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

Developing A Project Management Maturity Model to Enhance Execution Performance in Solar EPC Projects: A Case Study of an Engineering, Procurement, and Construction (EPC) Company

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Keywords:
Project Management Maturity; Crawford Maturity Model; Solar EPC; Mixed-Methods; PMBOK; Project Execution Delay.

Abstract
PT SEP (Solar Energy Project, a disguised company name) is an Engineering, Procurement, and Construction (EPC) company specializing in solar energy projects in Indonesia. This study assessed the company's current level of project management maturity and developed a tailored Project Management Maturity Model to improve project execution performance. A mixed-methods approach was employed, consisting of qualitative semi-structured interviews with five key informants to explore the underlying causes of project delays and a quantitative questionnaire administered to twenty respondents to measure maturity across seven PMBOK knowledge areas using Crawford's (2014) Project Management Maturity Model. The questionnaire demonstrated excellent internal consistency, with a Cronbach's alpha value of 0.939. The qualitative analysis generated seven knowledge-area themes and identified five interconnected root causes of project delays: the absence of integrated pre-project planning, reactive and fragmented procurement processes, experience-dependent scheduling practices, informal communication structures, and the lack of organizational learning mechanisms. Although the questionnaire results positioned the company at Level 4 (mean = 3.86), triangulation with interview findings revealed a systematic inflation of self-assessed maturity by one to two Crawford levels, indicating that the company's actual operational maturity was closer to the upper boundary of Level 2. Specifically, five of the seven knowledge areas were assessed at Level 2, while only two areas, namely Quality and Procurement, reached Level 3. Based on these findings, five integrated business solutions were developed: an Integrated Project Management Plan template, a procurement lead-time integration framework, a parametric scheduling database, a communication management plan template, and a lessons-learned database supported by a competency development framework. The findings demonstrate that single-method maturity assessments tend to overestimate organizational maturity, whereas mixed-methods triangulation provides a more accurate and actionable maturity profile for EPC contractors in emerging markets.

INTRODUCTION

The global transition toward net-zero emissions has positioned solar power as one of Indonesia's most strategic renewable energy assets. Solar energy is widely recognized as one of the most promising renewable energy sources for meeting increasing global energy demand, although its deployment continues to face technical, economic, and institutional challenges (Kabir et al., 2018). Indonesia has committed to achieving net-zero emissions by 2060 or earlier, with an interim target of reducing greenhouse gas emissions by 29% below business-as-usual levels by 2030, or up to 41% with international support (International Energy Agency

[IEA], 2022). Despite having favorable equatorial solar irradiation conditions, Indonesia's installed solar photovoltaic (PV) capacity reached only 0.3 GW by 2022, remaining significantly lower than that of regional neighbors such as Vietnam (18.5 GW), Thailand (3.1 GW), and Malaysia (1.9 GW) (International Renewable Energy Agency [IRENA], 2023). Bridging this gap requires not only supportive policy frameworks but also the operational capabilities of Engineering, Procurement, and Construction (EPC) contractors to deliver solar projects reliably, efficiently, and at scale (Mehta, 2024; Parhamfar et al., 2026; Vishwakarma & Suyambu, 2024).

PT SEP is an established solar EPC contractor in Indonesia that has completed more than 200 projects with a total installed capacity of 185 MW and received the Best EPC Company award at the 2023 Indonesia Best Electricity Award (IBEA). However, between 2021 and 2024, the company experienced recurring project execution delays ranging from 20% to 40% beyond the planned schedules. A preliminary review of project records indicated that these delays were not primarily caused by engineering limitations but by systemic weaknesses in project management practices, particularly in integrated planning, procurement coordination, schedule control, cross-functional communication, and organizational learning (Kerzner, 2017; Mahgoub & Zhang, 2026; Sultana, 2026). As project volumes continue to increase, reliance on ad hoc coordination and individual experience becomes a structural vulnerability rather than a competitive advantage (Kerzner, 2018).

Project management maturity models provide a structured approach for diagnosing organizational capabilities and identifying areas requiring improvement. Crawford's (2014) Project Management Maturity Model (PMMM) evaluates organizational capability across five maturity levels—Initial, Structured, Institutionalized, Managed, and Optimizing—which are mapped to the Project Management Knowledge Areas defined in the Project Management Body of Knowledge (PMBOK) (PMI, 2017). Previous research has demonstrated that maturity is multidimensional, with different Knowledge Areas often existing at different maturity levels within the same organization, and that higher levels of maturity are associated with improved project performance (Albrecht & Spang, 2014). Studies examining construction delays in emerging markets have consistently identified inadequate planning integration and weak coordination as among the most significant structural causes of schedule overruns (Al-Hazim et al., 2017).

The novelty of this research lies in its mixed-methods approach to assessing project management maturity within the solar EPC context. This study extends beyond conventional survey-based maturity assessments by incorporating qualitative interviews with key informants, enabling triangulation to identify potential biases and systematic inflation in self-assessment results. Furthermore, this research develops a tailored Project Management Maturity Model supported by five integrated business solutions based on Root Cause Analysis and VRIO evaluation of organizational resources.

Although previous studies have provided valuable insights into project management maturity and performance improvement, several research gaps remain. Most maturity assessments rely on a single methodological approach, typically self-administered questionnaires, which are vulnerable to self-assessment bias, particularly when respondents have an interest in presenting favorable organizational conditions (Mullaly, 2014). Limited research has combined qualitative and quantitative approaches to validate maturity assessments in the context of solar EPC contractors operating in emerging markets. Therefore, this research aimed to assess the project management maturity level of PT SEP using a mixed-methods approach and to develop a tailored Project Management Maturity Model to improve project execution performance. The objectives of this research were: (1) to identify the key factors contributing to project execution delays in solar EPC projects at PT SEP; (2) to assess the current level of project management maturity across seven PMBOK Knowledge Areas; and (3) to develop a Project Management Maturity Model and implementation plan to enhance project execution performance.

RESEARCH METHOD

Research Design

This research employed a mixed-methods case study design by combining qualitative and quantitative data collection within a single organization, PT SEP. A mixed-methods approach was selected because the research required complementary evidence to examine project execution delays and project management maturity. The qualitative component explored the underlying causes of delays through practitioners' experiences, while the quantitative component measured maturity levels across each Knowledge Area within the organization. The two data sources were collected in parallel, analyzed separately, and integrated during interpretation to generate comprehensive findings.

Qualitative Data Collection and Analysis

The qualitative component consisted of semi-structured interviews with five key informants selected through purposive sampling, representing the principal functions engaged in project delivery: a Project Manager, an Engineering Lead, a Supply Chain Staff member, a Logistics Officer, and a Site Construction Lead. The interview questions were structured according to the five maturity levels of Crawford's (2014) PMMM. Interviews were audio-recorded, transcribed, and analyzed using Creswell's (2012) six-step qualitative data analysis procedure: preparing and organizing the data, coding the database, forming themes, representing findings, interpreting meaning, and validating accuracy. Codes were developed inductively and grouped into categories aligned with the seven PMBOK Knowledge Areas; categories recurring across multiple respondents were elevated to themes. For each Knowledge Area, the interview evidence was scored against the Crawford (2014) maturity descriptors and aggregated to an achieved maturity level. Member checking was conducted by sharing the identified themes with two respondents to confirm accuracy, satisfying the communicative validation criterion.

Quantitative Data Collection and Analysis

The quantitative component consisted of a structured questionnaire administered to twenty respondents across five functional divisions (Project Management, Site Construction, Engineering, Supply Chain, and Logistics). The instrument comprised 32 items mapped to the seven PMBOK Knowledge Areas, each rated on a five-point scale corresponding to the five Crawford maturity levels. Instrument reliability was assessed using Cronbach's coefficient alpha, following the interpretation guidelines of George and Mallery (2003); the instrument achieved an overall alpha of 0.939, indicating excellent internal consistency. Responses were analyzed using descriptive statistics (mean and standard deviation) at both the item level and the Knowledge Area level, with mean scores mapped to the nearest Crawford level. The qualitative and quantitative findings were then triangulated Knowledge-Area-by-Knowledge-Area, classifying each result as convergent, divergent, or complementary. To translate the diagnostic findings into actionable solutions, the analysis applied Root Cause Analysis using a Cause Map methodology (Ammerman, 1998) and evaluated the company's organizational resources using the VRIO framework (Barney & Hesterly, 2015).

Table 1. Instrument Reliability (Cronbach's Alpha) by PMBOK Knowledge Area (N = 20)

Knowledge Area (Subscale)	Items	Cronbach's α	Internal Consistency
Communication Management	3	0.864	Good
Schedule Management	5	0.815	Good
Resource Management	6	0.805	Good
Stakeholder Management	4	0.798	Acceptable
Integration Management	7	0.777	Acceptable
Procurement Management	3	0.769	Acceptable
Quality Management	3	0.691	Questionable
Overall Instrument	32	0.939	Excellent

Source: Primary data, 2026 (computed following George & Mallery, 2003).

RESULT AND DISCUSSION

Qualitative Findings: Seven Knowledge-Area Themes and the Root Causes of Delay

The thematic analysis of the five interview transcripts, conducted following Creswell's (2012) six-step procedure, yielded seven themes — one for each PMBOK Knowledge Area assessed in this study. Five of these themes correspond to interconnected root causes of project execution delay, while the remaining two (Quality and Stakeholder Management) characterize areas of relative strength that nonetheless reveal maturity ceilings under closer probing. The five delay-related themes are not independent but form a mutually reinforcing system in which incomplete planning creates the conditions for reactive procurement, informal communication prevents timely upstream notifications, experience-based scheduling fails to anticipate delivery failures, and the absence of organizational learning prevents systematic correction over time.

First, the absence of integrated pre-project planning (Integration Management, Level 2).

Engineering, procurement, and construction sub-plans are developed separately using Microsoft Project and Excel but are not consolidated into a single governing Project Management Plan before mobilization. The Project Manager confirmed that while initiation templates exist, the integration of sub-plans into a single document does not happen consistently, and the Supply Chain respondent acknowledged that initiation documentation is high-level and incomplete at the procurement-planning detail level.

Second, reactive procurement and fragmented material delivery (Procurement Management, Level 3 overall; planning weak, vendor management strong).

Purchase orders are issued without a procurement timeline integrated with the construction schedule. The Logistics Officer quantified the consequence: one project generated 23 separate material deliveries (SPPB) against an ideal benchmark of two to three, representing a more than sevenfold multiplication of logistics cost attributable to upstream procurement fragmentation. Notably, the supply chain teams annually updated qualified-vendor register (Daftar Rekanan Terpilih) represents a strong Level 3–4 vendor-management capability that coexists with weak procurement planning, placing the Knowledge Area at Level 3 overall.

Third, experience-dependent schedule management (Schedule Management, Level 2).

Project schedules are built primarily on individual judgment rather than structured activity-dependency analysis or validated historical data. Although a company-wide daily, weekly, and monthly S-curve monitoring system has reached Level 3, recovery actions when delays are detected remain reactive overtime, additional manpower, or quality trade-offs. The Site Construction Lead corroborated that on-site progress monitoring is standardized and consistently applied (Level 3), while recovery planning remains experience-dependent (Level 2).

Fourth, informal cross-functional and client communication (Communication Management, Level 2).

Information flow is not governed by a written Communication Management Plan. A concrete manifestation was an incident in which a delivery arrived at a project site on a Saturday but could not be unloaded until Monday due to uncoordinated site access, incurring a two-day standby cost that was entirely avoidable.

Fifth, the absence of systematic organizational learning (Integration — Manage Project Knowledge, Level 2).

A formal post-project review process previously existed but has been discontinued. Lessons learned are not systematically captured, documented, or shared, so knowledge retention depends on individual memory, and the same delay patterns recur across projects. This finding is consistent with Assaf and Al-Hejji (2006) and Sambasivan and Soon (2007), who identified poor planning integration as the most structurally impactful cause of EPC schedule overruns.

Sixth, document-centric quality assurance with situational trade-offs (Quality Management, Level 3).

Unlike the five delay-driving themes, Quality Management emerged as a relative strength. The engineering team operates a formalized, document-centric quality process governed by the Master Delivery List (MDL), in which every deliverable passes through a defined submit–review–revise–approve cycle until full client approval, and an As-Built Drawing is compiled at closure. This satisfies Crawford's (2014) Level 3 criterion of standardized, consistently applied processes. However, the interviews revealed a structural ceiling preventing Level 4: when a project falls behind schedule, quality can be deliberately reduced as a recovery lever, indicating that quality assurance is not yet protected by the quantitative control characteristic of higher maturity.

Seventh, deadline-driven but informally managed stakeholder engagement (Stakeholder Management, Level 2).

Stakeholder engagement is shaped by a powerful regulatory constraint: rooftop and on-grid solar projects must be completed within six months, after which the government considers the project abandoned and permits must be reapplied for. The project manager aligns client, team, and management expectations at kick-off, but this engagement depends on individual initiative rather than a documented Stakeholder Engagement Plan. The client's scope is fixed only in broad outline at the outset, and client-initiated changes during construction are absorbed without a formal change-governance protocol, placing operational maturity at Level 2 despite a high self-reported survey score.

Figure 1 summarizes the interview-derived maturity profile across all seven PMBOK Knowledge Areas, expressed as the achieved Crawford level. Five of the seven Knowledge Areas — Integration, Stakeholder, Schedule, Communication, and Resource Management — sit at Level 2 (Structured Process), while Quality and Procurement Management reach Level 3 (Institutionalized). This profile reflects the lived operational reality described by practitioners, in contrast to the substantially higher self-reported scores presented in the following section.

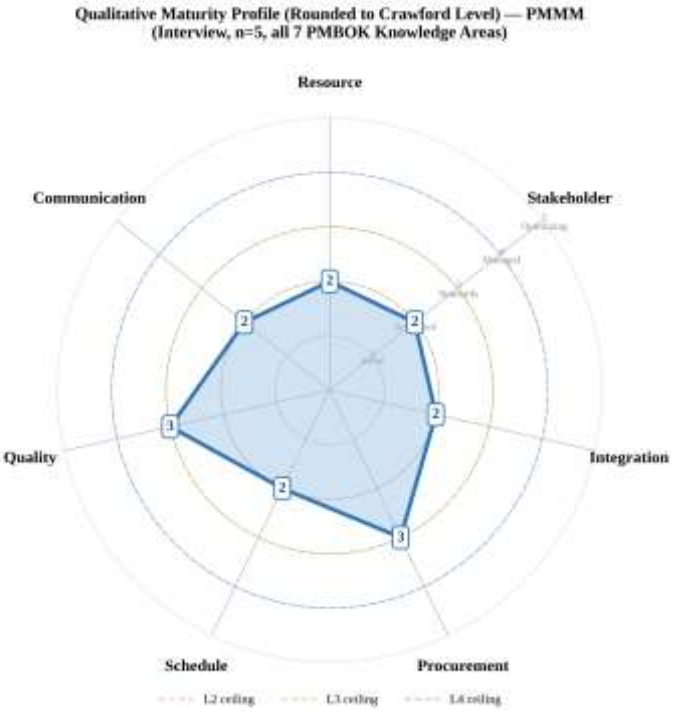

Figure 1. Qualitative Maturity Profile — Interview-Derived Crawford Levels by PMBOK Knowledge Area
Source: Researcher’s qualitative analysis, 2026.

Quantitative Findings: Maturity Assessment by Knowledge Area

The structured questionnaire of twenty respondents demonstrated excellent internal consistency, with an overall Cronbach’s alpha of 0.939; at the subscale level, six of the seven Knowledge Areas fell within the acceptable-to-good range (0.769–0.864) and Quality recorded a lower but tolerable value (0.691) attributable to its small item count. The instrument produced a grand mean of 3.86 across all 32 items, placing PT SEP at Crawford Level 4 (Managed Process) on aggregate, with all seven Knowledge Areas falling within the Level 4 band (3.50–4.49). Table 2 presents the maturity score for each Knowledge Area, and Figure 2 visualizes the same profile against the Level 2, 3, and 4 ceilings. Quality Management (mean = 4.27) sits at the upper edge and approaches Level 5, while Resource Management and Communication Management (both 3.68) anchor the lower edge. The narrow 0.59-point band suggests respondents perceive the organization as broadly competent across all areas.

Table 2. Quantitative Maturity Score by PMBOK Knowledge Area (n = 20)

Knowledge Area	Mean	SD	Crawford Maturity Level (Questionnaire)
Quality Management	4.27	0.61	Level 4 — Managed (approaching L5)
Stakeholder Management	3.96	0.76	Level 4 — Managed
Integration Management	3.96	0.63	Level 4 — Managed
Procurement Management	3.87	0.71	Level 4 — Managed
Schedule Management	3.76	0.79	Level 4 — Managed
Resource Management	3.68	0.73	Level 4 — Managed
Communication Management	3.68	0.90	Level 4 — Managed
Grand Mean	3.86	0.57	Level 4 — Managed Process

Source: Primary data, 2026.

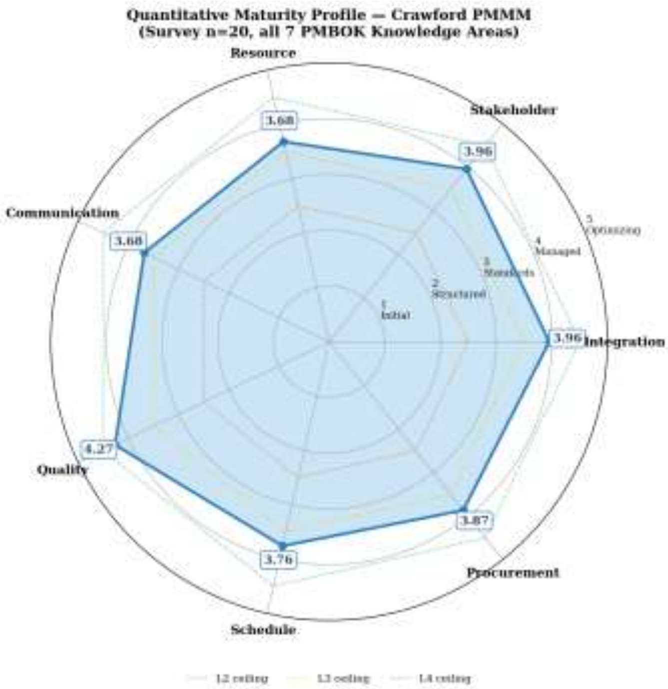

Figure 2. Quantitative Maturity Radar Profile — Seven PMBOK Knowledge Areas
Source: Primary data, 2026.

Integration of Qualitative and Quantitative Findings

The central analytical task of the mixed-methods design is to integrate the qualitative and quantitative findings into a single, defensible maturity assessment. To allow a direct, like-for-like comparison, both strands are expressed in whole Crawford levels. Table 3 presents the triangulation across all seven Knowledge Areas, and Figure 3 visualizes the comparison. The most important result is a systematic and unidirectional divergence: the questionnaire places all seven Knowledge Areas at Level 4, whereas the interviews place five at Level 2 and two at Level 3. This produces a uniform two-level gap for the five weaker areas (Integration, Stakeholder, Schedule, Communication, and Resource) and a one-level gap for the two stronger areas (Procurement and Quality). Rather than treating this divergence as a weakness, this study interprets it as analytically informative: the regularity of the structure that a constant two-level gap for the weaker areas and a constant one-level gap for the stronger ones shows that the discrepancy is systematic rather than random, revealing the self-assessment inflation effect that single-method assessments cannot detect.

Table 3. Mixed-Methods Triangulation Matrix — Seven PMBOK Knowledge Areas (Crawford Levels)

Knowledge Area	Qualitative (Interview)	Quantitative (Survey)	Integration Pattern
Integration	Sub-plans not consolidated; learning discontinued — Level 2	Level 4 (3.96)	Divergent (2-level gap): survey detects documentation; interview reveals integration is not operational
Stakeholder	Client alignment only at kick-off; no engagement plan — Level 2	Level 4 (3.96)	Divergent (2-level gap): survey rates a relative strength; interview shows engagement is individual-dependent
Schedule	Monitoring institutionalized; planning intuition-based — Level 2	Level 4 (3.76)	Divergent in absolute level (2-level gap) but convergent in within-KA ranking (monitoring above planning)
Communication	No formal plan; informal handovers — Level 2	Level 4 (3.68)	Divergent in level (2-level gap) but convergent in ranking: both flag communication as relatively weak
Resource	No structured training/competency infrastructure — Level 2	Level 4 (3.68)	Divergent in level (2-level gap) but convergent at item level: Q15 (training, 3.40) is the lowest item
Procurement	Weak planning offset by strong vendor management — Level 3	Level 4 (3.87)	Partially convergent (1-level gap): both detect the planning-vs-vendor bifurcation
Quality	Standardized MDL document-control cycle; QC traded off under pressure — Level 3	Level 4 (4.27)	Convergent (1-level gap): both rank Quality strongest; interview adds a Level 4 ceiling the survey misses

Source: Researcher's integration synthesis, 2026.

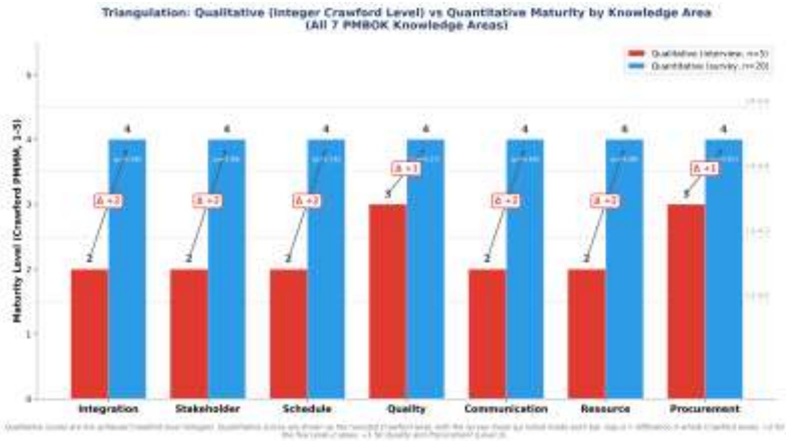

Figure 3. Triangulation Comparison — Qualitative (Integer Crawford Level) versus Quantitative by Knowledge Area
Source: Primary data, 2026.

Root Cause Analysis

Tracing the observed delay symptoms back to their systemic origins, the Root Cause Analysis (Figure 4) maps six observable incident categories through their immediate operational causes to their underlying root causes. The analysis confirms that the five delay-related themes are not isolated problems but manifestations of a small set of structural deficiencies: the absence of a Communication Management Plan, reactive procurement planning, the absence of an Integrated Project Management Plan, the absence of systematic organizational learning, and the absence of a parametric schedule database. Each root cause maps directly to one or more affected PMBOK Knowledge Areas, providing the basis for targeted intervention rather than symptom-level correction.

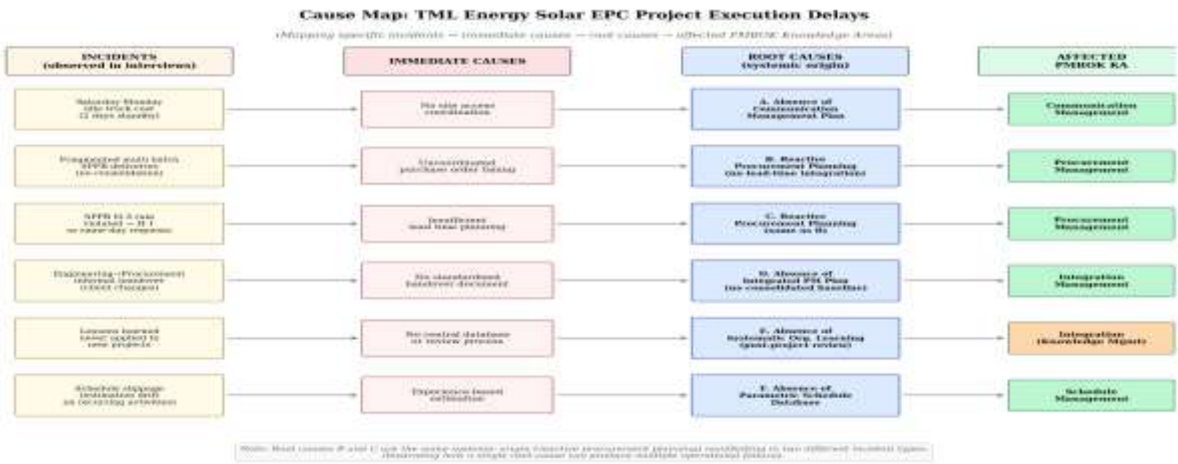

Figure 4. Cause Map — PT SEP Project Execution Delays
Source: Researcher's root cause analysis, 2026.

Discussion and Theoretical Implications

The findings contribute to the project management maturity literature in three ways. First, the study provides empirical evidence for the self-assessment inflation effect in an emerging-market EPC context, quantifying a systematic gap of one to two Crawford levels between survey and interview methods, two levels for the five weaker Knowledge Areas and one level for the two stronger ones. This supports the growing body of evidence that single-method maturity assessments overstate organizational maturity, particularly when surveys are administered to staff with a vested interest in favorable ratings (Mullaly, 2014; Albrecht & Spang, 2014). Second, the study supports Andersen and Jessen's (2003) multidimensional conception of maturity: within a single organization, the divergence between the strongest areas (Quality and Procurement at Level 3 operationally) and the weakest (the five Level 2 areas, with organizational learning the lowest) demonstrates that aggregate single-score measures obscure operationally important variation. Third, the integrated findings extend Crawford's (2014) framework by suggesting that organizations crossing from Level 2 to Level 3 face distinct structural barriers from the institutionalization of integration, communication, and learning that differ qualitatively from the barriers encountered when moving from Level 3 to Level 4.

Proposed Project Management Maturity Model and Business Solutions

Based on the root cause analysis and the VRIO evaluation of organizational resources, five integrated business solutions were developed. Each addresses a specific root cause while leveraging an existing organizational strength, so that improvement builds on systems practitioners already trust rather than replacing them. First, an Integrated Project Management Plan (IPMP) template consolidates engineering, procurement, and construction sub-plans into a single baseline with a four-way sign-off before mobilization, addressing the absence of integrated planning. Second, a procurement lead-time integration framework extends the existing Daftar Rekanan Terpilih by converting vendor performance history into lead-time-integrated procurement timelines, addressing fragmented delivery. Third, a parametric schedule database replaces experience-based estimation with structured historical data and three-point (PERT) estimation. Fourth, a communication management plan template with a stakeholder RACI matrix formalizes internal and client communication. Fifth, a lessons-learned database combined with a competency development framework reinstates the discontinued post-project review process and builds organizational learning capability.

Table 4. Proposed Business Solutions, Target Root Causes, and Expected Maturity Impact

Solution	Description	Affected PMBOK KA	Existing Strength Leveraged	Expected Maturity Impact
S1 — Integrated PM Plan (IPMP)	Single integrated baseline consolidating engineering, procurement, and construction sub-plans, with a four-way sign-off before mobilization	Integration	Existing initiation templates (MS Project, Excel)	Q2 3.80→4.30; Integration L2→L3
S2 — Procurement Lead-Time Framework	Extends the Daftar Rekanan Terpilih into a lead-time-integrated procurement schedule with delivery consolidation	Procurement; Schedule	Daftar Rekanan Terpilih (qualified-vendor register)	Q30 4.00→4.30; SPPB trips 23→3

Solution	Description	Affected PMBOK KA	Existing Strength Leveraged	Expected Maturity Impact
S3 — Parametric Schedule Database	Replaces intuition-based estimation with historical-data three-point (PERT) estimation	Schedule	Three-tier S-curve monitoring system	Q27 3.50→4.00; Schedule planning L2→L3
S4 — Communication Management Plan	Stakeholder RACI matrix, channel–frequency–format matrix, and site-access (H-2) protocol	Communication	Established daily reporting culture	Q18 3.65→4.30; Communication L2→L3
S5 — Lessons Learned DB + Competency Framework	Reinstates the discontinued post-project review and links roles to DJK/NABCEP/PMP certifications	Integration (Knowledge); Resource	Prior (discontinued) post-project review practice	Q15 3.40→4.00; Learning L2→L3

Source: Researcher's solution design, 2026.

Solution 1 — Integrated Project Management Plan (IPMP)

The IPMP template addresses the absence of integrated pre-project planning (Root Cause D). It consolidates the separate engineering, procurement, and construction sub-plans into a single governing baseline that must obtain a four-way sign-off — from the Engineering, Procurement, Construction, and Project-Manager functions — before a project may mobilize, thereby converting fragmented planning into an enforced organizational standard. Table 5 presents an extract of the template; the complete fillable template is available as a standalone deliverable.

Table 5. Solution 1 — Integrated Project Management Plan (IPMP) Template (extract)
Source: Researcher's solution design, 2026.

No	Section	Purpose & Content to Be Completed
1	Document Control	Basic project identity & document control: project name/code, client, location, system type, capacity (kWp), PIC for each function, document number, revision, status.
3	Project Overview	Project objective, client business need, key milestone targets (start, mechanical completion, commissioning, handover), and critical success criteria.
4	Scope & Key Deliverables	Clear separation between In Scope, Out of Scope, and Key Deliverables to be produced up to handover.
5	Project Governance & Roles	Core project role owners & key decision-makers (Sponsor, PM, Engineering, Procurement, Logistics, Site, QA/QC, HSE, PMO, Client Rep).
5.1	RACI Matrix	Mapping of responsibilities (R/A/C/I) for critical activities: final DED, drawing approval, PO release, shipment readiness, site readiness, mobilization approval, commissioning approval.
6	Stakeholder Alignment	List of key stakeholders (internal & external), primary interests, communication frequency, and communication owner.
7	Integrated Master Schedule	Cross-functional activity sequence from kickoff to handover; must display the key dependency: engineering approval → procurement release → delivery → site readiness → mobilization → installation → commissioning.

8	Engineering Plan	Engineering deliverables that are prerequisites for procurement & site execution: target issue date, approval/review date, dependency, and status.
9	Procurement Lead-Time Integration Plan	Critical items, vendors, lead times, PO dates, on-site requirements, ETA, batch delivery strategy, and PIC — focused on materials/services affecting installation start.
10	Logistics & Delivery Coordination Plan	Dispatch origin, dispatch strategy, number of shipments, transport mode, unloading & storage needs + Site Delivery Condition Check (access, unloading area, receiving rep, storage, permit).
11	Construction & Site Mobilization Plan	Mobilization date, working hours, team composition, critical equipment, daily coordination rhythm, and site execution sequence — final only when critical materials & site access are confirmed.
12	Resource Plan	Human resource needs & their source (internal/subcontractor), timing of need, and minimum competency (competency check).
13	Communication Management Summary	Information to be communicated, sender, recipient, frequency, format, & escalation trigger — minimum: engineering approval, procurement status, shipment readiness, site readiness, daily progress, weekly review.
14	Assumptions, Constraints & Dependencies	Clear separation between Assumptions, Constraints, and Dependencies that affect the project execution path.
15	Execution Watchlist (Risk Summary)	List of risks/dependencies that must be monitored: risk item, owner, trigger, mitigation, escalation.
16	Change & Issue Control Summary	A brief policy statement on how issues are logged and how changes are processed.
17	Quality & HSE Summary	Quality control points and HSE control points that must exist before & during execution.
18	Mobilization Readiness Checklist (Go/No-Go)	Checklist to be closed before mobilization (status YES/NO/N/A); if NO, mobilization is held; concluded with a decision: GO / HOLD / NO-GO.
19	Project Monitoring & Reporting Summary	List of core reports & their owners: daily site report, weekly integrated progress report, procurement tracker, delivery tracker, issue/change log.
20	Closing & Lessons Learned	Project closure deliverables (closure requirements) & lessons learned review agenda (lessons learned review plan).
21	Joint Approval & Sign-Off	Signatures of all core parties; if e-signature/email approval is used, the mechanism is recorded in comments/appendix.
22	Appendix / Supporting Attachments	Optional: drawing list, procurement tracker, delivery tracker, daily report format, HSE checklist, lessons learned form.

Solution 2 — Procurement Lead-Time Integration Framework

This framework addresses reactive and fragmented procurement (Root Causes B and C) by extending the company's existing Daftar Rekanan Terpilih into a planning instrument. Each material category is assigned a recorded lead time from historical SPPB data, from which order-by dates are back-calculated, and purchase orders are grouped into consolidated delivery batches. Figure 6 presents an extract showing the real solar-PV material categories used by the company.

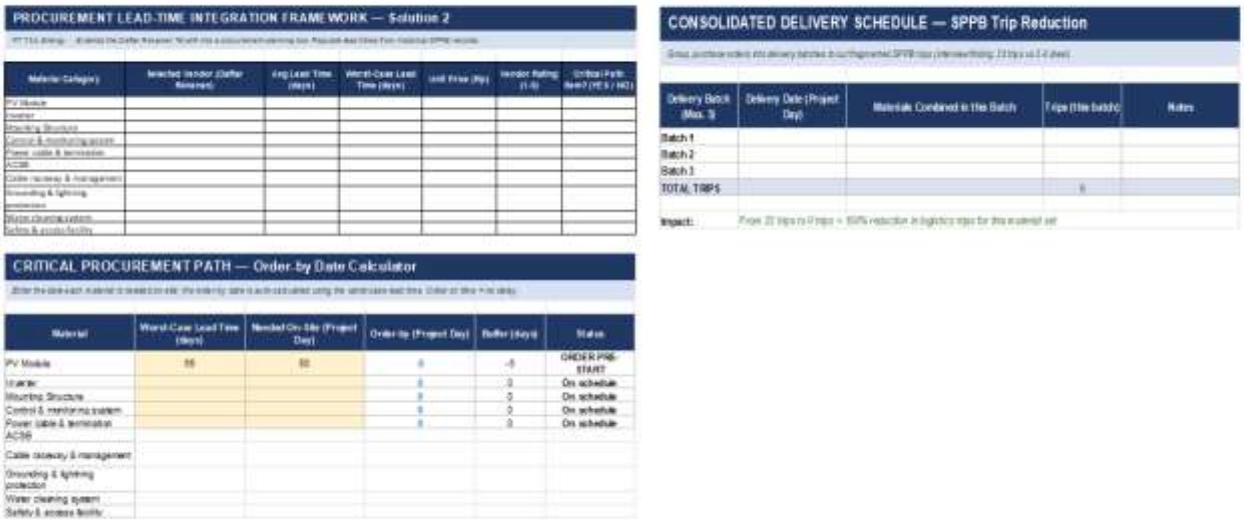

Figure 6. Solution 2 — Procurement Lead-Time Integration Framework (extract)
Source: Researcher’s solution design, 2026.

Solution 3 — Parametric Schedule Database

The parametric schedule database addresses experience-dependent scheduling (Root Cause F). It records historical activity durations normalized per 100 kWp and applies three-point (PERT) estimation, TE = (O + 4M + P) / 6, to produce defensible, data-based duration estimates that replace individual intuition. Figure 7 presents an extract populated with the fifteen solar-PV installation activities and their normalized durations.

Figure 7. Solution 3 — Parametric Schedule Database with PERT Estimation (extract)
Source: Researcher’s solution design, 2026.

Solution 4 — Communication Management Plan

The Communication Management Plan addresses informal cross-functional and client communication (Root Cause A). It comprises a stakeholder RACI matrix, a channel–frequency–format matrix, a communication log, and two mandatory protocols, including the

H-2 site-access rule that prevents the idle-truck standby documented in the interviews. Figure 8 presents an extract of the template.

Figure 8. Solution 4 — Communication Management Plan Template with RACI Matrix (extract)
Source: Researcher's solution design, 2026.

Solution 5 — Lessons Learned Database and Competency Development Framework

This solution addresses the absence of systematic organizational learning (Root Cause E) and the weakness in resource competency development. It reinstates the discontinued post-project review through a structured database that aggregates recurring issues by Knowledge Area, and pairs it with a competency matrix linking each role to required certifications (DJK, NABCEP, PMP). Figure 9 presents an extract of the template.

Figure 9. Solution 5 — Lessons Learned Database and Competency Framework (extract)
Source: Researcher's solution design, 2026.

Implementation Roadmap

These solutions are designed for phased implementation over an 18-month roadmap with three Crawford maturity checkpoints (at Months 3, 12, and 18). If implemented consistently, the qualitative assessment is projected to advance from Level 2 toward Level 3, while the survey grand mean is projected to rise from 3.86 toward 4.21 — together representing a substantive maturity transition rather than a documentation-only improvement. The VRIO analysis confirmed that PT SEP already possesses the building blocks for Level 3 maturity; the challenge is integration rather than capability creation.

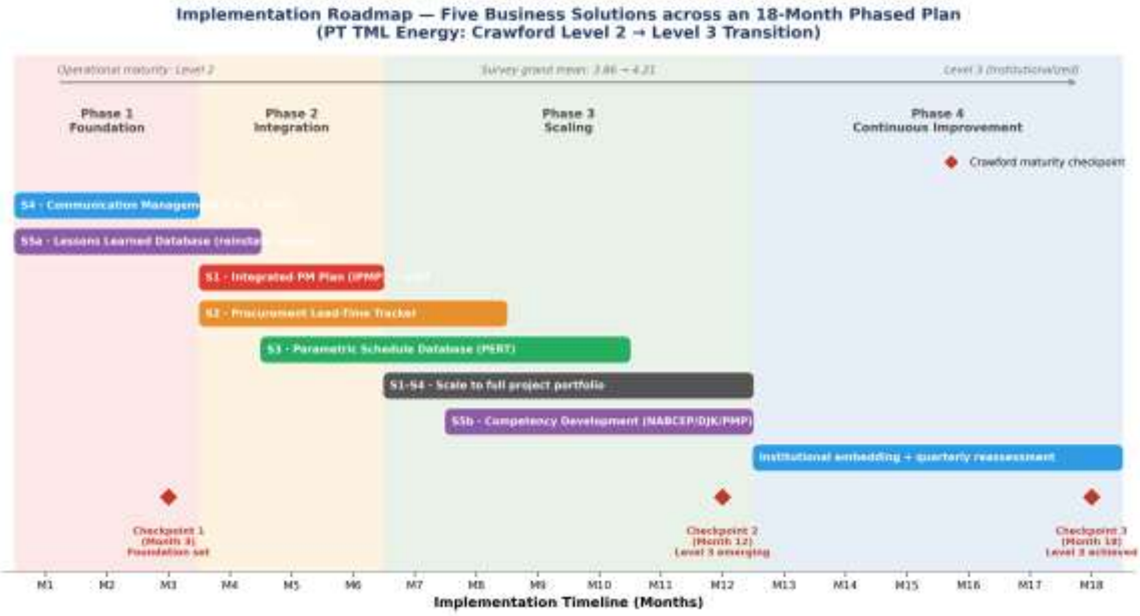

Figure 10. Implementation Roadmap — Five Business Solutions across an 18-Month Phased Plan

Source: Researcher's implementation plan, 2026.

CONCLUSION

The passage has been proofread and refined for grammar, punctuation, academic style, and terminology consistency within the context of "Developing A Project Management Maturity Model to Enhance Execution Performance in Solar EPC Projects: A Case Study of an Engineering, Procurement, and Construction (EPC) Company." Technical terms related to project management maturity, EPC, and organizational assessment have been adjusted to align with standard American English usage. The paragraph form and meaning have been retained.

This study assessed the project management maturity level of PT SEP, a solar EPC contractor in Indonesia, and developed a tailored maturity model to address recurring project execution delays ranging from 20% to 40%. The mixed-methods analysis generated seven Knowledge-Area themes and identified five interconnected root causes of delays: the absence of integrated pre-project planning, reactive and fragmented procurement processes, experience-dependent scheduling, informal communication practices, and the lack of organizational learning mechanisms. These factors collectively characterized the organization as operating at Level 2 (Structured Process), where individual competence often substituted for established institutional systems. Although the questionnaire results alone positioned the company at Level 4, with excellent reliability (Cronbach's $\alpha = 0.939$), triangulation with interview findings revealed a systematic inflation of self-assessed maturity by one to two levels. The results indicated that the company's operational maturity was more accurately positioned at the upper boundary of Level 2, with five Knowledge Areas assessed at Level 2 and two Knowledge Areas reaching Level 3.

The principal contribution of this research was both methodological and practical. The study demonstrated that single-method maturity assessments tend to overestimate organizational maturity, whereas mixed-methods triangulation provides a more accurate and actionable maturity profile, particularly for EPC contractors in emerging markets. The five proposed business solutions, anchored in the company's existing capabilities and structured within an 18-month implementation roadmap, provided a practical pathway for advancing from Level 2 toward Level 3 maturity. Future research should validate the proposed model through longitudinal implementation studies, expand the mixed-methods approach across multiple solar EPC contractors to establish industry-level benchmarks, and further investigate the effects of self-assessment inflation in other emerging-market construction contexts. The main limitation of this study was its single-organization case design, which restricted statistical generalizability; therefore, the findings were intended to provide analytical rather than statistical generalization.

REFERENCES

Albrecht, J. C., & Spang, K. (2014). Linking the benefits of project management maturity to project complexity. *International Journal of Managing Projects in Business, 7*(2), 285–301.

Al-Hazim, N., Salem, Z. A., & Ahmad, H. (2017). Delay and cost overrun in infrastructure projects in Jordan. *Procedia Engineering, 182*, 18–24.

Barney, J. B., & Hesterly, W. S. (2015). *Strategic management and competitive advantage: Concepts and cases* (5th ed.). Pearson.

Crawford, J. K. (2014). *Project management maturity model* (3rd ed.). Auerbach Publications / CRC Press.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Pearson.

International Energy Agency [IEA]. (2022). *An energy sector roadmap to net zero emissions in Indonesia*. IEA Publications.

International Renewable Energy Agency [IRENA]. (2023). *Renewable capacity statistics 2023*. IRENA Publications.

Kabir, E., Kumar, P., Kumar, S., Adelodun, A. A., & Kim, K.-H. (2018). Solar energy: Potential and future prospects. *Renewable and Sustainable Energy Reviews, 82*, 894–900. https://doi.org/10.1016/j.rser.2017.09.094

Kerzner, H. (2017). *Project management: A systems approach to planning, scheduling, and controlling* (12th ed.). John Wiley & Sons.

Kerzner, H. (2018). *Project management best practices: Achieving global excellence*. John Wiley & Sons.

Mahgoub, A., & Zhang, Y. (2026). Integrating technology, collaboration, and sustainability in supply chains and project management: A comprehensive review of efficiency, resilience, and strategic alignment. *Journal of Project Management, 11*(1).

Mehta, J. (2024). Design one, build many (D1BM) concepts in engineering, procurement, and construction (EPC). *Abu Dhabi International Petroleum Exhibition and Conference*, D021S060R005.

Mullaly, M. (2014). If maturity is the answer, then exactly what was the question? *International Journal of Managing Projects in Business, 7*(2), 169–185.

Parhamfar, M., Moazzami, M., & Taheri, M. (2026). *Enhancing large-scale solar power plant*

performance through an EPC framework: A 10 MW grid-connected case study.
Project Management Institute [PMI]. (2017). *A guide to the project management body of knowledge (PMBOK guide)* (6th ed.). Project Management Institute.
Sultana, R. (2026). A framework for cross-functional collaboration: Aligning project coordination, QA engineering, and client communication to maximize project performance. *American Journal of Scholarly Research and Innovation, 5*(01), 327–381.
Tigas Adrian, & Yudoko, G. (2023). *Proposed project management improvement plan for PT Wasterindo Manufaktur Indonesia using Crawford project management maturity model* [Master's thesis, Institut Teknologi Bandung]. ITB Library Digital Collection.
Vishwakarma, P. K., & Suyambu, M. R. (2024). An analysis of Engineering, Procurement and Construction (EPC)-contracts based on renewable energy. *Proceedings of the November.*