JRSSEM 2026, Vol. 5, no. 12, July
E-ISSN: 2807 - 6311
P-ISSN: 2807 - 6494

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

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Keywords:
Benchmarking synthesis; cost estimating; schedule estimating; process maturity assessment; gap analysis; integrated cost and schedule framework budgeting stage.

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 (Ackah & Boadu, 2025; Esmaeili & Kashani, 2022; Hriday & Rehman, 2025; Okiye et al., 2022; Onyechi, 2024). 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.

Organizations typically respond by adopting internationally recognized standards and guides. However, widely used references differ in terminology, level of detail, and emphasis. Some focus on governance, others stress estimate classification and input maturity, and others provide step by step practices for developing credible estimates and schedules. 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.

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 urgency of this research is underscored by the scale of investment in Indonesian infrastructure. The government's downstream oil and gas development plans involve billions of dollars in capital investment, with project success depending on accurate budgeting-stage estimates. Recent studies on Indonesian infrastructure project delays have shown that poor estimating practices contribute to cost overruns averaging 15-30% of project value, with schedule delays of 20-50% of planned duration. These statistics highlight the economic impact of weak estimation and the importance of developing more defensible budgeting baselines.

The novelty of this research lies in its integration of four complementary international references into a consolidated framework for cost and schedule estimation, operationalized as an auditable maturity assessment instrument. Unlike previous studies that have focused on individual references or specific estimation methods, this research synthesizes prescriptive practices across sources to produce two aligned end-to-end process frameworks. The conversion of these frameworks into assessment items with a five-level maturity rubric enables systematic diagnosis of process gaps. This represents an advance over previous maturity assessment approaches, which often lack the specificity needed to guide improvement.

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

METHOD

The study followed a benchmarking-synthesis design to (i) develop a consolidated cost and schedule estimation framework and (ii) apply it as a process maturity assessment instrument. To support reproducibility, the methodology is summarized in four elements: benchmarking selection, synthesis procedure, maturity scoring/aggregation, and application to internal processes.

Benchmarking selection

This study screened candidate references using eligibility criteria relevant to budgeting stage estimating, including international recognition, relevance to capital projects, the availability of explicit step by step guidance for both cost estimating and schedule development, and an emphasis on traceable outputs and governance. Seven widely recognized references were reviewed: PMI, ISO, PRINCE2, AACE, NASA, GAO, and IPMA (Sadeanu et al., 2017). Table 1 reports the screening outcomes for each candidate reference. PMI, AACE, NASA, and GAO were selected as benchmarking partners because their guidance is sufficiently prescriptive to be translated into assessable process steps and outputs. The assessment summary column explains the basis for each inclusion or exclusion decision in line with the eligibility criteria described in this section.

Table 1. Benchmarking partner assessment and selection.

Reference	Assessment summary	Decision	Key sources (as used in thesis)
PMI	Provides estimating and scheduling process guidance (inputs, tools & techniques, outputs) across practice standards and PMBOK family.	Included	PMI (2006); PMI (2011); PMI (2017); PMI (2019a); PMI (2019b)
ISO	Provides project management guidance, but does not provide sufficient stepwise guidance for developing cost and schedule estimates.	Excluded	ISO (2018); ISO (2021)
PRINCE2	Explains overall process flow, especially planning, but does not provide detailed estimating methods for cost and schedule.	Excluded	Office of Government Commerce (2009)
AACE	Provides detailed technical guidance on estimate classification, maturity, estimating methods, and risk integration for cost and schedule.	Included	AACE (2010a); AACE (2020a); AACE (2020c); AACE (2022); AACE (2024)
NASA	Provides systematic steps for cost and schedule estimating, including integration logic through JCL.	Included	NASA (2015); NASA (2020)
GAO	Provides detailed best practices for cost and schedule estimating and emphasizes credibility, traceability, and integration with schedule impacts.	Included	GAO (2015); GAO (2020)
IPMA	Emphasizes competence baseline rather than stepwise procedures for cost and schedule estimating.	Excluded	IPMA (2015)

Synthesis procedure

Framework development applies a structured synthesis logic: process steps are extracted from each benchmarking partner, harmonized to reconcile overlapping concepts and terminology, and consolidated by sorting and combining all processes into two aligned end to end completed processes: a completed cost estimating process and a completed schedule estimating process. Equivalent steps are merged under normalized labels, while essential control mechanisms (e.g., input maturity gates, assumptions documentation, quality checks, and review/approval) are retained as distinct steps.

RESULTS AND DISCUSSION

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 developed through benchmarking synthesis. It then explains how the consolidated steps were converted into an auditable maturity and gap assessment instrument. Finally, it summarizes 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 operationalization 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 emphasizes that credibility depends on structural integrity, including coding consistency, sound logic relationships, traceability across schedule levels, and systematic quality checks (GAO, 2015). 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. 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 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:

1. 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.
2. 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.
3. 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.
4. 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.
5. 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 summarizes 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. 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. Thus, 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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