



Time and Cost Trade-Offs Between Overtime and Workforce Expansion for Remaining Structural Work in a Building Project in Bali



I Gede Sastra Wibawa^a
I Made Anom Santiana^b
I Nyoman Ramia^c
I Made Budiadi^d
I Wayan Sudiasa^e
M. Yusuf^f

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Abstract

Schedule acceleration requires comparing additional resource costs with time-dependent overhead savings. This quantitative case study evaluates overtime and workforce expansion for remaining structural work in the XYZ Tabanan building project, Bali, Indonesia. A Microsoft Project precedence network and Microsoft Excel cost calculations compare eight acceleration scenarios with a baseline of 200 working days and IDR 74.414 billion. The Monday–Saturday calendar places the unaccelerated structural completion milestone on 20 October 2026, starting on 2 March 2026 without national-holiday exclusions. Costs comprise IDR 70.000 billion in direct costs, IDR 2.414 billion in allocated fixed indirect costs, and overhead of IDR 10 million per active working day; contractor profit and value-added tax are excluded. In the reported outputs, four hours of overtime yields 114.62 working days and IDR 74.351 billion, while workforce scenario W4 yields 72.98 working days and IDR 74.076 billion. Time reductions are 42.690% and 63.510%, and cost reductions are 0.085% and 0.455%, respectively. Workforce expansion has the lowest reported cost, reflecting overhead savings that exceed its additional direct cost. However, reproducing the accelerated durations requires the activity-level network, calendar settings, and trade-specific resource assignments. The scenario ranking therefore remains conditional on schedule and cost validation.

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Corresponding author:

I Gede Sastra Wibawa,

Department of Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia.

Email address: gedesastrawibawa@pnb.ac.id

^a Department of Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia

^b Department of Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia

^c Department of Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia

^d Department of Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia

^e Department of Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia

^f Department of Mechanical Engineering, Politeknik Negeri Bali, Badung, Indonesia

1 Introduction

When a delayed construction activity controls project completion, managers may consider extending working hours or increasing crew capacity. These alternatives affect both production and expenditure. Their economic value depends on whether time-dependent cost savings offset the cost of acceleration. Critical-path analysis provides a basis for connecting activity durations, precedence relationships, and project completion (Kelley Jr., 1961). However, shortening selected activities does not necessarily shorten the entire project by the same amount, because another path may become critical.

Time–cost tradeoff analysis evaluates feasible combinations of activity duration and cost. Optimization research has considered larger decision spaces through genetic algorithms (Feng et al., 1997) and, more recently, multi-objective particle swarm optimization for activities with alternative execution modes (Agarwal et al., 2024). These approaches show why the lowest cost among a few predefined scenarios should be distinguished from a global optimum. In an applied case study, a transparent account of the tested alternatives and their constraints is therefore essential.

The discrete formulation represents each activity through a finite set of duration–cost alternatives. De et al. (1995), examined this formulation and its solution difficulties, while Demeulemeester et al. (1996), developed exact procedures for deterministic project networks. A recent systematic review documents the range of time–cost optimization models used in construction management (ElSahly et al., 2023). Hybrid metaheuristics have also been developed for larger discrete problems (Son & Nguyen Dang, 2023). These developments provide methodological context for the present comparison, whose eight predefined scenarios explore only a limited portion of the possible decision space.

Labor-based acceleration also requires realistic productivity assumptions. Jeunet & Orm (2020), incorporated overtime, temporary labor, productivity, and quality requirements into an optimization model. Empirical work by Hanna et al. (2005a), identified productivity losses associated with extended overtime in labor-intensive construction trades. Additional workers may likewise encounter congestion and coordination losses, as reported in research on overmanning (Hanna et al., 2005b). These studies support examining the two strategies separately; they do not establish productivity coefficients for structural work in the present project.

The distinction between additional working time and additional productive output is supported by the scheduled-overtime analysis of Thomas & Raynar (1997). Simulation research further shows that omitting productivity deterioration can overstate the schedule benefit of overtime (Woo, 2016). Studies of schedule compression (Chang et al., 2007) and congested work areas (Thomas et al., 2006) likewise indicate that acceleration requires attention to the conditions under which crews perform their tasks. Such evidence motivates project-specific productivity checks rather than direct transfer of coefficients from other trades or sites.

Indonesian case studies have compared overtime with additional labor using time–cost tradeoff analysis (Fardila & Adawyah, 2021). A recent study of a sports building project also showed that a limited crashing iteration could improve the schedule without recovering the contractual target (Widiastuti et al., 2025). Meanwhile, work on takt planning emphasizes the costs associated with capacity and other production buffers (Tommelein, 2024). Taken together, this literature indicates that an acceleration decision must account for both feasible production changes and the cost components that actually vary with duration.

The present case concerns a building project in Tabanan for which the source records describe an early delay involving piling materials. The study compares four overtime scenarios and four workforce-expansion scenarios for critical structural activities. Its contribution is an application-specific comparison of the reported duration and cost outcomes, supported by explicit arithmetic and feasibility checks. It does not propose a new optimization algorithm. The objectives are to identify the lowest-cost reported alternative within each scenario family, quantify differences relative to a common baseline, and determine which assumptions require verification before an acceleration strategy can be adopted.

2 Materials and Methods

Case setting and data

The study uses a quantitative single-case design based on construction records for the XYZ Tabanan building project in Tabanan Regency, Bali, Indonesia. The reported research period extends from December 2025 to August 2026. The analysis covers remaining structural work and uses the project budget, initial schedule, unit-rate analyses, daily wage rates, and productivity observations from December 2025. The acceleration alternatives are modeled scenarios; field implementation outcomes are not reported. The modeled structural completion date extends beyond the reported research period.

The analytical baseline comprises 200 working days of remaining structural work. The status date is 1 March 2026, and the modeled remaining-work period starts on Monday, 2 March 2026. Counting Monday through Saturday and making no exclusions for national holidays, the 200th working day is 20 October 2026. This is the revised unaccelerated completion milestone for the structural scope and replaces the earlier forecast of 9 August 2026. It is not presented as an observed completion date or as the original contractual deadline. The previously reported date of 15 July 2026 is not used to anchor the revised analytical baseline. The recorded piling-material delay of 21 working days remains a separately reported historical measure; it is not derived from the revised forecast.

The analytical cost denominator is IDR 74,414,413,783.78. It comprises structural direct costs, fixed indirect costs allocated to the structural scope, and time-dependent site overhead. Architectural finishing, contractor profit, and value-added tax (VAT) are excluded. Site overhead is charged only for active working days, rather than elapsed calendar days; curing on a Sunday does not, by itself, create a chargeable overhead day. Monetary values are expressed in Indonesian rupiah (IDR) at the source-record price basis, without currency conversion or inflation adjustment.

Table 1
Daily wage inputs reported in the project records

Labor category	Daily wage in IDR
Foreman	175,000.00
Lead craft worker	160,000.00
Mason	145,000.00
Reinforcement worker	145,000.00
Carpenter	150,000.00
Welder	145,000.00
General laborer	141,375.00

Source: supplied manuscript, citing project records for 2025. These are model inputs, not independently verified wage-compliance findings.

Network and scenario definitions

The precedence network was constructed in Microsoft Project using work-breakdown activities, normal durations, and predecessor relationships. Three principal critical work categories are formwork, reinforcing steel, and concrete placement. Table 2 gives the total quantities for all remaining structural work, rather than quantities per repeated work package. The stated dependencies are finish-to-start with zero lag, and activities identified as critical have zero total float. Parallel branches may contain such relationships; a finish-to-start link does not imply that every activity in the project belongs to a single sequence.

Table 2
Reported quantities and normal crews for the critical work categories

Work category	Quantity	Normal crew	Total persons
Formwork	400 m ²	1 foreman, 3 carpenters, 5 general laborers	9
Reinforcing steel	20 tonnes	1 foreman, 4 reinforcement workers, 4 general laborers	9
Concrete placement	150 m ³	1 foreman, 2 masons, 6 general laborers	9

Source: authors' project data.

Quantities cover the entire remaining structural scope. The reinforcing-steel activity has a normal duration of 20 working days. Each normal crew includes one foreman. Activity subdivision, the other normal durations, and predecessor and resource assignments must be reported in the detailed schedule.

The alternatives comprise one to four overtime hours beyond the stated eight-hour daily production baseline, or one to four additional workers in targeted crews without extending that baseline. Workforce additions are limited to carpenters and reinforcement workers, with one crew per targeted work category receiving the increment; the concrete-placement crew is unchanged. Additions apply to both targeted categories in a scenario, while actual activity overlap follows the network. The exact allocation of the scenario increment between the two trades must be stated in the resource schedule. Concrete curing is a separate, noncompressible task lasting seven elapsed calendar days on a dedicated seven-day calendar with no holiday exceptions. It must retain that elapsed duration when the productive-work calendar excludes Sundays. Resource leveling was disabled. After each scenario, the authors report recalculating the full network and checking that workers were not assigned simultaneously to incompatible activities. Explicit treatment of working-time availability is consistent with time–cost models incorporating time-switch constraints (Vanhoucke et al., 2002). Resource-constrained scheduling research also treats precedence and resource availability as distinct feasibility requirements (Hartmann & Briskorn, 2022). These principles support checking both task calendars and concurrent resource assignments when evaluating the present acceleration scenarios.

Analytical relationships and cost accounting

For activity i , normal duration is defined by Equation 1, where Q_i denotes the activity quantity and P_{i0} denotes normal daily production. The quantity, production rate, and duration must use consistent units. The authors have supplied additional model parameters, but a complete activity-level workbook remains necessary to reproduce the existing scenario totals.

$$d_{i0} = \frac{Q_i}{P_{i0}} \quad (1)$$

For overtime h , Equation 2 uses the average relative productivity η_{ih} across the h overtime hours and a normal production baseline H_0 of eight hours per day. Relative productivity is set to 0.85 for the first overtime hour and 0.75 for each subsequent hour. The resulting averages for one, two, three, and four overtime hours are 0.850, 0.800, 0.7833, and 0.775, respectively. According to the project team, these coefficients were derived from a time–motion study conducted during the early structural phase in December 2025. The underlying observations and estimation procedure are needed to establish how task output per labor-hour was normalized and averaged, and how variable these estimates were.

$$d_{ih} = d_{i0} \times \frac{H_0}{H_0 + h\eta_{ih}} \quad (2)$$

For a crew with normal productive headcount n_i , k additional workers, and relative per-worker productivity ϕ_{ik} , Equation 3 models the accelerated duration. The expanded-crew scenarios use $\phi_{ik} = 0.90$ to represent reduced productivity under increased workface density; the normal baseline retains its original productivity. The supplied time–motion clarification concerns overtime coefficients and does not independently establish this crowding factor. Because additions target carpenters and reinforcement workers, the productive headcount and supporting labor must be defined by trade. A foreman or general laborer cannot automatically be treated as interchangeable with an added

craft worker. This distinction is consistent with workforce-management principles that consider work assignments, crew structure, and relationships among crews (Randolph Thomas & Horman, 2006).

$$d_{ik} = d_{i0} \times \frac{n_i}{(n_i + k)\varphi_{ik}} \quad (3)$$

Project duration must be obtained from the recalculated network. It is not the sum of the individual time savings. The incremental direct cost per day of activity compression, or cost slope, is expressed in Equation 4 for an accelerated duration smaller than its normal duration. For discrete execution modes, this is a slope between the selected alternatives rather than proof of a linear cost function. Discrete time–cost formulations similarly require the available execution alternatives to be specified at the activity level (De et al., 1995; Demeulemeester et al., 1996).

$$CS_i = \frac{C_{ic} - C_{i0}}{d_{i0} - d_{ic}} \quad (4)$$

For scenario *s*, Equation 5 separates analytical cost into direct cost C_s^D , fixed indirect cost C^f , and time-dependent site overhead rT_s . The normal direct cost is IDR 70,000,000,000.00, the fixed indirect cost is IDR 2,414,413,783.78, and the overhead is IDR 10,000,000.00 per active working day. The confirmed normal charging period of 200 working days gives overhead of IDR 2,000,000,000.00 and reproduces the analytical baseline exactly. T_s denotes chargeable active working days; it must be reconciled with the reported remaining duration when activity calendars differ, or a curing-only interval has no active work. The cost reconstruction in Section 3.3 retains the supplied assumption that chargeable days equal the tabulated working-day duration.

$$C_s = C_s^D + C^f + rT_s \quad (5)$$

Table 3
Supplied components of the normal analytical cost

Cost component	Amount in IDR
Normal direct cost	70,000,000,000.00
Fixed indirect cost	2,414,413,783.78
Time-dependent overhead at $200 \times$ IDR 10 million	2,000,000,000.00
Total analytical baseline	74,414,413,783.78

Fixed indirect cost is allocated in proportion to the floor area associated with the remaining structural work relative to total building floor area. In accounting terms, allocated fixed indirect cost equals the relevant fixed indirect-cost pool multiplied by that area ratio. The allocation is held constant across scenarios. The area measurements, underlying cost pool, and account classifications are needed to reproduce IDR 2,414,413,783.78 and demonstrate that daily site overhead has not also been included in the fixed pool.

For the 20-tonne reinforcing-steel activity, the authors specify a normal duration of 20 working days, corresponding to normal production of 1 tonne per working day. At two overtime hours, the additional equivalent productive time is $0.85 + 0.75 = 1.60$ normal-productivity hours. Equation 2 therefore gives $20 \times 8/(8 + 1.60) = 16.6667$ working days, displayed as 16.67. This calculation is internally consistent as an activity-duration illustration, provided fractional working days are handled consistently in the schedule. It does not validate the remaining-structure duration of 135.00 days reported for O2.

The model converts each daily wage to an hourly rate by dividing by eight, and applies premiums of 1.5 for the first overtime hour and 2.0 for later hours. The project team attributes this convention to an internal employment agreement and a claimed regional exception under Government Regulation No. 35 of 2021. That attribution is recorded as an author-supplied explanation, pending identification of the specific applicable legal instrument. The production baseline and the statutory payroll divisor must be distinguished. A reproducible activity-cost example also requires category-specific wages, worker-days, materials, equipment, and the allocation of overhead.

Government Regulation No. 35 of 2021 distinguishes ordinary working time from arrangements for specified sectors or types of work (Republic of Indonesia, 2021). Articles 23–24 refer longer-working-time arrangements to ministerial provisions, while Article 25 addresses their implementation in employment agreements or company rules. An internal agreement alone does not identify the legal basis for a regional exemption. Under the general payroll provisions, Article 32 uses monthly wages divided by 173 for the hourly overtime rate, and Article 33 specifies conversion from daily wages. Accordingly, use of a daily-wage divisor of eight and the proposed weekly roster requires a documented applicable basis; compliance is not established by the current explanation.

Comparison and validation

The arithmetic review recalculates duration and cost reductions from the tabulated baseline and scenario totals using Equations 6 and 7. Percentages are rounded to three decimal places after calculation. Reported durations are retained to two decimal places; their decimal representation does not establish comparable accuracy in field scheduling.

$$E_s^T = \frac{T_0 - T_s}{T_0} \times 100\% \quad (6)$$

$$E_s^C = \frac{C_0 - C_s}{C_0} \times 100\% \quad (7)$$

The lowest reported cost is identified by direct enumeration of the supplied alternatives. No significance tests are applied because the scenario outputs are deterministic rather than independent observations. The validation in this revision checks the supplied arithmetic, schedule dates, production relationships, and cost identities. The complete native scheduling files and itemized scenario cost workbook were not available for independent replication. Accordingly, model inputs, derived arithmetic checks, and existing scenario outputs are distinguished throughout the results.

3 Results and Discussions

3.1 Results

Reported scenario outcomes

Table 4 presents the existing scenario outputs for remaining structural work, with percentages recalculated from the displayed baseline and totals. Increasing the overtime label from one to four hours is associated with progressively shorter reported durations. Total cost increases from O1 to O3 before falling at O4. The additional information in Section 2 does not reproduce these outputs; their internal consistency is examined in Section 3.3.

Table 4
Reported structural-scope scenario totals and recalculated reductions

Scenario	Duration working days	Total analytical cost IDR	Time reduction %	Cost reduction %
N	200.00	74,414,413,783.78	0.000	0.000
O1	160.56	74,357,346,888.03	19.720	0.077
O2	135.00	74,368,256,065.27	32.500	0.062
O3	118.91	74,404,672,105.74	40.545	0.013
O4	114.62	74,350,860,770.62	42.690	0.085
W1	136.01	74,359,100,072.65	31.995	0.074

Scenario	Duration working days	Total analytical cost IDR	Time reduction %	Cost reduction %
W2	106.86	74,228,079,537.86	46.570	0.250
W3	87.52	74,141,114,477.15	56.240	0.367
W4	72.98	74,075,749,578.04	63.510	0.455

N = baseline; O1–O4 = one to four overtime hours; W1–W4 = workforce increments of one to four in the targeted carpenter and reinforcement crews. The allocation per crew remains to be documented. Durations represent remaining structural work in working days. Percentages are calculated from the displayed values. The table retains the reported outputs pending replication of the native schedule and itemized costs.

Within the overtime family, O4 has the lowest reported cost, IDR 74,350,860,770.62, and the shortest reported duration, 114.62 working days. Relative to the baseline, this corresponds to 85.38 working days and IDR 63,553,013.16 saved. The respective reductions are 42.690% and 0.085%. O3 provides a smaller cost margin, saving only IDR 9,741,678.04 despite its substantial reported duration reduction.

Within the workforce family, both duration and cost decrease across the four alternatives. W4 reports 72.98 working days and IDR 74,075,749,578.04, corresponding to 127.02 working days and IDR 338,664,205.74 saved. The recalculated reductions are 63.510% and 0.455%. W4 is the most favorable reported point within the tested workforce range. Its implementation requires explicit headcounts for each targeted crew, rather than relying on the scenario label alone.

Comparison of the lowest reported costs

Table 5
Comparison of the reported O4 and W4 structural-work scenarios

Measure	O4	W4
Remaining structural duration in working days	114.62	72.98
Working days saved versus baseline	85.38	127.02
Cost saving versus baseline in IDR	63,553,013.16	338,664,205.74
Time reduction in percent	42.690	63.510
Cost reduction in percent	0.085	0.455

W4 is 41.64 working days shorter and IDR 275,111,192.58 cheaper than O4 in the supplied results. Its duration reduction is greater by 20.820 percentage points, while its cost reduction is greater by approximately 0.370 percentage points. Accordingly, W4 dominates O4 in the reported two-criterion comparison. This numerical dominance remains conditional on both alternatives being technically feasible and evaluated using the same cost boundary.

Conditional feasibility and cost checks

The revised calendar is internally consistent at baseline: 2 March through 20 October 2026 contains exactly 200 Monday–Saturday working dates when national holidays are not excluded. The updated date resolves the previous mismatch between the 200-day duration and the earlier forecast. It represents an analytical unaccelerated forecast, not evidence that the recorded 21-working-day delay has been recovered. Calendar assignments and chargeable overhead days must still be checked separately for each accelerated scenario, including the seven-elapsed-day curing task.

The authors attribute the additional schedule compression to automatic rescheduling of parallel secondary paths in the native scheduling model. A change in the controlling path does not by itself demonstrate additional productive capacity. For an unchanged network represented on one common working-time scale, the project duration is at least

the duration of every retained path. If each activity duration is reduced by no more than a given proportional factor, the original critical path therefore remains a lower-bound constraint, even if another path becomes critical. Applying Equation 2 uniformly to 200 days gives diagnostic references of 180.79, 166.67, 154.59, and 144.14 working days for one to four overtime hours. All reported overtime durations are shorter. These references are not exact bounds for the clarified mixed-calendar model, which must be recalculated using actual task timestamps. If the model also changes precedence links, overlaps, release constraints, or execution methods, those changes must be reported as additional interventions; they cannot be attributed to overtime alone.

Workforce checks must reflect the clarified trade-specific additions. Using all nine crew members as interchangeable productive workers would give an activity-duration factor of $9/(13 \times 0.90) = 0.76923$ for four added workers. That assumption is not established for the mixed-trade crews. Counting only the three carpenters or four reinforcement workers gives different activity factors, subject to the capacity of supporting labor and equipment. Consequently, the previous whole-project scaling comparison cannot validate or rule out W4 by itself. Reproducing 72.98 working days requires the trade-level production model, increment allocation, retained concrete-placement duration, curing tasks, and the complete recalculated network.

The supplied cost components reconcile exactly with the analytical baseline. Using the stated overhead rate and fixed indirect cost, the existing scenario totals imply the direct costs shown in Table 6. These direct costs are obtained by subtracting fixed indirect cost and duration-dependent overhead from each reported total. They are accounting identities, not independent activity-cost estimates. In particular, O4 requires IDR 790,246,986.84 more direct cost than baseline, and W4 requires IDR 931,535,794.26 more. The activity workbook must substantiate these increments; under these inputs, workforce expansion does not have the smaller direct-cost increase.

Table 6
Direct costs implied by the supplied total costs and overhead model

Scenario	Implied direct cost IDR	Increase from normal direct cost IDR
O1	70,337,333,104.25	337,333,104.25
O2	70,603,842,281.49	603,842,281.49
O3	70,801,158,321.96	801,158,321.96
O4	70,790,246,986.84	790,246,986.84
W1	70,584,586,288.87	584,586,288.87
W2	70,745,065,754.08	745,065,754.08
W3	70,851,500,693.37	851,500,693.37
W4	70,931,535,794.26	931,535,794.26

For W4 relative to O4, the reported 41.64-working-day difference implies IDR 416,400,000.00 less time-dependent overhead. Its implied direct cost is IDR 141,288,807.42 higher. Their net difference is the reported IDR 275,111,192.58 cost advantage. This decomposes the supplied totals but does not validate either schedule or the underlying expenditure.

The clarified budget bridge defines contractor profit as 10% of the stated pre-tax contract amount, rather than a 10% markup on underlying cost. Thus, $\text{IDR } 82,682,681,981.98 \times 0.10 = \text{IDR } 8,268,268,198.20$ after rounding; deducting this profit amount yields the analytical baseline of IDR 74,414,413,783.78. This percentage-of-contract-value definition supports multiplication by 0.90. According to the authors, VAT is excluded from the quoted contract amount and recorded in a separate accounting sheet; no VAT deduction is applied again in this bridge.

Removing profit defines a cost basis for scenario comparison, but does not make the comparison one of direct costs alone. Equation 5 retains fixed indirect cost and variable site overhead, and the latter materially affects the ranking. The contract amount used in the bridge must also match the remaining structural scope: subtracting profit

alone cannot exclude architectural work or already completed work if either is present in that amount. The itemized schedule must confirm this scope and resolve the previously identified IDR 999.99 discrepancy between its listed amounts and stated subtotal.

3.2 Discussion

Interpretation of the scenario ranking

The existing totals favor workforce expansion, conditional on reconciliation of the accelerated schedules and cost assumptions. The clarified scope is remaining structural work, so reported savings cannot be extrapolated to completion of the entire building. W4 must be interpreted through its actual allocation of additional carpenters and reinforcement workers. Neither its label nor a simplified crew ratio establishes that the targeted additions can deliver 72.98 working days.

The direction of the reported ranking is consistent with the Indonesian comparison by [Fardila & Adawyah \(2021\)](#), which also reported a more favorable outcome for additional labor than for overtime. Differences in work content, crew composition, and scheduling assumptions prevent using that agreement to validate the present magnitudes. [Widiastuti et al. \(2025\)](#), further illustrate that schedule improvement may still fall short of a completion target. Here, the revised 20 October 2026 forecast resolves the baseline calendar inconsistency. Demonstrating recovery of the historical delay would additionally require the applicable contractual milestone and reproducible accelerated completion dates.

The overtime coefficients are attributed to project-specific time–motion observations from December 2025, while the workforce crowding factor remains a separately supplied assumption. Empirical construction studies report productivity losses under extended overtime ([Hanna et al., 2005a](#)) and overmanning ([Hanna et al., 2005b](#)), but do not establish the numerical coefficients for this project. The sampling and estimation details of the local study are necessary to assess transfer from the earlier phase to the remaining structural activities. No direct fatigue or congestion measurements have been supplied, so these mechanisms should not be described as observed causes of the scenario differences. The wider evidence on overtime, schedule compression, and congestion reinforces the need to verify these effects against local production records ([Thomas & Raynar, 1997](#); [Woo, 2016](#); [Chang et al., 2007](#); [Thomas et al., 2006](#)).

Economic margin and sensitivity

The clarified baseline is dominated by direct and fixed indirect costs. With daily overhead set at IDR 10 million per working day, the existing O4 result implies overhead savings of IDR 853.8 million offset by a direct-cost increase of IDR 790.247 million. W4 implies overhead savings of IDR 1,270.2 million offset by a direct-cost increase of IDR 931.536 million. This arithmetic explains why the reported cost reductions are much smaller than the reported duration reductions, conditional on the supplied values. The direct-cost increments and the avoidability of overhead still require supporting records. Distinguishing cost types is also consistent with the production-buffer discussion in the literature ([Tommelein, 2024](#)).

The absolute savings provide a simple break-even check. Holding the reported durations and all other assumptions constant, an unaccounted net cost of IDR 63,553,013.16 would eliminate O4's savings relative to baseline. For W4, the corresponding amount is IDR 338,664,205.74. An additional differential cost against W4 of IDR 275,111,192.58 would erase its reported advantage over O4. These values are arithmetic margins, not a completed probabilistic sensitivity analysis. They show the scale of recruitment, supporting equipment, supervision, or productivity losses that the final model must examine.

An adequate sensitivity analysis would vary the daily avoidable overhead, task-specific productivity factors, crew capacity, and relevant wage costs within documented ranges. Each variation must trigger a fresh schedule and cost calculation. Assigning an arbitrary percentage penalty to the final project duration would not capture shifts in criticality or resource conflicts. Such an analysis remains future work until the input records are available.

The literature provides several routes for extending this analysis once reliable input data become available. [Feng et al. \(2000\)](#), combined simulation and genetic algorithms to evaluate construction time–cost decisions under uncertainty. [Herroelen & Leus \(2005\)](#), distinguish stochastic, reactive, and robust scheduling approaches, while [Hazır et al. \(2011\)](#), model uncertain activity costs through intervals in a robust discrete time–cost framework. These

methods could help assess whether the reported ranking persists under plausible input variation; they have not been applied to the present dataset.

Practical implications and limitations

A contractor could use the workforce alternative as a candidate for detailed planning after checking crew balance, workforce capacity, material supply, lifting and concrete-placement capacity, and supervision. Concrete curing, inspection, and other technical hold points must retain their required durations. Overtime alternatives likewise require a feasible weekly roster and a defensible wage and productivity basis. Neither strategy should be implemented solely because it gives the smallest value in an unverified summary table. Quality should also be retained as an explicit decision criterion: time–cost–quality optimization demonstrates how it can be evaluated alongside duration and cost (El-Rayes & Kandil, 2005).

The study concerns one project and eight predefined alternatives. The revised baseline calendar, active-working-day overhead policy, crew categories, curing convention, and profit deduction are specified. Remaining limitations concern replication of the accelerated mixed-calendar network, the allocation and productivity of added trades, the time–motion estimates, the payroll basis, and itemized scenario costs. Resource leveling was disabled, so resource feasibility depends on the separate assignment checks reported by the authors. Cost uncertainty, weather, rework, quality outcomes, and occupational safety outcomes were not quantified. These limitations prevent a claim of validated feasibility or global optimality (Feng et al., 1997; Agarwal et al., 2024; Jeunet & Orm, 2020).

4 Conclusion

Among the reported alternatives for remaining structural work, workforce scenario W4 has the lowest total analytical cost and shortest duration: IDR 74,075,749,578.04 and 72.98 working days. Relative to the baseline of 200 working days and IDR 74,414,413,783.78, the arithmetic reductions are 63.510% in time and 0.455% in cost. Four overtime hours give IDR 74,350,860,770.62 and 114.62 working days, corresponding to reductions of 42.690% and 0.085%. The reported workforce advantage reflects greater overhead savings despite a larger implied direct-cost increase.

The confirmed Monday–Saturday calendar places the unaccelerated structural completion milestone on 20 October 2026 when national holidays are not excluded. The normal cost components and the clarified 10%-of-contract-value profit deduction reproduce the analytical baseline, and the two-hour overtime example gives 16.67 working days for reinforcing steel. These checks resolve the baseline date and arithmetic definitions but do not validate the accelerated schedules. Workforce expansion remains a candidate for implementation only after the native network, trade assignments, productivity calibration, payroll basis, and underlying costs substantiate the reported scenario advantage.

Declarations

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Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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