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Research Paper

Optimizing Road Reconstruction Scheduling through Time-Cost Trade-Off and Fast-Track Methods with Quality Evaluation: Evidence from East Kalimantan, Indonesia

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ABSTRACT: *Road reconstruction in active traffic corridors requires schedule recovery strategies that reduce delay without creating disproportionate cost or quality risk. This study develops and compares Time-Cost Trade-Off (TCTO) and fast-track acceleration strategies for the Muara Badak-Batas Bontang 3 Road Reconstruction Project in East Kalimantan, Indonesia. At the status date of September 14, 2025, cumulative planned progress was 22.855%, whereas actual progress was 15.526%, producing a negative deviation of 7.329%. A remaining-work Precedence Diagram Method network was constructed from verified quantities, station locations, road sides, technical sequences, and resource data, and was analyzed using the Critical Path Method. The normal remaining duration was 117 calendar days, with completion projected for January 9, 2026, or nine days beyond the contract deadline. TCTO simulations evaluated one to three additional work hours per day; the selected two-hour overtime alternative reduced the duration to 101.19 days, required Rp180,146,867 in additional direct cost, and produced a cost slope of Rp11,394,489 per day. The fast-track alternative used two coordinated work fronts and reduced five critical Finish-to-Start lags from 14 to seven days with an accelerating admixture. It achieved a 101-day duration, an additional direct cost of Rp138,836,515, and a cost slope of Rp8,677,282 per day. Quality performance was evaluated by 21 experts using ten weighted indicators. The quality index was 86.85% for overtime and 89.23% for fast-track. The fast-track alternative was therefore superior in time, cost efficiency, and perceived quality, but its application remains conditional on trial-mix verification, early-age flexural-strength testing, dedicated resources at each front, coordinated traffic management, and independent quality-control coverage.*

KEYWORDS: *Critical path method, fast track, project acceleration, road reconstruction, time-cost trade-off.*

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I. INTRODUCTION

Road infrastructure is a fundamental component of regional accessibility, logistics, public services, and economic integration. In East Kalimantan, provincial roads connect administrative centers, settlements, mining and plantation areas, industrial corridors, and access routes supporting the new national capital region. Reconstruction is required where structural pavement capacity has deteriorated beyond the effectiveness of routine or periodic maintenance. Because road work is performed along elongated and spatially dispersed corridors, often while traffic remains active, schedule management must integrate technical sequence, resource movement, work-zone safety, and public access [11,13,14,19].

Road reconstruction delays extend traffic disruption, increase the use of labor and equipment, prolong site overhead, expose the project to weather and access uncertainty, and postpone the functional benefit of the infrastructure. A negative difference between planned and actual progress is only an initial warning; an effective recovery plan must identify the remaining work, reconstruct the current network logic, determine the critical path, and focus acceleration on activities that control the completion date [1,2,10,15]. Acceleration that is applied to noncritical work may add cost without reducing total project duration.

The Critical Path Method (CPM) provides the analytical basis for identifying zero-float activities and estimating the earliest achievable completion under a defined network. Two commonly used acceleration approaches are Time-Cost Trade-Off (TCTO) and fast-track. TCTO shortens activity durations by increasing direct resources, working hours, or equipment and evaluates the resulting crash cost and cost slope [7,9,17]. Fast-track reduces project duration by overlapping activities, changing precedence logic, reducing justified lags, or opening parallel work fronts [3-6,16]. Each method creates different operational consequences: overtime can increase fatigue, supervision burden, and equipment operating time, whereas parallel fronts require additional equipment, traffic-control capacity, communication, and quality-control personnel.

Previous studies have demonstrated meaningful schedule reductions through both methods. Fast-track applications have reduced durations by changing Finish-to-Start relationships to overlapping logic with controlled lag [3-6]. TCTO studies have shown that alternative combinations of overtime, labor, and equipment generate different crash durations and unit costs of time reduction [7,9,17]. However, project-acceleration decisions are frequently based on time and direct cost alone. The quality implications of extended working hours, accelerated concrete strength development, divided supervision, and multiple work fronts are often discussed qualitatively but are not integrated into a common decision framework [8,18].

This study addresses that gap through a case study of the Muara Badak-Batas Bontang 3 Road Reconstruction Project. The project had a 196-day contract period from June 19 to December 31, 2025 and included a 2.74-km effective treatment length, 7.00-m planned carriageway, cement-concrete pavement, shoulders, foundation layers, structures, and pavement markings. Work was executed on half of the roadway under an alternating traffic-control system [20]. By September 14, 2025, the project had a negative progress deviation of 7.329%, requiring a technically defensible recovery strategy.

The objectives are to: (1) reconstruct the remaining-work network and identify critical activities; (2) compare TCTO through additional working hours with fast-track through two work fronts and lag reduction; (3) evaluate each alternative in terms of time, added direct cost, cost slope, quality, and technical feasibility; and (4) determine the most suitable acceleration alternative. The novelty lies in using the same verified remaining-work baseline to compare mechanisms that are operationally different, while incorporating a weighted quality assessment and explicit implementation conditions.

II. LITERATURE REVIEW

2.1. Critical-Path Control and Remaining-Work Scheduling

Construction project control links planning, execution, monitoring, and corrective action to the time, cost, quality, and resource objectives of the project [1,2]. For a delayed project, analysis should not merely reuse the original schedule. Completed activities must be removed, ongoing activities must be represented by their remaining quantities, and activities that have not yet started must be recalculated using the latest method, resources, locations, and precedence relationships. Precedence Diagram Method networks are particularly suitable where road activities are divided by station, side, or work front and use Finish-to-Start or Start-to-Start logic [12].

CPM determines early and late dates and total float for each activity. Activities with zero total float form the critical path and directly control completion. Schedule recovery should primarily target those activities while repeatedly checking whether acceleration creates a new critical path. In repetitive road construction, reducing the duration of pavement activities may shift control to shoulders, markings, testing, or traffic-restoration work; therefore, network recalculation is required after every major logic or productivity change.

2.2. Time-Cost Trade-Off Through Overtime

TCTO evaluates the relationship between normal duration, crash duration, normal cost, and crash cost. The marginal cost of reducing one day is expressed as Cost slope = (Crash cost - Normal cost) / (Normal duration - Crash duration). A lower cost slope indicates a more economical time reduction, provided that the accelerated activity remains critical and technically feasible [7,9,17]. Overtime is attractive because it uses the existing work sequence and equipment configuration; however, productivity during additional hours is commonly lower than productivity during normal hours.

Extended shifts may increase fatigue, reduce concentration, complicate lighting and traffic control, prolong concrete-production and equipment-operation periods, and weaken the consistency of inspection and documentation. Therefore, the apparent simplicity of overtime does not eliminate quality and safety risks. The selected overtime duration should satisfy the contract date with the smallest justified additional cost rather than simply maximize schedule compression [7,10].

2.3. Fast-Track, Parallel Fronts, and Quality Risk

Fast-track accelerates delivery by allowing technically compatible activities to overlap or by executing similar work simultaneously at separate fronts. Prior studies have reported substantial duration reductions when critical Finish-to-Start relationships were changed to Start-to-Start or when lags were rationally reduced [3-6]. In road reconstruction, spatial separation can support parallel execution, but the approach is constrained by access, material supply, equipment availability, work-zone length, and traffic-management capacity.

For cement-concrete pavement, a reduction in the waiting period between opposite road sides must not be based on age alone. Concrete must achieve the flexural strength required for load transfer or traffic opening, and all requirements for fresh concrete, consolidation, finishing, curing, jointing, surface tolerance, and testing remain applicable [14,19]. Accelerating admixtures can improve early strength, but compatibility, dosage, workability, setting time, and long-term strength must be verified by trial mix and project-specific testing. Fast-track also requires independent inspection and quality-control coverage at each active front.

2.4. Integrated Time-Cost-Quality Evaluation

Time and cost alone cannot represent the full consequences of acceleration. Time-Cost-Quality Trade-Off extends the decision by considering whether a strategy maintains material quality, workmanship, inspection, testing, and final performance [8,18]. A weighted expert assessment is useful where alternatives have not yet been fully implemented and objective quality outcomes are unavailable. Indicator importance can be normalized into weights, performance can be converted to a percentage, and the quality index can be calculated as Qk = sum (wj x Pjk). The resulting index is comparative; it does not replace acceptance testing or specifications.

The integrated framework used in this study therefore treats schedule compliance as a necessary condition, direct cost and cost slope as efficiency measures, the quality index as a comparative measure, and technical feasibility as an implementation gate. An alternative is recommended only when all mandatory resource, testing, supervision, and traffic-control requirements can be met.

III. RESEARCH METHOD

3.1. Research Design and Case Setting

The research used a quantitative evaluative case-study design. The unit of analysis was the remaining work of the Muara Badak-Batas Bontang 3 Road Reconstruction Project in Marangkayu District, Kutai Kartanegara Regency, East Kalimantan. The status date was September 14, 2025, corresponding to the end of Week 12 reporting. The analysis period began on September 15, 2025 and ended at the contractual deadline of December 31, 2025.

Primary data consisted of quality-importance scores, alternative performance scores, and structured expert judgments. Secondary data included contracts and addenda, baseline and updated schedules, S-curves, progress reports, final and actual quantities, backup quantities, bid unit-price analyses, equipment and labor rates, strip maps, drawings, work methods, inspection reports, and concrete test documents [20]. Data were reconciled so that quantities, locations, activity status, and cost components referred to the same status date.

Table 1. Research structure and acceleration alternatives

Element	Definition/Setting	Primary Output
Baseline A0	Remaining-work PDM network based on verified quantities, STA, road side, technical sequence, normal productivity, and normal lags.	Normal duration, completion date, and critical path
Alternative A1	TCTO through 1, 2, or 3 additional working hours per day on critical cement-concrete pavement activities; overtime effectiveness = 80%.	Crash duration, added labor and equipment cost, cost slope
Alternative A2	Two-front fast-track; normal 14-day lag tested first, followed by 10-, 7-, and 5-day critical lags using accelerating admixture where required.	Duration, front resources, admixture quantity, added direct cost
Quality evaluation	Twenty-one purposively selected experts assessed 10 indicators using a five-point Likert scale.	Indicator weights, performance percentages, quality index
Decision criteria	Contract compliance, duration reduction, added direct cost, cost slope, quality index, and technical feasibility.	Recommended alternative and implementation conditions

3.2. Network Development and Critical Path Method Analysis

The remaining quantities were calculated as final measured quantities minus cumulative quantities completed by the status date. Activities were decomposed by work type, station range, left or right side, and treatment condition. Durations were calculated from remaining volume and verified normal productivity. The network used Finish-to-Start and Start-to-Start relationships with explicit lags for technical waiting, relocation, testing, and minimum work-zone availability. Microsoft Project was used to calculate early and late dates, total slack, critical activities, and the projected completion date.

The normal network retained a three-day lag from lean concrete to cement-concrete pavement and a 14-day lag before traffic transfer and work on the opposite side. Acceleration requirements were determined from the difference between the CPM completion date and the contract deadline. After each alternative was simulated, the network was recalculated to verify the critical path and final date.

3.3. Time-Cost Trade-Off and Fast-Track Simulations

Alternative A1 applied overtime only to detailed cement-concrete pavement activities on the critical path. Normal effective working time was seven hours per day. Additional working-time scenarios of one, two, and three hours per day were evaluated with 80% productivity effectiveness during overtime. Labor overtime and additional equipment-operating cost were calculated from the contractor's bid unit prices and project rates. Indirect cost savings were excluded because reliable project-specific indirect-cost data were unavailable.

Alternative A2 first opened a second pavement front while retaining the normal 14-day lag. Seven truck mixers were allocated as three units to Front 1 and four units to Front 2. The second front required one additional truss screed paver, two concrete vibrators, and two flagmen. To create schedule reserve, five critical lags were subsequently tested at 10, seven, and five days. Accelerating admixture was assigned only to the concrete volume affected by the reduced lag. The seven-day scenario was considered technically admissible only if trial-mix and early-age flexural-strength results demonstrated that traffic transfer was safe.

3.4. Quality and Feasibility Evaluation

The expert sample comprised 21 stakeholders: two commitment-making officers, two field coordinators, three site engineers, four inspectors, four material technicians, three project managers, and three quality-control personnel. Respondents were selected purposively based on direct experience with concrete-pavement projects and knowledge of time, cost, quality, resources, or field supervision.

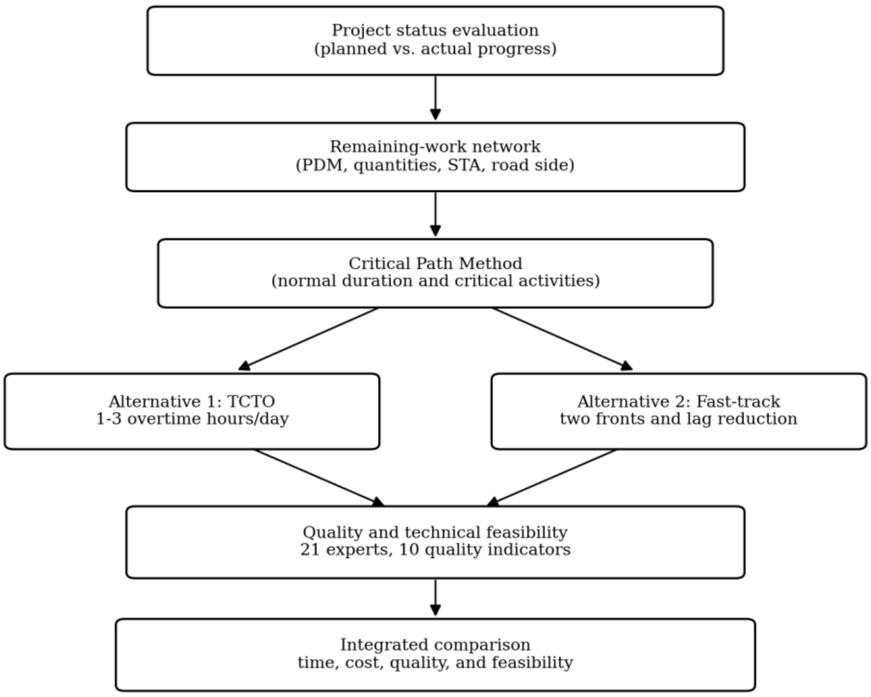

Figure 1. Research analysis workflow

Ten quality indicators were assessed: material and fresh-concrete quality; workability and setting time; early-age flexural strength; final flexural strength; dimensional accuracy, dowels, and tie bars; consolidation and finishing; curing; smoothness, texture, joints, and cracking; supervision and quality control; and rework risk. The mean importance score of each indicator was normalized to a weight. Alternative performance was converted to a percentage of the maximum five-point score, and the weighted quality index was calculated. Structured interviews were used to interpret resource conflicts, traffic-control needs, inspection coverage, testing, and implementation risks. The workflow is shown in Figure 1.

IV. RESULT AND DISCUSSION

4.1. Project Status and Normal Critical Path Method Schedule

At the status date, planned cumulative progress was 22.855% and actual progress was 15.526%, resulting in a negative deviation of 7.329%. The owner issued an acceleration warning on September 15, 2025, indicating that the recovery plan had to identify remaining quantities, productivity, network logic, critical activities, resources, and the ability to meet the contract deadline [20].

The reconstructed network showed that the critical sequence was dominated by cement-concrete pavement. It included one lean-concrete activity, 34 detailed pavement activities, and two pavement-marking activities with zero total slack. The normal remaining duration was 117 calendar days from September 15, 2025 to January 9, 2026. Only 108 days were available to the contract deadline, so the project required a minimum reduction of nine days, equivalent to 7.69% of the normal remaining duration.

Table 2. Baseline project and CPM status

Parameter	Result	Interpretation
Planned cumulative progress	22.855%	Target at September 14, 2025
Actual cumulative progress	15.526%	Verified project progress
Progress deviation	-7.329%	Project behind schedule
Available time to contract end	108 calendar days	September 15-December 31, 2025
Normal remaining duration	117 calendar days	CPM result
Projected normal completion	January 9, 2026	Nine days beyond contract deadline
Minimum duration reduction	9 calendar days	Required recovery

4.2. Time-Cost Trade-Off Through Additional Working Hours

The remaining cement-concrete pavement volume was 5,113.01 m3. Normal productivity was 51.19 m3/day. One hour of overtime shortened the project to 108.28 days but still exceeded the contract period, whereas two and three hours met the deadline. The three-hour scenario achieved the greatest compression but had a higher additional direct cost and cost slope. The two-hour scenario was selected because it met the deadline with a 6.81-day reserve and avoided the unnecessary cost and fatigue exposure of a three-hour extension.

The selected A1.2 scenario increased pavement productivity to 62.89 m3/day and reduced the active pavement duration to 83.84 days. The project duration became 101.19 days, with completion on December 25, 2025. Added labor cost was Rp103,154,641 and added equipment cost was Rp76,992,226, resulting in total additional direct cost of Rp180,146,867 and a cost slope of Rp11,394,489 per day. These results confirm that greater overtime does not automatically provide the most efficient recovery, consistent with TCTO studies in which every crash level produces a distinct marginal cost [7,9,17].

4.3. Fast-track Through Two Fronts and Lag Reduction

Opening two pavement fronts while retaining the normal 14-day lag reduced the duration from 117 to 108 days and produced completion exactly on December 31, 2025. This A2.0 scenario met the contract date at a relatively small added fast-track cost of Rp8,966,005, but it had no schedule reserve. Because a zero-reserve plan remains vulnerable to rain, equipment failure, supply disruption, and traffic interference, additional controlled lag reduction was evaluated.

Reducing five critical lags from 14 to 10 days shortened the schedule to 104 days. A seven-day lag reduced it to 101 days and completion on December 24, 2025. Further reduction to five days did not shorten the project because another sequence became controlling; this illustrates the diminishing benefit of crashing one part of a network after the critical path shifts. The selected A2.2 scenario required accelerating admixture for 450.80 m3 of concrete, equivalent to 2,319.12 kg, and produced 16 overlapping working days. Added fast-track resources cost Rp8,966,005 and the admixture cost Rp129,870,510, for total additional direct cost of Rp138,836,515 and a cost slope of Rp8,677,282 per day.

Table 3. Acceleration simulation results

Code	Acceleration Strategy	Project Duration	Duration Reduction	Additional Direct Cost	Cost Slope / Status
A1.1	TCTO: +1 h/day	108.28 days	8.72 days	Rp88,508,300	Rp10,150,034/day; does not meet
A1.2	TCTO: +2 h/day	101.19 days	15.81 days	Rp180,146,867	Rp11,394,489/day; meets
A1.3	TCTO: +3 h/day	96.00 days	21.00 days	Rp256,187,380	Rp12,199,399/day; meets
A2.0	Two fronts; 14-day lag	108 days	9 days	Rp8,966,005	Rp996,223/day; meets, no reserve
A2.1	Two fronts; 10-day lag	104 days	13 days	Not selected	Meets
A2.2	Two fronts; 7-day lag	101 days	16 days	Rp138,836,515	Rp8,677,282/day; meets
A2.3	Two fronts; 5-day lag	101 days	16 days	Higher technical risk	No additional time benefit

4.4. Quality Evaluation

Curing and surface/joint performance received the highest importance weights (10.47% each), followed by final flexural strength (10.37%). The distribution indicates that experts did not evaluate acceleration solely through early strength; long-term strength, curing continuity, surface quality, joints, and cracking remained central. Supervision and quality control also received a substantial weight of 10.06%, reflecting the importance of maintaining inspection capacity when hours or work fronts increase.

Table 4. Weighted quality-performance results

Code	Quality Indicator	Weight	TCTO Performance	Fast-Track Performance
K1	Material and fresh-concrete quality	9.86%	90.48%	90.48%
K2	Workability and setting time	9.34%	86.67%	88.57%
K3	Early-age flexural strength	9.86%	88.57%	96.19%
K4	Final flexural strength	10.37%	89.52%	92.38%
K5	Dimensions, dowels, and tie bars	10.06%	86.67%	88.57%
K6	Consolidation and finishing	10.06%	86.67%	88.57%
K7	Curing implementation	10.47%	85.71%	87.62%
K8	Smoothness, texture, joints, and cracking	10.47%	86.67%	88.57%
K9	Supervision and quality control	10.06%	80.95%	82.86%
K10	Rework risk	9.45%	86.67%	88.57%
	Weighted quality index	100.00%	86.85%	89.23%

The weighted quality index was 86.85% for the two-hour overtime alternative and 89.23% for the fast-track alternative. Fast-track obtained its largest advantage in early-age flexural strength because the method explicitly required accelerating admixture, trial-mix control, segregated batch identification, and verification before traffic transfer. It also scored slightly higher for workability, dimensional control, consolidation, finishing, curing, surface and joint quality, supervision, and rework risk. These results are comparative perceptions, not evidence that either method automatically satisfies acceptance criteria; actual compliance must be demonstrated through inspection and testing [14,19].

4.5. Integrated Comparison and Managerial Implications

Both selected alternatives satisfied the contract deadline, but fast-track performed better on the principal quantitative criteria. It was 0.19 day faster, required Rp41,310,352 less additional direct cost, had a cost slope Rp2,717,207 per day lower, and achieved a quality index 2.38 percentage points higher. Fast-track also created a seven-day schedule reserve compared with 6.81 days for overtime. The comparison is summarized in Table 5 and Figure 2.

The normal schedule created a potential minimum contractual penalty of Rp62,416,349.78 for nine days, based on the value of unfinished functional work. The added cost of either acceleration alternative exceeded that minimum penalty. Nevertheless, the managerial decision cannot be reduced to a penalty comparison. Completion beyond the contract period may delay handover and road use, prolong traffic restrictions, increase exposure to weather and additional delay, and affect contractual and supplier performance. Acceleration cost should therefore be interpreted as a risk-control expenditure rather than simply as an alternative to paying a penalty.

Table 5. Integrated comparison of normal and selected acceleration schedules

Parameter	Normal Schedule	TCTO: 2-H Overtime	Fast-Track: Two Fronts + Admixture
Remaining duration	117.00 days	101.19 days	101.00 days
Projected completion	9 Jan 2026	25 Dec 2025	24 Dec 2025
Position against contract	9 days late	6.81-day reserve	7-day reserve
Duration reduction	-	15.81 days	16.00 days
Additional direct cost	Rp0	Rp180,146,867	Rp138,836,515
Cost slope	-	Rp11,394,489/day	Rp8,677,282/day
Quality index	Not assessed	86.85%	89.23%
Technical status	Does not meet deadline	Feasible with overtime controls	Recommended with testing and resource conditions

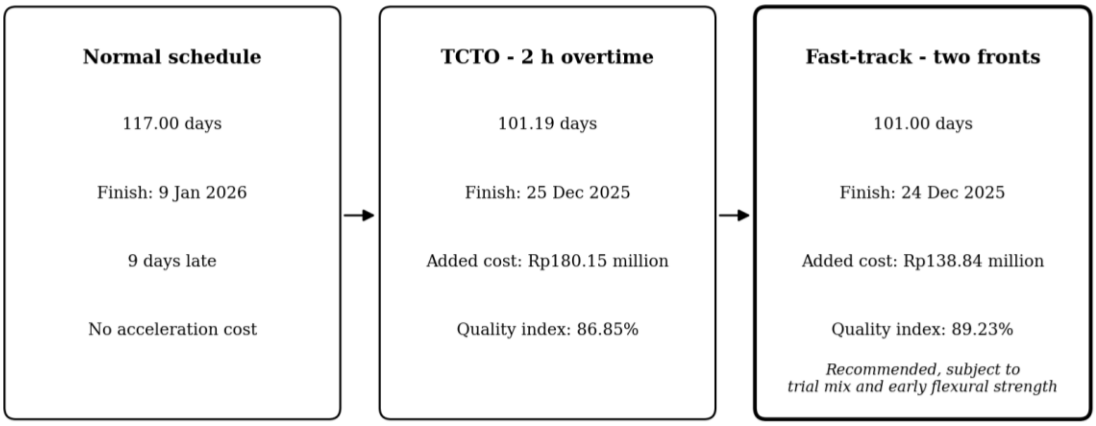

Figure 2. Comparative performance of the normal, TCTO, and fast-track schedules

Fast-track is the recommended alternative only under defined implementation conditions. First, two fronts should be established with the normal 14-day lag, which already meets the contract deadline, while trial-mix and early-age flexural-strength evidence is obtained. The lag should be reduced to seven days only for the five critical relationships where the strength requirement is verified. Second, the project must provide separate pavement equipment, inspection, quality-control, material-testing, and traffic-control functions at both fronts. Third, each active front should be limited to approximately 500 m and coordinated within one corridor-wide traffic-management system. Fourth, all batches containing admixture must be traceable by front, segment, dosage, and casting date.

The two-hour overtime alternative remains a practical contingency if the accelerating admixture is not approved, trial-mix results are unsatisfactory, the second front cannot be resourced, or inspection capacity is inadequate. Its implementation should use shift rotation, adequate lighting, equipment checks, and dedicated quality supervision during additional hours. The results thus support a staged recovery strategy: use low-risk two-front parallelization first, activate justified lag reduction only after technical verification, and retain overtime as a controlled fallback.

4.6. Limitations

The study is based on one road project and a deterministic remaining-work network. The cost analysis includes measurable direct changes but excludes indirect-cost savings, financing effects, and the full economic value of reduced traffic disruption. The quality index is based on 21 expert judgments and should be validated using actual implementation and laboratory data. Weather, traffic incidents, equipment failure, variability in hauling cycles, and uncertainty in early strength were not modeled probabilistically. These limitations restrict statistical generalization but do not reduce the practical value of the transparent case-based comparison.

V. CONCLUSION

The remaining-work network for the Muara Badak-Batas Bontang 3 Road Reconstruction Project produced a normal CPM duration of 117 days and completion on January 9, 2026, nine days beyond the contract deadline. Critical work was dominated by one lean-concrete activity, 34 cement-concrete pavement activities, and two pavement-marking activities. The result demonstrates that recovery planning must be based on the current remaining network rather than on aggregate progress deviation alone.

TCTO with two additional working hours per day reduced the project duration to 101.19 days, added Rp180,146,867 in direct cost, produced a cost slope of Rp11,394,489 per day, and achieved a quality index of 86.85%. Fast-track with two fronts and a verified seven-day lag reduced the duration to 101 days, added Rp138,836,515, produced a cost slope of Rp8,677,282 per day, and achieved a quality index of 89.23%. Fast-track was therefore the most suitable alternative in the integrated time-cost-quality comparison.

The recommendation is conditional. Trial mix and early-age flexural-strength tests must verify traffic-transfer readiness; seven truck mixers must be allocated across the two fronts; an additional truss screed paver, two concrete vibrators, and two flagmen must be available; and each front must have sufficient inspection and quality-control capacity. The 14-day two-front scenario can be used as the minimum recovery plan while test evidence is developed, and two-hour overtime can be retained as a contingency. Future research should combine actual post-implementation data with indirect costs, resource-constrained scheduling, sensitivity analysis, and probabilistic simulation.

REFERENCES

[1]. Soeharto, I. (1997). *Manajemen proyek: Dari konseptual sampai operasional*. Jakarta: Erlangga.

[2]. Santosa, B. (2008). *Manajemen proyek: Konsep dan implementasi*. Yogyakarta: Graha Ilmu.

[3]. Tjaturono, & Mochtar, I. B. (2009). Development of a fast-track method to reduce project time and cost: A case study of medium-cost housing in Malang, East Java. *Media Komunikasi Teknik Sipil*, **17**(*1*): pp. 39-53.

[4]. Dahlan, A., Nainggolan, T. H., & Winanda, L. A. R. (2019). Evaluation of time and cost control using Critical Path Method and fast-track. *Jurnal Sondir*, **1**: pp. 1-8.

[5]. Akhirudin, A. F. (2020). Acceleration of construction project duration using the fast-track method. *Jurnal Pendidikan Teknik dan Vokasional*, **3**(*2*): pp. 77-91.

[6]. Lucmana, M. J. F., Iskandar, T., & Kartika, D. (2021). Fast-track scheduling analysis for the Lab for Science Policy and Communication Project at Jember University. *Student Journal Gelagar*, **3**(*1*): pp. 1-7.

[7]. Messah, Y. A., Berelaku, D. C. S., & Ramang, R. (2023). Comparison of additional working time and additional labor on project implementation cost. *Jurnal Teknik Sipil*, **12**(*2*): pp. 215-228.

[8]. Elkliny, A. F., Sanad, H. M., & Etman, E. E. (2023). Time-cost-quality tradeoff considering resource-scheduling problems. *Ain Shams Engineering Journal*, **14**: pp. 102524.

[9]. Nabila, F. (2023). Optimization of time and cost in building construction using the Time Cost Trade Off method. *Journal of Civil Engineering and Planning*, **4**(*2*): pp. 199-210.

[10]. Irfanto, R., Tjoanda, W., & Lidyawati, R. (2024). Analysis of acceleration cost additions in road infrastructure projects in Southeast Maluku Regency. *Jurnal Teknik Sipil*, **13**(*2*): pp. 219-232.

[11]. Hakim, L., & Kasmuri, M. (2024). Evaluation of rigid-pavement cost and construction methods using paver and conventional equipment: A case study of Cimanggis-Cibitung Toll Road Section 2. *Proceedings of the National Civil Engineering Seminar*, pp. 144-149.

[12]. Arifuddin, R., Fatimah, A. N., & Fadlillah, M. R. (2024). Analysis of scheduling methods in building projects: A case of Line of Balance and Precedence Diagram Method. *Media Komunikasi Teknik Sipil*, **30**(*2*): pp. 177-185.

[13]. Satrio, R., & Kholik, A. (2025). Implementation of a Traffic Management Plan for rigid-pavement reconstruction work on the Cikopo-Palimanan Toll Road. *Proceedings of Seminar Teknologi Majalengka*, pp. 657-664.

[14]. Wulandari, A. N., & Wacono, S. (2025). Concrete quality control in rigid-pavement road improvement projects. *Proceedings of the National Civil Engineering Seminar*, pp. 92-101.

[15]. Kartika, D., Winanda, L. A. R., & Irawan, J. (2025). Analysis of construction project schedule acceleration to overcome delay. *Jurnal Info Manpro*, **14**(*2*): pp. 63-71.

[16]. Pradnyadari, N. L. M. A. M., Sari, N. N. D. P., & Sunatha, I. G. N. (2026). Acceleration of construction project implementation using the fast-track method. *Jurnal Ilmiah Teknik UNMAS*, **6**(*1*): pp. 71-77.

[17]. Rajagukguk, T. B. N., Winanda, L. A. R., Munasih, & Surbakti, S. (2026). Project scheduling optimization using the Time-Cost Trade Off method. *Jurnal Konstruksi*, **24**(*1*): pp. 94-100.

[18]. Rizal, A. (2018). Time Cost Quality Trade Off analysis for bridge construction: A case study of the Ngelo Bridge Project. *Siimo Engineering*, **2**(*1*): pp. 37-42.

[19]. Ministry of Public Works and Housing, Republic of Indonesia. (2018). *General Specifications of Bina Marga 2018 for Road and Bridge Construction Works (Revision 2)*. Directorate General of Highways.

[20]. East Kalimantan Provincial Public Works, Spatial Planning and Public Housing Agency. (2025). *Muara Badak-Batas Bontang 3 Road Reconstruction Project Documents*. Internal project document.