningful variation in both duration and cost for each construction method. The higher F-statistics for the conventional models suggest stronger combined relationships in those equations, although model-fit coefficients were not reported in the available thesis tables and should be provided in a future submission package.

4.4. Conventional-Method Regression Results

Table 6. Multiple regression results for conventional construction

Variable	Duration B	t	p	Cost B (IDR)	t	p
Constant	-46.177	-1.757	0.087	-2,575,867,477	-6.293	< 0.001
Rainfall	-0.014	-0.575	0.569	3,431,647.787	9.265	< 0.001
Logistics access	0.796	3.633	0.001	9,682,911.775	2.839	0.007
Labor productivity	4.152	0.212	0.833	94,760,792.700	0.311	0.758
Contractor experience	0.804	1.161	0.253	46,132,573.340	4.280	< 0.001
Segment length	-0.048	-3.819	< 0.001	1,000,325.161	5.131	< 0.001

Conventional duration was significantly related to logistics access and segment length. Cast-in-situ work depends on repeated movement of materials, ready-mix concrete, formwork, reinforcement, workers, and ordinary equipment. Access constraints can therefore create waiting time and interrupted production. The segment-length coefficient was statistically significant and negative in the fitted equation; this direction may reflect repetition effects, coding of duration performance, or unobserved project characteristics, and should not be interpreted as a universal claim that longer projects finish faster.

Conventional cost was significantly influenced by rainfall, logistics access, contractor experience, and segment length. Rainfall can generate dewatering, protection, idle resources, overtime, and remedial work. Logistics affects haulage and resource continuity. Experience may influence planning and cost-control decisions, while segment length directly changes quantity and production requirements. Productivity was not independently significant after the other variables were controlled.

4.5. Precast-Method Regression Results

Table 7. Multiple regression results for precast construction

Variable	Duration B	t	p	Cost B (IDR)	t	p
Constant	-20.969	-1.530	0.135	-131,190,554.600	-4.500	< 0.001
Rainfall	-0.016	-2.620	0.013	-13,082.879	-0.473	0.639
Logistics access	-0.050	-3.836	< 0.001	199,270.546	0.846	0.403
Labor productivity	0.368	3.323	0.002	86,321,378.030	2.885	0.007
Contractor experience	4.084	0.290	0.773	6,139,219.339	7.395	< 0.001
Segment length	0.546	1.400	0.170	26,058.721	1.994	0.054

Precast duration was significantly influenced by rainfall, logistics access, and labor productivity. Although component production occurs off-site, transport and installation remain weather-sensitive. Rain can restrict excavation, base preparation, crane operations, jointing, and safe access. Logistics is particularly critical because the delivery sequence must match lifting capacity and installation readiness. Productivity reflects the efficiency of handling, alignment, connection, and supporting field work.

Precast cost was significantly influenced by productivity and contractor experience. Efficient crews reduce crane time, rehandling, installation errors, and idle transport. Experienced contractors are more capable of planning molds, delivery windows, lifting equipment, temporary storage, connection details, and quality control. Segment length approached but did not reach the 5% threshold ($p = 0.054$), suggesting that scale may still be managerially relevant even though its partial effect was not statistically conclusive.

The contrast between models reveals different risk structures. Conventional work is more sensitive to site geometry, access, rainfall-related field exposure, and cumulative quantities. Precast work concentrates risk around coordinated logistics, installation productivity, and specialized experience. This finding is consistent with literature that identifies supply-chain readiness and contractor capability as prerequisites for successful precast implementation [5,7,8,16].

4.6. Model-Based Method Recommendation

Table 8. Classification of project records using the fitted duration and cost models

Actual Method	Recommended Precast	Precast With Time Priority	Conventional With Cost Priority	Total
Conventional	24	21	0	45
Precast	27	0	14	41
Total	51	21	14	86

The classification favored precast construction in 72 of 86 cases (83.7%) when direct and time-priority recommendations were combined. All 45 records originally executed conventionally were reclassified toward precast, either directly or because of the predicted duration advantage. Among the 41 precast records, 27 remained direct precast recommendations, whereas 14 shifted toward conventional construction when cost was prioritized.

The classification should be used as decision support, not as an automatic prescription. A suitable procurement strategy is to prioritize precast when the schedule is tight, repetition is high, routes and lifting areas are reliable, and qualified installation teams are available. Conventional construction remains valuable where dimensions are irregular, access cannot support component transport or cranes, utility conflicts require frequent adjustment, or the cost of precast logistics outweighs the time benefit. Hybrid construction can combine precast box culverts with cast-in-situ transitions, outlets, covers, and irregular sections.

Managerial actions derived from the models include: early route and access surveys; delivery and crane simulations; weather-responsive look-ahead schedules; buffer planning for critical materials and equipment; productivity targets for installation crews; competency requirements for site engineers; and explicit cost-time decision criteria during method selection. These controls operationalize the time, cost, quality, and resource-management principles of construction project management [17,18].

4.7. Limitations

The study is observational and geographically concentrated, so causal interpretation and generalization should be cautious. The available statistical output did not report group means, standard deviations, model R-squared values, confidence intervals, or external validation results. The classification procedure also requires validation on independent projects. Future research should add structural quality, safety, equipment capacity, material availability, geotechnical conditions, utility density, and life-cycle cost; apply robust or generalized regression where residual assumptions are uncertain; and compare results across regions and drainage typologies.

V. CONCLUSION

The comparative analysis demonstrates that precast and conventional drainage methods differ significantly in project duration but not in actual cost. The duration test was significant ($t = 4.150$; $p < 0.001$), while the cost test was not ($t = 0.440$; $p = 0.661$). The evidence therefore positions time, rather than average cost, as the principal differentiator between the two methods in the analyzed East Kalimantan projects.

The method-specific regressions show that conventional duration is governed mainly by logistics access and segment length, while conventional cost is affected by rainfall, logistics, contractor experience, and segment length. Precast duration is affected by rainfall, logistics, and productivity, whereas precast cost is affected by productivity and contractor experience. These differences confirm that the two methods require distinct risk-control priorities.

Precast or time-priority precast construction was recommended for 83.7% of the project records. It is consequently the preferred option when schedule acceleration is critical and logistics, lifting, installation productivity, and contractor competence are adequately prepared. Conventional or hybrid construction remains appropriate where adaptability and cost considerations dominate. The practical conclusion is not that one method should replace the other, but that selection should be based on quantified project conditions and explicit time-cost priorities.

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