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Developing an Accountable Budget Baseline for Infrastructure Projects: A Consolidated Cost and Schedule Estimation Framework and Maturity Assessment

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Abstract

Organizations frequently rely on multiple international references for cost estimating and schedule development, yet these references use different terminology, levels of detail, and emphases, which can leave budgeting stage estimation fragmented and difficult to audit. This paper develops a consolidated, stepwise framework by synthesizing prescriptive practices from PMI, AACE, NASA, and GAO, and applies the framework as an auditable process maturity assessment instrument. A benchmarking synthesis approach was used to screen candidate references for capital project relevance and explicit guidance for cost estimating and schedule development. Process steps were extracted, harmonized across sources, and consolidated into two aligned end to end process frameworks for cost estimating and schedule estimating. The consolidated steps were converted into assessment items, rated on a five level maturity scale, and summarized using achieved versus maximum scoring. Application to PT Pertamina Patra Niaga (PPN)'s budgeting stage practices indicates that the current cost estimating process reaches 56/70 (80%) maturity, while the current schedule estimating process reaches 46/90 (51%). The previous cost estimating process scores 43/70 (61%). The most prominent gaps relate to the formal documentation of ground rules and assumptions, typically captured in a Basis of Estimate, and to schedule model discipline, particularly coding, logic structure, and systematic schedule quality checks. Overall, the findings show that the framework is practical to implement and supports evidence based prioritization of process improvements toward more transparent, accountable, and reliable budgeting baselines for capital and infrastructure related investments.

Introduction

Cost overruns and schedule slippages remain common in capital projects, particularly in infrastructure intensive sectors such as downstream oil and gas. One recurring contributor is weak budgeting stage estimation. Cost and schedule baselines are often produced as separate deliverables, while uncertainty is handled inconsistently, which reduces the defensibility of the approved baseline and weakens subsequent project control (De Meyer et al., 2002; Szwarcfiter et al., 2023; Coteț et al., 2026; Kerzner, 2025; Raj & Islam, 2022).

Organizations typically respond by adopting internationally recognized standards and guides. However, widely used references differ in terminology, level of detail, and emphasis. Some

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focus on governance, others stress estimate classification and input maturity, and others provide step by step practices for developing credible estimates and schedules (Hriday & Rehman, 2025; Fardous, 2025; Rahimpour et al., 2022). In a multi reference environment, teams may still implement different sequences, omit important control points, and document assumptions unevenly, even when citing the same authorities (Mincu, 2022; Bartelheimer et al., 2025; Laban et al., 2026).

A second challenge is the lack of an auditable way to diagnose process maturity. Organizations often know that their estimating practice needs improvement, but they cannot clearly pinpoint which parts of the process are underdeveloped and how severe the gaps are. Without a structured assessment instrument, improvement tends to be driven by anecdote, varies across units, and is difficult to track over time. This limitation is especially critical at the budgeting stage, where baseline decisions require clear justification.

The paper contributes in three ways: it synthesises a consolidated cost and schedule estimation framework, operationalises it into an auditable maturity and gap assessment instrument, and demonstrates its application to budgeting stage practices to identify dominant gaps and improvement priorities.

Literature Review / Theoretical Framing

This section establishes the conceptual basis for two elements of the paper. The first is benchmarking synthesis as a structured way to integrate guidance from multiple international references. The second is process maturity assessment as an auditable approach to diagnose implementation gaps.

Benchmarking is widely used to translate external best practices into internal improvements. In cost and schedule estimating, however, benchmarking rarely involves adopting a single reference. Organizations often consult several authorities because each offers different strengths, such as governance, estimate classification, credibility checks, or structured procedures (Önder & Zengin, 2022). This paper therefore treats benchmarking as a form of structured integration rather than a descriptive comparison of standards.

The synthesis logic can be explained through three sequential steps. First, decomposition is used to extract comparable process steps from each reference. Second, normalization is used to reconcile overlaps and align terminology so that similar practices are described consistently. Third, consolidation is used to arrange the normalized steps into coherent end to end processes that can be implemented and reviewed.

A process framework serves two practical functions. It provides a clear sequence of activities for producing traceable baselines, and it defines minimum expectations for inputs, controls, and outputs. In cost estimating, these expectations typically include scope structuring and quantification, data acquisition and normalization, estimate construction, and uncertainty treatment (Jafary et al., 2026; Hriday & Rehman, 2025). In schedule estimating, baseline credibility depends on disciplined activity definition, sound logic relationships, appropriate calendars and constraints, and systematic quality checks that validate schedule structure. Comparative applications of scheduling methods have also shown that different representations vary in how clearly they expose critical paths and logic relationships, which reinforces the importance of schedule model discipline when a baseline is reviewed and used for control (Silvianita et al., 2018; Tarek & Rahman, 2022; Hriday, 2022; Rojas et al., 2025).

In capital projects, cost credibility is closely tied to schedule credibility because schedule deviation often translates into cost impacts through time dependent exposure, productivity effects, and rework. For that reason, a consolidated framework is stronger when it aligns cost and schedule baselining through shared control points and accommodates uncertainty

ISSN: 2716-3865 (Print), 2721-1290 (Online)

reasoning as part of baseline decision support, without turning the study into a stand alone quantitative risk methods paper.

Even when a framework is available, organizations still need a repeatable way to diagnose where implementation is weak. Process maturity assessment addresses this need by translating best practice items into an auditable checklist and applying a rubric that differentiates levels of implementation quality, from not implemented, to informal, to partially implemented, to standardized, and finally to well controlled and evidence based practice (Zargaran & Ghorbanpoor, 2026; Eugenio-Gozalbo et al., 2022). This approach is most defensible when assessment is anchored to observable evidence such as documented deliverables, procedures, checklists, and review records, rather than perceptions alone. In addition, delay oriented case research has illustrated the value of structuring causes and consequences using systematic risk reasoning in project execution settings, which supports more disciplined discussions about controls and mitigation (Silvianita et al., 2017; Crawford & Jabbour, 2024). Prior research has benchmarked Indonesian downstream oil and gas estimating practices against global guidance and used decision models to prioritize gaps. However, that work typically emphasizes selecting a single preferred reference, whereas this paper synthesizes multiple authoritative sources into a consolidated framework and operationalizes it as a maturity assessment instrument (Zilikram, 2023).

Methods

Research Design

This study employed a benchmarking-synthesis design to develop consolidated cost- and schedule-estimating frameworks and operationalize them as an evidence-based process maturity and gap assessment instrument. The methodological procedure consisted of four main stages: benchmarking-reference selection, framework synthesis, maturity scoring and aggregation, and application of the assessment instrument to internal budgeting-stage estimating processes.

Benchmarking Reference Selection

Seven internationally recognized project-management references were initially reviewed: the Project Management Institute (PMI), International Organization for Standardization (ISO), PRINCE2, Association for the Advancement of Cost Engineering International (AACE), National Aeronautics and Space Administration (NASA), Government Accountability Office (GAO), and International Project Management Association (IPMA) (Sadeanu et al., 2017).

The references were screened using four eligibility criteria: international recognition, relevance to capital and infrastructure projects, availability of explicit step-by-step guidance for cost estimating and schedule development, and emphasis on traceable outputs, governance, and review mechanisms. Each reference was assessed consistently against these criteria. References containing sufficiently detailed and operational procedures were retained for framework synthesis, whereas those limited to general project-management principles or competence standards were excluded.

Table 1. Benchmarking Reference Screening and Selection

Reference	Assessment against eligibility criteria	Decision	Key sources
PMI	Provides structured cost-estimating and schedule-development guidance, including inputs, tools and techniques, outputs, work breakdown structures, and risk-management practices.	Included	PMI (2006); PMI (2011); PMI (2017); PMI (2019a); PMI (2019b)

ISSN: 2716-3865 (Print), 2721-1290 (Online)

ISO	Provides general project-management and work breakdown structure guidance but does not offer sufficiently detailed stepwise procedures for developing cost and schedule estimates.	Excluded	ISO (2018); ISO (2021)
PRINCE2	Describes overall project-planning and management processes but provides limited technical guidance on cost- and schedule-estimating methods.	Excluded	Office of Government Commerce (2009)
AACE	Provides detailed technical guidance on estimate classification, input maturity, estimating methods, Basis of Estimate documentation, and cost and schedule risk analysis.	Included	AACE (2010a); AACE (2020a); AACE (2020c); AACE (2022); AACE (2024)
NASA	Provides systematic cost- and schedule-estimating procedures, including integrated uncertainty and Joint Confidence Level analysis.	Included	NASA (2015); NASA (2020)
GAO	Provides detailed best practices for credible cost estimates and reliable schedules, emphasizing traceability, documentation, validation, and integration.	Included	GAO (2015); GAO (2020)
IPMA	Primarily emphasizes individual and organizational competence rather than detailed stepwise procedures for cost and schedule estimation.	Excluded	IPMA (2015)

Based on this screening process, PMI, AACE, NASA, and GAO were used as the principal benchmarking references for framework development.

Framework Synthesis Procedure

Relevant process steps, inputs, outputs, controls, documentation requirements, and review mechanisms were extracted from each selected benchmarking reference and organized in a comparative matrix. The extracted elements were then harmonized to reconcile differences in terminology, sequence, and level of detail.

Semantically equivalent practices were combined under standardized labels. However, essential control mechanisms—including input-maturity verification, technical-baseline definition, documentation of ground rules and assumptions, uncertainty analysis, quality assessment, review, and formal approval—were retained as separate process steps.

The harmonized elements were subsequently consolidated into two aligned end-to-end frameworks: a cost-estimating framework and a schedule-estimating framework. Shared control points, including the work breakdown structure, technical baseline, input-readiness requirements, uncertainty treatment, documentation, review, and approval, were aligned across both frameworks to strengthen process integration and auditability.

Development of the Maturity Assessment Instrument

Each step in the consolidated frameworks was converted into an assessable process item. Implementation maturity was evaluated using a five-level rubric: 1) Not implemented: no evidence that the practice was performed; 2) Informal or ad hoc: the practice was performed occasionally without a consistent procedure; 3) Partially implemented or inconsistent: some

ISSN: 2716-3865 (Print), 2721-1290 (Online)

evidence was available, but implementation remained incomplete or inconsistent; 4) Standardized and generally consistent: the practice was formally established and routinely implemented; 5) Well controlled and evidence-based: the practice was standardized, consistently implemented, reviewed, and supported by auditable evidence.

The assessment was based on observable documentary evidence rather than perceptions. The evidence examined included internal procedures, templates, checklists, bills of quantity or take-off files, pricing worksheets, supporting quotations, Basis of Estimate documents, risk registers, schedule files, schedule-review outputs, and review or approval records.

Maturity Scoring and Aggregation

The author assigned the item scores using the predefined maturity rubric and maintained an evidence trail documenting the basis for each rating. Where an assessment item consisted of several related controls, the relevant subcriteria were examined individually before an overall item score was assigned.

To reduce interpretive bias, ratings were triangulated across multiple available artifacts and applied consistently to the previous and current estimating processes. The maturity ratio was calculated as follows:

$$\text{Maturity Ratio} = \frac{\text{Total Achieved Score}}{\text{Maximum Possible Score}} \times 100\%$$

The maximum possible score was determined by multiplying the number of assessment items by the maximum maturity score of five. Achieved-versus-maximum scoring was used to compare maturity across process domains and identify practices that had not yet been fully institutionalized.

Application to Internal Budgeting-Stage Processes

The maturity assessment instrument was applied to the budgeting-stage estimating practices of PT Pertamina Patra Niaga. The assessment covered the previous and current cost-estimating processes and the current schedule-estimating process.

Internal workflows and available documentary artifacts were mapped against the consolidated assessment items. Each item was rated according to the completeness, consistency, formalization, and auditability of the available evidence. Items with relatively low maturity ratings were grouped into recurring gap themes to identify weaknesses and establish process-improvement priorities.

Results and Discussion

This section presents three principal findings. First, the benchmarking synthesis produced consolidated cost- and schedule-estimating frameworks. Second, the consolidated process steps were operationalized as an auditable maturity and gap assessment instrument. Third, application of the instrument to PT Pertamina Patra Niaga’s budgeting-stage practices revealed differences in maturity between cost- and schedule-estimating processes and identified the most important areas requiring improvement.

Consolidated Cost-Estimating Framework

The benchmarking synthesis of PMI, AACE, NASA, and GAO resulted in a consolidated cost-estimating framework consisting of 13 principal process steps. The framework integrates technical estimating activities with governance, documentation, uncertainty treatment, review, and approval requirements. Unlike the selective use of individual standards, the consolidated framework presents an end-to-end sequence that clarifies the required inputs, analytical activities, control points, and outputs of a defensible cost estimate.

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Table 2. Consolidated Cost-Estimating Framework

No.	Process	Explanation
1	Define cost-estimate purpose	Identify why the estimate is being prepared, such as for a feasibility study, budget approval, or bid submission, and clarify how it will support decision-making.
2	Assign estimate class and confirm required deliverables	Determine the estimate class based on the level of project definition and verify that the required deliverables and data maturity are available.
3	Establish the estimating technical baseline	Define the baseline package required to produce a complete and traceable estimate.
3a	Define the WBS and work-package structure	Prepare the work breakdown structure at the required level and ensure that work packages are traceable.
3b	Verify key technical deliverables	Confirm the drawings, specifications, and other technical documents used as estimating inputs.
3c	Confirm the execution strategy	Establish the execution and contracting assumptions that may affect scope, productivity, indirect costs, and pricing.
3d	Document schedule assumptions for estimating	Record milestones, calendars, durations, and schedule assumptions that influence time-related costs.
3e	Validate quantities and resource assumptions	Verify the take-off basis, quantities, productivity rates, and resource assumptions used in the estimate.
4	Quantify scope content	Measure and list the quantities of materials, labor, equipment, and other work items required to execute the project.
5	Identify ground rules and assumptions	Document the assumptions, constraints, exclusions, and special conditions under which the estimate is prepared.
6	Obtain, validate, normalize, and analyze estimating data	Collect historical data, vendor quotations, and productivity rates; verify their accuracy; and normalize them to current project conditions.
7	Develop the point estimate	Prepare the base cost estimate before contingency by combining verified quantities with the selected cost data.
7a	Cost the scope using the selected methodology	Apply appropriate estimating methods, such as analogous, parametric, unit-rate, or detailed take-off methods.
7b	Apply overhead, profit, and mark-ups	Include approved commercial components, including contractor overhead, profit, taxes, and other mark-ups.
8	Conduct sensitivity analysis	Assess the effects of changes in key assumptions, such as material prices and productivity rates, on the total estimated cost.
9	Conduct integrated risk and uncertainty analysis	Evaluate the probability distribution of cost outcomes by considering both cost and schedule uncertainty.
10	Budget costs	Convert the approved estimate into a time-phased budget for expenditure planning and cost control.
11	Analyze cash flow	Examine the projected expenditure pattern to determine whether funding availability aligns with the implementation schedule.
12	Review and document the estimate	Conduct quality assurance or peer review and document the estimate basis, methodology, assumptions, risks, and results.

ISSN: 2716-3865 (Print), 2721-1290 (Online)

13	Present the estimate to decision-makers	Communicate the estimated cost, uncertainty range, major risks, and recommendations to relevant stakeholders.

The framework strengthens estimate traceability by requiring the estimate purpose, classification, technical baseline, assumptions, and supporting data to be explicitly documented. It also extends the process beyond estimate calculation by incorporating sensitivity analysis, integrated risk analysis, cash-flow assessment, review, and formal communication.

Consolidated Schedule-Estimating Framework

Using the same synthesis approach, a consolidated schedule-estimating framework was developed. The framework consists of 16 principal steps covering schedule purpose, input maturity, activity development, coding, sequencing, resource allocation, duration estimation, quality assessment, risk analysis, approval, baselining, and communication.

Table 3. Consolidated Schedule-Estimating Framework

No.	Process	Explanation
1	Define schedule-estimate purpose	Identify why the schedule is being prepared and how it will be used for planning, budgeting, approval, or control.
2	Select schedule-estimate class and confirm input maturity	Determine the schedule class and verify that the required technical information and project-definition maturity are available.
3	Collect the WBS and technical deliverables	Gather the work breakdown structure, design documents, scope information, and other technical inputs required for schedule development.
4	Select the time unit	Define the smallest time unit, such as hours, days, or weeks, to be used consistently throughout the schedule.
5	Determine the schedule outline	Establish the required level of schedule detail in accordance with the WBS and project requirements.
6	Establish the schedule coding structure	Develop standardized activity codes by phase, discipline, location, work package, or other relevant classifications.
7	Capture all milestones and activities	Identify the milestones and detailed activities required to complete the project scope.
8	Sequence activities using logical relationships	Connect activities using appropriate relationships, including finish-to-start, start-to-start, finish-to-finish, and start-to-finish.
9	Assign resources and costs to activities	Allocate labor, equipment, materials, and related costs to scheduled activities where applicable.
10	Estimate activity durations	Determine realistic activity durations based on productivity, resource availability, complexity, and project conditions.
11	Perform resource leveling	Adjust activity timing and resource allocation to align resource demand and cash-flow requirements with availability.
12	Conduct schedule assessment	Review the schedule for completeness, logical integrity, traceability, and compliance with established requirements.

ISSN: 2716-3865 (Print), 2721-1290 (Online)

12a	Verify horizontal and vertical traceability	Confirm that relationships are consistent across activities and that lower-level schedules align with higher-level milestones.
12b	Confirm the critical path and critical activities	Verify that the critical path is valid and represents the longest logical route to project completion.
12c	Ensure reasonable total float	Confirm that float values are realistic and are not distorted by excessive constraints or incomplete logic.
13	Perform integrated schedule-risk analysis	Conduct quantitative risk analysis to determine an appropriate schedule reserve and contingency.
14	Approve the schedule	Obtain formal authorization from relevant stakeholders before the schedule is adopted.
15	Baseline the schedule model	Establish the approved schedule as the formal reference for measuring project performance.
16	Document and communicate the schedule	Record schedule assumptions, constraints, calendars, logic, and risk considerations and communicate the approved baseline to stakeholders.

The resulting framework shows that schedule credibility depends not only on estimating activity durations but also on coding consistency, logical relationships, traceability, resource integration, quality checks, and formal baseline governance. These elements are particularly important because weaknesses in the schedule can directly affect cost estimates, cash-flow projections, and budgeting decisions.

Maturity and Gap Assessment Results

The consolidated frameworks were subsequently applied as maturity assessment instruments. The assessment showed clear differences between the previous cost-estimating process, the current cost-estimating process, and the current schedule-estimating process.

Table 4. Summary of Maturity Assessment Results and Recurring Gap Themes

Process domain	Achieved score	Maximum score	Maturity ratio	Key recurring gaps
Previous cost-estimating process	43	70	61%	Limited formalization of the estimate purpose and estimate class; absence of documented ground rules and assumptions; limited sensitivity analysis; and limited integrated risk reasoning.
Current cost-estimating process	56	70	80%	Incomplete standardization of the WBS and technical baseline; weak Basis of Estimate discipline; selective use of sensitivity analysis; and limited integration of cost and schedule risk analysis.
Current schedule-estimating process	46	90	51%	Weak coding structure and logic-network discipline; limited resource loading and leveling; insufficient systematic schedule-quality checks; and limited integrated schedule-risk reasoning.

The current cost-estimating process achieved the highest maturity ratio at 80%, compared with 61% for the previous cost-estimating process. This represents an improvement of 19

ISSN: 2716-3865 (Print), 2721-1290 (Online)

percentage points. The increase indicates that several foundational estimating practices have become more structured and consistently implemented.

However, the current schedule-estimating process achieved only 51%. This result indicates that schedule development remains substantially less mature than cost estimating. The imbalance is important because cost-estimating credibility depends partly on reliable schedule information, particularly for time-dependent costs, cash-flow development, productivity assumptions, escalation, and uncertainty analysis.

Documentary Evidence Supporting the Maturity Scores

Selected assessment items and documentary evidence are presented in Table 5. The examples illustrate how maturity ratings were connected to observable practices and records.

Table 5. Selected Evidence Supporting Representative Maturity Scores

Assessment item	Score	Evidence examined	Assessment rationale
Document ground rules and assumptions through a Basis of Estimate	1	No formal Basis of Estimate document was identified; assumptions were only implicit in working files.	The absence of a traceable Basis of Estimate means that assumptions cannot be reviewed or audited consistently.
Establish the estimating technical baseline	3	WBS and scope-breakdown files, selected technical inputs, and partial execution and schedule assumptions.	Some baseline components were available, but the documentation was incomplete and not consolidated.
Establish the schedule coding structure	1	No coding dictionary or formal coding rules; activity attributes were not standardized.	Without a coding structure, consistent filtering, reporting, and traceability cannot be achieved.
Sequence activities using logical relationships	2	Schedule files showed serial or parallel sequencing but contained limited relationship detail and minimal logic checks.	Activity sequencing existed but was applied informally and without sufficient logic-network discipline.
Confirm the critical path and critical activities	5	Critical-path outputs and validation records were available in the schedule checks.	The critical path was explicitly reviewed and supported by auditable evidence.
Approve the baseline estimate and schedule	5	Approval memos, emails, sign-off records, review minutes, or checklists.	A consistent approval trail demonstrated that formal review and authorization were implemented.

The evidence indicates that formal approval procedures and critical-path validation were relatively mature and consistently supported by auditable records. In contrast, the documentation of key assumptions, ground rules, and schedule coding practices remained among the weakest areas of the assessment. This imbalance suggests that governance activities at the final review and authorization stage were stronger than the technical and documentary foundations used to develop the baseline itself. Although the estimate and schedule were formally approved, weaknesses in assumption documentation, coding consistency, and model traceability may still reduce the transparency, reproducibility, and overall credibility of the approved baseline.

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Comparison of Previous and Current Maturity Profiles

The comparison between the previous and current processes is summarized in Table 6.

Table 6. Comparison of Previous and Current Maturity Profiles

Process domain	Previous process	Current process	Change
Cost estimating	43/70 (61%)	56/70 (80%)	Increased by 19 percentage points
Schedule estimating	Not assessed	46/90 (51%)	No historical comparison available

The cost-estimating improvement indicates that the current process has adopted more structured practices than the previous process. Nevertheless, the 80% maturity ratio should not be interpreted as full compliance. Important gaps remain in technical-baseline standardization, Basis of Estimate documentation, sensitivity analysis, and integrated cost and schedule risk assessment.

The absence of a previous schedule-estimating assessment prevents a direct longitudinal comparison. However, the current score of 51% demonstrates that schedule-estimating practices require more substantial improvement than cost-estimating practices.

Major Gap Themes and Improvement Priorities

Two dominant gap themes emerged from the assessment. The first relates to Basis of Estimate discipline. Ground rules, assumptions, exclusions, estimating methods, data sources, and uncertainty considerations were not consistently documented in a formal and auditable format. Without a complete Basis of Estimate, differences between estimates, project stages, or revisions become difficult to explain and justify.

The second major gap relates to schedule-model discipline. Weak activity coding, incomplete logical relationships, limited resource loading, and insufficient systematic quality checks reduce the schedule's reliability as a control-grade baseline. Although critical-path validation was performed, this practice alone was insufficient to ensure complete schedule integrity. A credible schedule also requires traceability across schedule levels, realistic float, appropriate calendars and constraints, and disciplined logic development.

These findings demonstrate that improvements in cost estimating alone cannot produce a fully defensible budgeting baseline. Cost and schedule estimates are interdependent, particularly where cost outcomes are influenced by project duration, activity sequencing, resource utilization, escalation, and time-related risks.

The improvement process should therefore be implemented in stages. The first priority is to strengthen baseline traceability through standardized WBS requirements, complete technical inputs, and mandatory Basis of Estimate documentation. The second priority is to improve schedule-model integrity through standardized coding, disciplined logic relationships, resource loading, and routine schedule-quality assessment. Once these foundations are consistently applied, more advanced practices, including integrated cost and schedule risk analysis, can be implemented more effectively.

Overall, the consolidated framework provides an evidence-based basis for diagnosing process maturity and prioritizing improvement actions. Its application shows that PPN's current cost-estimating process has improved considerably, but schedule-estimating weaknesses continue to limit the reliability, transparency, and auditability of budgeting-stage baselines.

This section presents the results in a sequence that mirrors the three aims set out in the Introduction. It begins by reporting the consolidated cost and schedule estimation framework

ISSN: 2716-3865 (Print), 2721-1290 (Online)

developed through benchmarking synthesis. It then explains how the consolidated steps were converted into an auditable maturity and gap assessment instrument. Finally, it summarises what is learned when the instrument is applied to budgeting stage practices in PPN, including the resulting maturity profile and the most influential gap themes.

The first result is the consolidated framework shown in Table 2 and Table 3. Instead of treating international references as separate documents that are consulted selectively, the synthesis integrates complementary prescriptive practices into a coherent process for cost estimating and a parallel process for schedule estimating. Importantly, the framework makes governance and control points explicit. These include readiness checks for input maturity, requirements for baseline definition, documentation expectations, and formal review and approval steps. As a result, traceability is strengthened because the framework clarifies which inputs must be available, how estimates and schedules are constructed, and what evidence supports the key assumptions that shape the baseline.

The second result is the maturity and gap assessment instrument derived from the framework. Each consolidated step is translated into an assessable item and rated using a five level rubric anchored to observable artifacts. This operationalisation shifts process evaluation away from general impressions and toward an evidence based diagnosis. Maturity can be discussed using concrete indicators, such as whether the required deliverables exist, whether checklists and review records are used consistently, whether assumptions are documented in a structured way, and whether the schedule model includes the attributes needed for credibility. The achieved versus maximum scoring approach also supports consistent comparison across items and across process domains.

The third result comes from applying the instrument to budgeting stage practices in PPN, as summarized in Table 4 and Table 5. The assessment indicates that the current cost estimating process reaches 56 out of 70 (80% maturity), while the current schedule estimating process reaches 46 out of 90 (51%). The previous cost estimating process scores 43 out of 70 (61%). The profile suggests that cost estimating maturity has strengthened over time, but schedule estimating remains a binding constraint for producing a defensible budgeting baseline. In practical terms, improvements to cost estimating alone are unlikely to yield a fully credible baseline if schedule modelling discipline remains underdeveloped, because cost estimates often depend on schedule structure, sequencing logic, and time related exposure.

Across the assessment, two recurring gap areas emerge as particularly influential. The first concerns Basis of Estimate discipline, especially the consistent documentation of ground rules and assumptions that supports traceability and repeatability. Without this foundation, it becomes difficult to justify the baseline and to explain why estimates differ across projects or revisions. The second gap relates to schedule model discipline. Schedule assessment guidance emphasises that credibility depends on structural integrity, including coding consistency, sound logic relationships, traceability across schedule levels, and systematic quality checks (GAO, 2015; Roy et al., 2025; Rosson, 2026). When these elements are weak, the schedule cannot function reliably as a control grade baseline. This, in turn, makes cost estimates that depend on schedule inputs harder to defend, even when cost estimating practices are improving.

Taken together, the maturity profile provides a defensible basis for sequencing process improvements. Initial efforts should focus on strengthening traceability foundations, including standardized technical baseline inputs and consistent Basis of Estimate documentation (Odarushchenko et al., 2025; Gonzalez et al., 2026). The next priority is reinforcing schedule model integrity through a clear coding structure, disciplined logic development, and routine schedule quality assessment. Once these foundations are stable and consistently applied, higher effort capabilities such as integrated cost and schedule risk

ISSN: 2716-3865 (Print), 2721-1290 (Online)

reasoning can be introduced more effectively, because the underlying inputs and governance controls are already reliable. Beyond internal process value, this sequencing supports more reliable delivery of capital and infrastructure related investments and strengthens the transparency and accountability of budgeting stage decision making.

Limitations

This paper has the following limitations:

The application focuses on budgeting stage estimating practices within PPN. The maturity profile and recurring gaps presented therefore reflect a specific organizational context and documentation environment, so generalization to other organizations or project portfolios should be made with caution.

The instrument assesses implementation maturity by examining inputs, controls, documentation quality, and verification practices. It does not validate predictive accuracy or quantify how maturity improvements translate into cost or schedule performance outcomes within the scope of this paper.

Maturity scoring was conducted by a single rater, namely the author. To reduce interpretive bias, the assessment applied a fixed rubric, maintained an item level evidence trail, and triangulated judgments across multiple artifacts where available. Future work should test inter rater consistency.

The synthesis is limited to four benchmarking partners, namely PMI, AACE, NASA, and GAO, because these sources provide sufficiently prescriptive stepwise guidance for cost estimating and schedule development. Other candidates may offer complementary perspectives that are not captured in the consolidated framework.

The maturity results depend on the internal evidence and artifacts available at the time of assessment. As procedures, tools, templates, and datasets evolve, the maturity profile should be updated to reflect process changes and to confirm whether improvements are sustained in practice.

Conclusion

This paper responds to a practical weakness in budgeting stage estimation. Although international guidance for cost estimating and schedule development is widely available, it is often dispersed across multiple references with different terminology and levels of detail. In practice, this fragmentation can lead to uneven implementation, inconsistent documentation, and limited auditability of the approved baseline. The conclusion therefore follows the same three objectives stated in the Introduction and summarises the main findings in a coherent way.

The first objective was to consolidate prescriptive practices from PMI, AACE, NASA, and GAO into a stepwise framework for cost estimating and schedule estimating. The resulting frameworks provide a clear sequence of activities and make critical control points explicit, such as readiness checks for input maturity, baseline definition requirements, documentation expectations, and review and approval steps. By making these controls visible and structured, the framework strengthens traceability and improves the conditions for consistent implementation across projects.

The second objective was to translate the consolidated steps into an auditable maturity and gap assessment instrument. Each step was converted into an assessable item, rated using a five level rubric, and summarized through achieved versus maximum scoring. This approach shifts evaluation away from general perceptions and toward observable evidence, such as deliverables, checklists, assumptions records, and schedule outputs, which makes the diagnosis more transparent and repeatable.

ISSN: 2716-3865 (Print), 2721-1290 (Online)

The third objective was to apply the instrument to budgeting stage practices in PPN. The assessment indicates that the current cost estimating process reaches 56 out of 70 (80% maturity), while the current schedule estimating process reaches 46 out of 90 (51%). The previous cost estimating process scores 43 out of 70 (61%). Two dominant gaps emerge from the assessment. The first concerns Basis of Estimate discipline, particularly the consistent documentation of ground rules and assumptions to support traceability and repeatability. The second concerns schedule model discipline, especially coding and logic structure supported by systematic schedule quality checks. Together, these gaps help explain why a budgeting baseline can remain difficult to defend even when cost estimating practices improve.

Overall, the findings provide an evidence based basis for sequencing improvements toward more defensible budgeting baselines. Priority should be given to strengthening traceability foundations, including technical baseline consistency and Basis of Estimate documentation, followed by improvements in schedule model integrity through disciplined coding, logic development, and routine schedule quality checks. Beyond internal process value, these improvements support more reliable delivery of capital and infrastructure related investments and strengthen the transparency and accountability of budgeting stage decision making.

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