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RESEARCH ARTICLE

Performance assessment in construction project management: Insights from an engineering, procurement, and construction management case study

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Abstract

The construction industry underpins global development but continues to face challenges such as complexity, fragmentation, and stakeholder misalignment. While project management is critical to improving outcomes, limited empirical research explores how standardized knowledge areas affect success in complex real-world contexts. Despite the widespread adoption of project management practices, their integrated application within Engineering, Procurement, and Construction Management (EPCM) environments remains underexplored. This study addresses this gap by examining how standardized PMBOK® knowledge areas influence project performance in a large-scale EPCM project. This case study evaluates the twelve Project Management Body of Knowledge (PMBOK®) areas, including the Construction Extension, within a major EPCM project—an international airport delivered under a government-funded contract. A mixed-methods design was employed, integrating document analysis, field observation, and interviews with senior personnel. Performance was assessed using a multi-criteria framework based on the Simple Multi-Attribute Rating Technique (SMART), examining both the importance and execution of each knowledge area. Results show cost, schedule, and quality management as the strongest contributors to success, while risk, stakeholder, and procurement management underperformed relative to their strategic importance. Integration and Health, Safety, Security, and Environmental (HSSE) management were moderately effective, supported by Enterprise Resource Planning (ERP) systems and structured planning. The study underscores the critical role of experienced managers in coordinating interdependencies and driving performance. Contributions include a structured evaluation framework, practitioner-focused recommendations to strengthen underperforming areas, and insights for aligning project management practices with performance objectives in complex project environments.

1. Introduction

The construction industry plays a pivotal role in the global economy, contributing substantially to Gross Domestic Product (GDP) and employment across the world [1]. Yet, despite its strategic importance, construction projects continue to face persistent challenges—including cost overruns, delays, and quality deficiencies—that undermine performance

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and stakeholder confidence [2]. The growing complexity and fragmentation of modern construction environments demand more rigorous approaches to project planning and execution.

In this context, project success is recognized as a multifaceted and evolving concept. Traditionally measured through the "iron triangle" of time, cost, and quality, success now increasingly includes stakeholder satisfaction, sustainability, and strategic alignment [3, 4]. However, the absence of universally accepted success criteria complicates performance evaluation across diverse project contexts. Scholars argue that the definition of success must be project-specific, shaped by stakeholder expectations, external constraints, and the project's lifecycle phase [5, 6].

To address these complexities, standardized project management (PM) frameworks such as the *Project Management Body of Knowledge (PMBOK®) Guide* [7], *PRINCE2* [8], and *ISO 21500* [9] have been developed to guide systematic planning, execution, and control. These frameworks introduce structured knowledge areas and process groups aimed at improving decision-making, risk management, and stakeholder communication throughout the project lifecycle. In the construction sector, aligning these standards with organizational strategies and real-time project data has shown promise in enhancing performance outcomes.

Performance measurement frameworks further support these standards by offering tools to evaluate project effectiveness. These frameworks incorporate not only technical KPIs—such as cost, schedule, and quality—but also broader dimensions like innovation, sustainability, and stakeholder engagement [4, 10]. Despite their utility, the application of such frameworks remains inconsistent, and few studies provide an integrated analysis of how PM knowledge areas influence real-world project outcomes.

Despite the prevalence of project management frameworks, their integrated application in Engineering, Procurement, and Construction Management (EPCM) settings remains underexplored. This study aims to address this gap by exploring the application of PMBOK® knowledge areas in an EPCM setting. The EPCM delivery model—where the contractor manages design, procurement, and execution of project delivery on behalf of the client—offers a unique context for evaluating the integrated impact of all twelve knowledge areas [11]. Using a case study of an international airport project, the research employs a mixed-methods design, combining document review, semi-structured interviews, and direct observation.

The study pursues three objectives: (i) to identify the PM knowledge areas most critical to performance in an EPCM environment; (ii) to develop a multi-criteria performance measurement framework tailored to EPCM projects; and (iii) to propose evidence-based strategies for improving project delivery.

While limited to a single case study, this research provides a nuanced understanding of how PM knowledge areas interact in an EPCM environment. The findings offer both theoretical and practical contributions by providing a structured assessment framework and proposing evidence-based strategies for improving project delivery. They also provide actionable recommendations for aligning PM practices with performance goals in complex, high-stakes construction environments [10, 12-15].

This study further contributes novelty on several levels. It provides one of the few comprehensive empirical assessments that delve into all twelve PMBOK® knowledge areas and their Construction Extension within a single EPCM project. While prior research has often focused on individual knowledge areas, specific contract types (e.g., EPC only, cost plus fee, lump sum turn key, or design–build), or narrow performance dimensions, this study adopts a holistic, integrative approach linking technical, organizational, and governance perspectives. Methodologically, it combines mixed methods and the Simple Multi-Attribute Rating Technique (SMART) to evaluate both the relative importance and actual performance of knowledge areas—an approach rarely applied in EPCM contexts. Theoretically, it

positions project performance within the dual lens of organizational learning and governance, advancing the understanding of how structured management frameworks operate under complex, multi-stakeholder conditions. Collectively, these features differentiate the study and extend existing knowledge on standardized project management application in EPCM delivery contracts.

2. Research Methodology

The study follows a structured four-step research workflow to evaluate project management performance in EPCM projects, comprising literature review, data collection, data analysis, and data interpretation, with each step building on the previous to ensure a comprehensive assessment (Fig. 1).

While the workflow details these four steps, the methodology can also be framed in two main phases: Phase 1, Literature Review and Framework Development, corresponds to the first step, and Phase 2, Case Study Application and Empirical Investigation, encompasses data collection, analysis, and interpretation, thus providing both a detailed and conceptually structured overview of the research process.

2.1. Phase 1: Literature review and framework development

The first phase involved an extensive literature review, including a detailed examination of the Project Management Body of Knowledge (PMBOK® Guide) [16] and its Construction Extension [17]. This review identified the twelve project management knowledge areas and examined their documented influence on project outcomes. The literature emphasizes that performance in project-based organizations is shaped not only by technical competence but also by the underlying organizational learning and governance mechanisms that determine how knowledge is created, shared, and institutionalized across project functions [18, 19]. Within this theoretical lens, performance assessment becomes a reflection of how effectively organizations learn from experience and translate that learning into structured managerial practices, decision-making routines and approaches as well as accountability systems.

Recent studies further reinforce these relationships. Shang et al. [20] demonstrated that cross-organizational control and knowledge sharing significantly influence project performance in whole-process engineering consulting environments, highlighting governance as a core performance driver. Similarly, Jiao and Bu [21] found that organizational learning capabilities enhance resilience and adaptability in construction projects, linking learning mechanisms to sustained project success.

Building on these perspectives, as the EPCM delivery model can be viewed as a governance structure encompassing complete lifeline with wide perspective of processes, assessing project management performance on the evaluated EPCM project captured both process efficiency and learning-based outcomes.

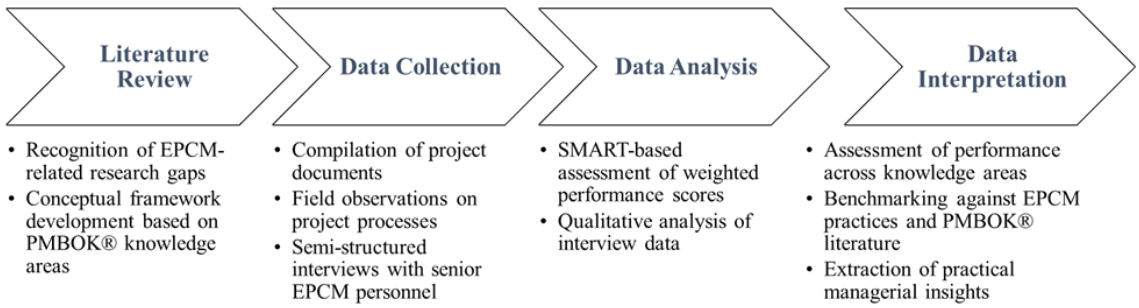

Fig. 1. Overview of the research methodology

This study adopts such a framework by means of mapping the twelve PMBOK® knowledge areas against key performance dimensions and acknowledging that each knowledge area contributes to the organization's collective capability to manage complexity, uncertainty, and interdependence.

To operationalize this conceptual foundation, the study employed the SMART, a decision-making method used to assess both the relative importance and actual performance of each knowledge area. SMART enables weighted scoring and comparative analysis through score normalization and composite ranking, supporting systematic performance evaluation across diverse management domains. The outcomes of this phase informed the study's conceptual framework and guided the design of data collection and analysis in subsequent phases.

2.2. Phase 2: Case study application and empirical investigation

The second phase consisted of an in-depth case study of an EPCM project delivered by a global contractor under a government-funded contract. The EPCM model, wherein the contractor manages design, procurement, and construction while representing the project owner, provided a robust platform for examining the integration of all twelve PMBOK® knowledge areas in a multi-stakeholder environment.

A case study methodology [22-24] was used to explore how and why project management practices influenced project outcomes. Triangulation was achieved through three complementary data collection methods:

• *Document Review:* Over 100 internal project documents were analyzed, including contracts, management plans (e.g., scope, schedule, cost, quality, Health, Safety, Security, and Environmental – HSSE), project charters, technical reports, monthly progress reports, risk registers, KPIs, procurement logs, stakeholder records, and financial statements encompassing a wide spectrum of project documentation categorized across the twelve PMBOK® knowledge areas. These provided both strategic insight and operational detail across all knowledge areas. The primary objective was to evaluate how these knowledge areas were formally defined, planned, and monitored throughout the project lifecycle. This documentary analysis validated data collected from other sources and revealed latent gaps between intended project procedures and their implementation.

• *Direct Field Observations:* The researcher conducted on-site observations over a six-month period, focusing on key phases of the EPCM project lifecycle, including design coordination, procurement planning, and construction execution. Observations were performed across various locations such as site offices, construction zones, coordination meetings, and quality inspections. Field notes were systematically recorded using a standardized observation protocol, which included time stamps, location, activity descriptions, and notable interactions among team members. These field observations also enabled researcher to facilitate the establishment of a contextual framework, thereby offering a crucial link between the documented plans and the actual execution in the real world. Moreover, direct field observations captured the cultural communication barriers, reliance on informal practices, and the uneven adoption of digital tools. These issues were anticipated to be overlooked through interviews or pure document analysis. This triangulation approach enriched the overall findings and ensured a more holistic understanding of project management performance within the EPCM context.

• *Semi-Structured Interviews:* Semi-structured interviews were a critical component of the data collection process, designed to capture the lived experiences, perceptions, and professional judgments of senior personnel directly involved in the management and execution of the EPCM project. A total of four interviews were conducted with high-level stakeholders occupying strategic roles within the project organization: Project Manager, Planning Manager, Program Director, and Quality Manager. The selection of participants

was deliberate, with the objective of ensuring both role diversity and depth of experience. Each interview was conducted in a private setting, with a duration ranging from 60 to 90 minutes, to encourage the provision of spontaneous responses. These interviews explored the application, effectiveness, and perceived impact of the twelve PMBOK® knowledge areas. Interview questions (Appendix A) assessed familiarity with PMBOK® standards, success of implementation, and the perceived contribution of each knowledge area to overall project performance. The interview protocol was developed based on the conceptual framework derived from the PMBOK® Guide and its Construction Extension. Key themes explored during the interviews included:

- The perceived importance of each of the twelve PMBOK® knowledge areas in the context of the project,
- The effectiveness of their implementation, including enablers and barriers encountered,
- Reflections on how interdependencies among knowledge areas affected overall performance,
- Evaluations of tools and systems used,
- Leadership and team-related factors contributing to success or underperformance,
- Recommendations for future improvement, including training needs, system enhancements, and stakeholder engagement strategies.

This integrated approach enriched the empirical depth of the study and addressed a notable gap in the literature concerning EPCM project environments. All participants provided informed consent, and the study adhered to institutional ethical guidelines for interviewee research. Respondent profiles are summarized in Table 1.

Although the sample consisted of four participants, all held senior leadership roles directly responsible for project management, planning, coordination, execution and delivery. This elite sampling approach was intentionally adopted to capture high-level strategic insights and organizational perspectives unavailable to lower-tier staff. Such purposive selection is consistent with qualitative case study methodology, where participants are chosen for the depth and relevance of their expertise rather than statistical representativeness [22]. Moreover, data saturation was achieved as no new themes emerged after the fourth interview, indicating adequacy for the exploratory nature of this study.

3. Results and Discussion

3.1. Performance evaluation

This study employed the SMART to evaluate the relative contribution of each PMBOK® knowledge area to overall project success. First, experts assigned importance scores to each knowledge area based on their perceived criticality in achieving project objectives. These individual scores were gathered through structured interviews aligned with key questions from the project's conceptual framework. A joint consensus session was then conducted to finalize and rank the general performance of the knowledge areas. The resulting importance scores were normalized into weights summing to one. Separately, each knowledge area's performance in the case study project was independently assessed. Finally, a weighted score for each knowledge area was calculated by multiplying its importance weight by its performance score, yielding a composite measure that reflects both significance and execution quality. Normalization was applied using Equation (1):

Table 1. Interviewees' profiles

No	Age	Education	Position	Experience	PMP Certificate
1	55	Civil Engineering (BS) Master of Business Administration (MA)	Project Manager	31	Yes
2	47	Industrial Engineering (BS)	Planning Manager	24	No
3	64	Civil Engineering (BS & MSc)	Program Director	40	Yes
4	50	Electrical Engineering (BS) Computer and Control Engineering (MSc)	Quality Manager	27	No

$$w_i = \frac{I_i}{\sum I_i} \quad (1)$$

where I_i is the raw importance score for knowledge area i. Weighted performance was then calculated as (Eq. 2):

$$S_i = w_i \times P_i \quad (2)$$

where Pi represents the performance score. For example, for Cost Management, with w=0.098 and P=95, the weighted score equals 9.268. This enables comparative analysis across all knowledge areas.

As detailed in Table 2, the overall project performance score was 83.22, indicating a high level of success. Scores were normalized between 0 and 100. A total project score above 80 denotes high performance according to SMART normalization thresholds used in previous studies. Accordingly, the overall score of 83.22 reflects a strong level of project success and demonstrates close alignment between the importance and execution of the twelve knowledge areas. The most influential knowledge areas were cost and quality management, while scope, risk, and stakeholder management underperformed relative to their importance. Notably, the weighted analysis revealed that procurement, risk, and stakeholder management merit greater focus to enhance future project outcomes.

Fig. 2 visualizes the weighted contribution of each PMBOK® knowledge area using a color-coded classification: green for Core Contributors, yellow for Supporting Contributors, and orange for Marginal Contributors. The chart clearly illustrates that Cost, Quality, and Schedule Management achieved the highest performance and strategic alignment, reinforcing their classification as Core Contributors. In contrast, Risk, Stakeholder, and Procurement Management appear at the lower end of the spectrum, underscoring their underperformance and categorization as Marginal Contributors. Supporting Contributors such as Integration, HSSE, and Communication Management performed moderately well but present opportunities for improvement through enhanced coordination and system integration. This graphical summary reinforces the prioritization logic behind the proposed improvement strategies.

Core Contributors: Cost Management, Schedule Management, and Quality Management emerged as the strongest contributors to project success, each with weighted scores exceeding 8.7. Cost management (9.268) was a key success factor, with strong performance in planning, forecasting, and control. The use of Earned Value Management and proactive stakeholder engagement facilitated financial discipline despite project delays.

Table 2. Performance assessment of the project

Knowledge Area	Importance Score (I)	Importance Weight (w)	Performance Score (P)	Weighted Score (S)
Integration Management	90	0.088	80	7.024
Scope Management	90	0.088	70	6.146
Schedule Management	90	0.088	100	8.780
Cost Management	100	0.098	95	9.268
Quality Management	100	0.098	90	8.780
Resource Management	75	0.073	90	6.585
Communication Management	80	0.078	85	6.634
Risk Management	85	0.083	70	5.805
Procurement Management	70	0.068	75	5.122
Stakeholder Management	85	0.083	70	5.805
HSSE Management	80	0.078	90	7.024
Financial Management	80	0.078	80	6.244
Overall	1025	1.000		83.220

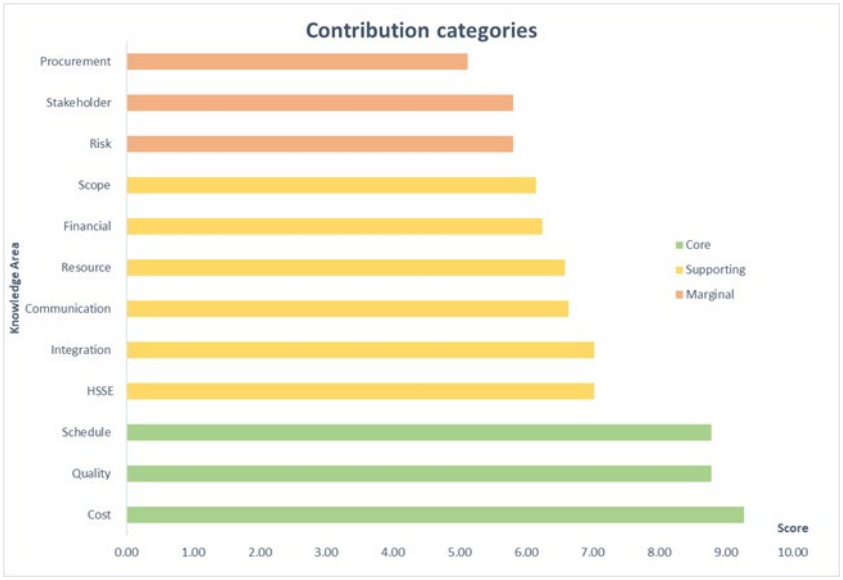

Fig. 2. Contribution categories of PMBOK® knowledge areas

The interdependence of cost with schedule, quality, and stakeholder management was evident, confirming that successful cost outcomes rely on integrated cross-functional coordination [25, 26]. As one interviewee emphasized: *"Earned value management is simple, yet a very practical and effective technique for ascertaining the variances and performances of the project numerically so that the team can make meaningful forecast and also identify appropriate corrective actions*." These findings align with recent studies emphasizing the strategic role of value engineering in enhancing cost efficiency and procurement outcomes in construction projects [27]. The integration of value engineering principles supports proactive planning and supplier coordination, which are critical in EPCM environments.

Schedule management (8.780) benefited from robust integration of master and sub-package plans and use of WBS structures. However, delays emerged due to complex contractor interfaces and unrealistic planning that failed to consider actual site conditions. Effective schedule management demands realistic sequencing, buffer inclusion, and ongoing reviews, and is strongly tied to scope and stakeholder management [28, 29].

Quality management (8.780) was supported by comprehensive assurance systems integrated with procurement and scope management. However, limited engagement with sub-package contractors affected consistent quality standards. A quality manager noted: *"Quality should be a focus from the beginning of the project through to final completion."* Early contractor involvement and continuous monitoring were identified as vital for minimizing rework and ensuring quality consistency [2, 30].

Supporting Contributors: Integration Management and HSSE Management, both with weighted scores of 7.024, demonstrated strong functional performance. Integration efforts were generally effective due to senior management support and structured execution plans [31]. Enterprise Resource Planning (ERP) systems helped enhance cross-departmental collaboration and real-time decision-making [32, 33], although Owner-driven changes occasionally disrupted coordination, reinforcing the need for stronger stakeholder alignment [34, 35]. HSSE implementation aligned with regulatory frameworks and best practices [36, 37], although a weak safety culture—partly due to Owner disengagement—limited its impact.

Communication Management, Resource Management, Financial Management, and Scope Management scored between 6.1 and 6.6, indicating

moderate effectiveness. Communication (6.634) was deemed critical for transparency and alignment. While structured processes existed, inconsistent implementation across teams reduced their effectiveness. This supports findings on the importance of consistent communication in multicultural and multidisciplinary environments [38, 39].

Resource management (6.585) featured effective allocation, dynamic staffing, and regular tracking. However, the absence of a formal training policy limited performance improvements. Literature strongly links workforce development to better safety, productivity, and financial performance [19, 40]. Similarly, one interviewee stated: *"Building an experienced and skilled management team and workforce was the cornerstone of success in the project."*

Financial management (6.244) contributed to project stability through strategic planning, accurate tracking, and timely payments. The role of this area has been highlighted by the interviewees as: *"Financial management is a strategic and well-coordinated process focused on value creation and cash flow maximization. Project management achieve these goals by communicating business plans to interdisciplinary teams, motivating them to achieve the objectives defined therein, and making data driven decisions."* Digital tools enhanced transparency, while continuous projection reviews supported alignment with project goals [41, 42].

Scope management (6.146), although contractually defined, was hindered by unclear communication, scope creep, and frequent design changes. The lack of robust change control mechanisms limited tracking and led to delays, reflecting literature that emphasizes the importance of early risk identification, clear scope definition, and disciplined change control [43-45].

Marginal Contributors: Risk Management, Stakeholder Management, and Procurement Management were the weakest-performing areas, each scoring below 6.0. Risk management (5.805) was limited by insufficient early identification, unclear ownership, and weak mitigation strategies. These gaps were exacerbated by the limited influence over the Owner, confirming that effective risk culture and clearly assigned responsibilities are essential in managing construction uncertainty [46, 47]. Additionally, the reactive nature of risk handling—particularly the absence of structured pre-construction risk workshops or contingency planning—meant that risks often became visible only after affecting cost and schedule outcomes. Without a designated risk champion or consistent oversight mechanism, mitigation strategies lacked follow-through and cross-functional alignment.

Stakeholder management (5.805) began early but suffered from inconsistent follow-through and limited influence over the Owner. The lack of regular, tailored communication reduced stakeholder satisfaction and contributed to cost and schedule issues. As highlighted in prior studies, top management support and good communication are fundamental to successful stakeholder relations [48, 49]. In this case, the EPCM contractor's limited contractual leverage impeded its ability to manage upward expectations or influence Owner-driven changes. Moreover, the absence of a structured stakeholder engagement plan—beyond initial mapping—meant emerging concerns were not adequately addressed as the project evolved, diminishing trust and alignment among key actors.

Procurement management (5.122) underperformed due to critical interdependencies, notably weak engineering support. Coordination between EPCM contractors and subcontractors was critical but often insufficient, emphasizing the need for appropriate contract selection and robust supplier evaluation [50, 51]. Delayed technical inputs disrupted tendering schedules and led to reactive procurement decisions, which in turn affected quality and schedule performance. Furthermore, lack of integrated planning between procurement and project controls created bottlenecks in vendor onboarding, material logistics, and interface management. Procurement's close links to schedule and integration further magnified its downstream impacts, underscoring the importance of early engagement, modular procurement strategies, and continuous monitoring of vendor performance.

Overall, the findings underscore the interconnectedness of the twelve knowledge areas, emphasizing that balanced, well-integrated management supported by leadership commitment, clear processes, and robust systems is crucial for construction project success. Areas such as integration, cost, schedule, and quality management showed strong practices, while gaps in risk, stakeholder, and communication management highlight opportunities for improvement. This holistic understanding can inform both theory and practice in construction project management.

3.2. Interdependencies among knowledge areas

As detailed in Table 3, the case study revealed that performance outcomes across PMBOK® knowledge areas were strongly shaped by interdependencies rather than isolated domain execution. For instance, Scope Management decisions directly affected Schedule, Cost, and Risk Management through scope changes and approval delays. Likewise, Procurement Management exerted a cascading influence on Quality, Resource, and Schedule performance, largely due to late vendor onboarding and engineering misalignments.

Table 3. Empirical interdependencies among knowledge areas

Influencing Knowledge Area	Impacted Knowledge Areas	Empirical Evidence
Integration Management	Communication, Schedule, Procurement, Resource, Stakeholder	ERP systems improved real-time tracking, but effectiveness dropped during low stakeholder engagement or fragmented communication.
Scope Management	Schedule, Cost, Risk	Frequent design changes and weak change control led to schedule slippage and unplanned costs. Risks were not re-assessed after scope adjustments.
Schedule Management	Cost, Risk, Integration	Delays triggered cost increases and contractual risks; poor synchronization across disciplines disrupted integration efforts.
Cost Management	Financial, Procurement, Stakeholder	Cost overruns stressed financial tracking, created payment issues, and strained owner relations.
Communication Management	Stakeholder, Integration, HSSE	Inconsistent information sharing led to unclear expectations, weak safety messaging, and fragmented coordination.
Risk Management	Cost, Schedule, Procurement, Financial	Weak early risk planning resulted in missed delays, material shortages, and budgeting gaps. Unclear ownership exacerbated the impact.
Procurement Management	Quality, Resource, Schedule, Cost	Late vendor onboarding and weak engineering support caused rework, quality lapses, and cascading cost-schedule disruptions.
HSSE Management	Stakeholder, Resource	Weak safety culture—partly due to Owner disengagement—limited contractor compliance and affected workforce morale and stability.
Financial Management	Cost, Procurement, Risk	Unanticipated tax and compliance issues delayed procurement payments; poor cash flow planning amplified cost volatility.

Integration Management emerged as a central enabler across domains, facilitated by ERP tools, though its effectiveness depended heavily on coordinated Stakeholder and Communication Management.

Risk Management demonstrated wide-ranging effects on Cost, Schedule, and Procurement performance but was undermined by weak early identification and unclear ownership of risks. Financial Management was closely linked to Cost, Procurement, and Risk domains, where inadequate forecasting and tax planning disrupted budget stability. HSSE Management, while generally strong, was constrained by limited Owner

engagement, reducing its influence on resource morale and stakeholder credibility.

These interconnections illustrate that underperformance in one area frequently propagated challenges in others, reinforcing the importance of system-level integration and proactive coordination and influence across all knowledge domains. Effective orchestration of these interdependencies requires not only technical alignment but also strategic leadership capable of harmonizing diverse project functions. As one interviewee aptly observed: "*If we consider the project as a work to be performed by an orchestra, the project manager is the conductor of this orchestra and the notes to be played are the works defined under knowledge areas.*"

The findings are consistent with megaproject literature [2, 19] which highlights systemic coordination and stakeholder alignment as recurring performance challenges. Recent reviews further emphasize the growing significance of governance structures, digital integration, and stakeholder dynamics in megaprojects [52]. Compared with EPC delivery models, EPCM projects exhibit greater dependence on governance and communication mechanisms due to their managerial, rather than contractual, authority. This distinction underscores that project success depends on governance effectiveness, collaboration, and leadership continuity—factors closely tied to organizational learning and communication quality.

These observations align with prior studies underscoring cross-domain effects and feedback mechanisms in project governance and performance systems [34, 46]. In complex project environments, knowledge areas influence one another through dynamic, bidirectional relationships. For example, Integration and Communication Management provide the structural coordination that links Cost, Schedule, and Quality performance, while Stakeholder and Risk Management exert reciprocal effects through feedback loops and decision-making alignment. The relationships illustrated in Fig. 3 capture these varying levels of interaction and influence, portraying the systemic nature of project performance within an EPCM governance structure.

Fig. 3 illustrates the interactions among the 12 PMBOK® knowledge areas, with each area represented as a labeled box. Color coding is used to indicate contribution levels: green for core; yellow for supporting; and orange for marginal contributors, offering a visual summary of both individual and interconnected project management strengths and weaknesses.

3.3. Critical success factors

Effective project management in construction is essential for mitigating risks, managing change, and achieving performance objectives in terms of time, cost, and quality [53]. Based on in-depth interviews with senior personnel involved in the EPCM project, several critical success factors (CSFs) were identified. These are grouped into three thematic areas for clarity, as shown in Fig. 4 and explained below.

3.3.1. Leadership & team competencies

- *Experienced Project Managers:* All interviewees emphasized that the project manager's leadership, communication skills, and strategic decision-making were central to success. Literature echoes this, highlighting project manager competence as a key determinant of project outcomes [18, 54].
- *Project Team Leader Characteristics:* Visionary leadership, trust-building, adaptability, and decisiveness under uncertainty are noted in literature as essential attributes [54].
- *Personnel Training & Education:* The lack of formal training programs was cited as a performance constraint by participants. The literature also stresses training and skill development as essential to productivity and safety [55, 56].

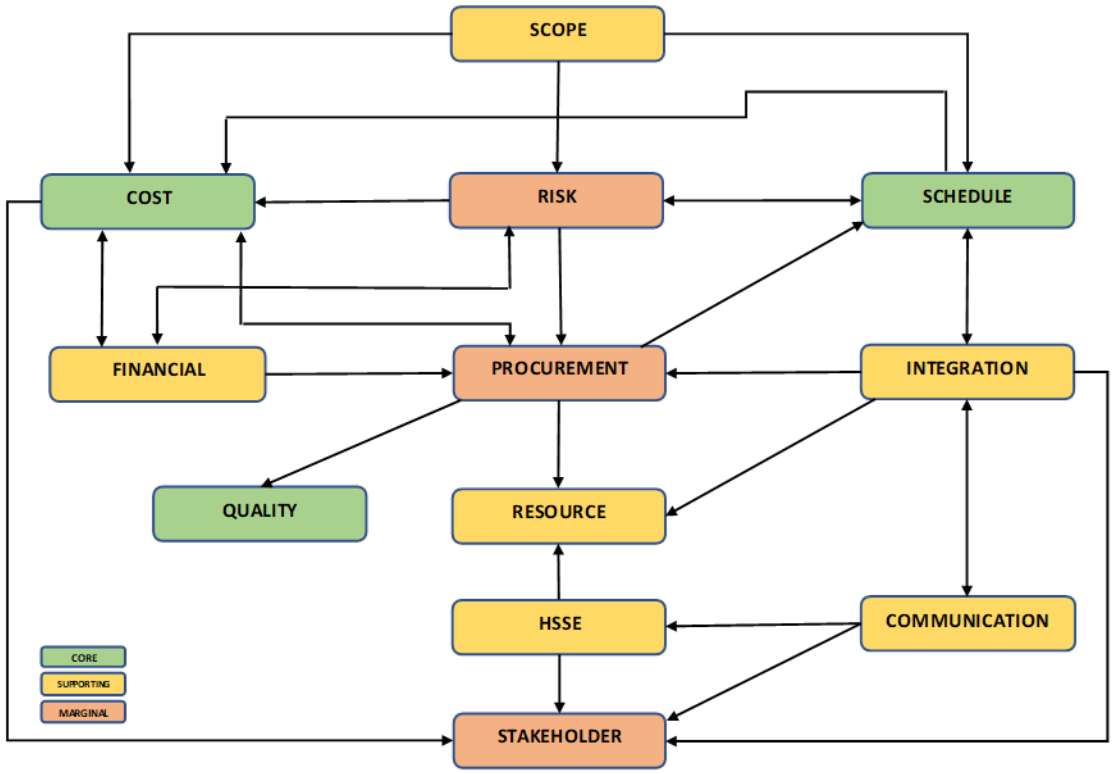

Fig. 3. Visual map of interdependencies among PMBOK® knowledge areas

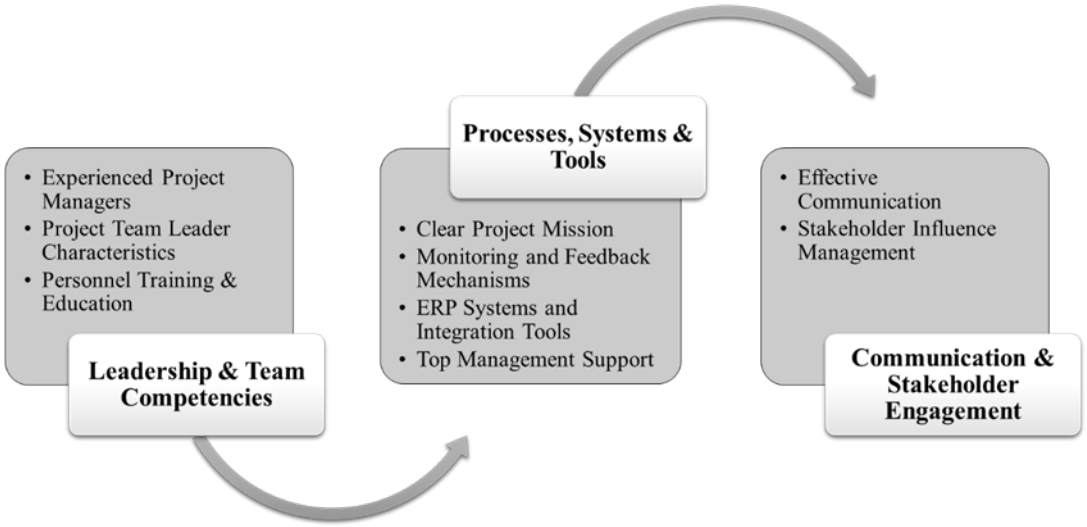

Fig. 4. CSFs in EPCM projects

3.3.2. Processes, systems & tools

• *Clear Project Mission:* A clearly defined and communicated project purpose helps align teams and reduce ambiguity [57]. Interviewees confirmed that mission clarity was beneficial during planning and early execution.

• *Monitoring and Feedback Mechanisms:* Participants cited ongoing reviews and real-time KPIs as key to performance tracking. Atkinson [3]

and Kerzner [10] similarly highlight the importance of continuous monitoring and control.

- *ERP Systems and Integration Tools:* Interviewees identified ERP platforms as critical enablers of integration, transparency, and timely decision-making. While underrepresented in older literature, recent work affirms the growing role of digital tools in project integration [32].
- *Top Management Support:* Strong leadership from executive sponsors was essential in securing resources and driving accountability, consistent with findings by Belassi & Tukel [54] and Crawford [58].

3.3.3. Communication & stakeholder engagement

- *Effective Communication:* Communication breakdowns were commonly cited as causes of misalignment and delay. Literature reinforces the importance of structured, consistent communication, especially in multicultural teams [38, 39].
- *Stakeholder Influence Management:* Limited control over Owner decisions was frequently mentioned as a barrier. Participants emphasized the need for early stakeholder mapping and sustained engagement—echoed in studies on stakeholder dynamics in construction [48, 59].

Overall, the integration of these factors supports successful project delivery aligned with organizational goals. Table 4 summarizes the lessons learned, recommended strategies to enhance the performance within each knowledge areas as well as indicating the responsible parties for those strategies. Some key recommendations being:

- Invest in stakeholder management protocols and influence strategies
- Integrate risk management early into planning with clear ownership
- Expand formal training programs for project teams and managers
- Standardize ERP and communication platforms to reduce fragmentation
- Embed flexible scheduling and feedback mechanisms into project lifecycles

The findings from this EPCM case study underscore a broader challenge in large-scale construction projects: technically robust practices—such as cost and schedule control—often fall short when systemic or organizational barriers go unaddressed. In environments characterized by fragmented authority and multi-stakeholder coordination, such as EPCM delivery models, project success hinges not only on procedural compliance with PM frameworks, but also on proactive stakeholder engagement, cross-disciplinary alignment, and empowered leadership. Specifically, underperformance in risk, stakeholder, and procurement management reflects deeper governance and integration issues that cannot be solved by procedural tools alone. Future guidance, training programs, and digital tool adoption should explicitly account for these system-level dynamics to support more resilient and adaptive project delivery strategies across diverse construction contexts.

4. Conclusion

The construction industry, while vital to global economic development, faces escalating complexity due to technological advancement, increasing project scale, and the diversification of stakeholder interests. In this evolving landscape, effective project management is essential for achieving performance objectives amid uncertainty and fragmentation.

This study examined how the twelve project management knowledge areas—defined by the PMBOK® Guide and its Construction Extension—contribute to project success, using a large-scale Engineering, Procurement, and Construction Management (EPCM) airport project as its empirical foundation.

The findings demonstrate a strong linkage between the systematic application of PMBOK® knowledge areas and improved project outcomes. Cost, schedule, quality, integration, and scope management emerged as the most influential drivers of success, each showing high execution quality and strategic alignment. ERP systems were

Table 4. Recommended strategies

Knowledge Area	Lessons Learned	Strategies	Responsible Parties
Integration Management	• Begin integration efforts early and continue throughout the project. • Engage stakeholders continuously to align objectives. • Foster cross-functional collaboration to anticipate and resolve issues.	• Clarify roles, objectives, and scope to prevent misalignment. • Assign accountable leaders and define ownership for integration and interfaces. • Track performance using KPIs and structured reporting. • Leverage digital tools for integration and interface coordination. • Capture lessons learned systematically to support continuous improvement.	Project Manager, Project Team, Discipline Managers, Quality Control and Assurance Team, Client, Interface Manager, Data Analysts, IT Department, Document Control Team
Scope Management	• Clearly define project boundaries to prevent scope creep. • Conduct regular scope reviews to stay aligned with goals. • Include all stakeholders in scope verification for shared understanding.	• Set clear, shared objectives and communicate them across the project. • Engage experienced stakeholders early in bid and scope development. • Estimate durations and milestones accurately to align planning and expectations. • Establish a unified project vision to promote alignment and reduce ambiguity.	Project Manager, Client, Project Team Members, Quality Control and Assurance Team, Designers, Legal Advisors, Planning Team, Contractors/Subcontractors
Schedule Management	• Develop detailed, realistic schedules from the outset. • Involve stakeholders in timeline planning for better accuracy. • Continuously monitor and adapt schedules to manage deviations.	• Include risk-based contingencies in schedule planning. • Appoint an experienced leader for the project controls function. • Clarify roles and align planning efforts across all stakeholders and disciplines. • Integrate interface management into the scheduling process.	Project Manager, Planning Team, Contractors/Subcontractors, Risk Management Team, Client
Cost Management	• Use monthly cost reports and quarterly forecasts for control. • Incorporate historical data and market trends into estimates. • Include contingencies and adjust budgets proactively.	• Raise cost awareness across the organization through training. • Assign clear ownership of budget line items based on the cost account structure. • Implement an integrated cost control system with regular management reviews.	Project Manager, Project Control Team, Finance Department, Senior Management, Human Resources Department, Budget Line-Item Owners, Training Providers, Client

Table 4. Cont'd

Quality Management	• Establish and communicate clear quality criteria. • Conduct regular audits and reviews. • Promote quality awareness through training and team-wide engagement.	• Strengthen QA/QC integration with engineering and procurement teams. • Define clear quality objectives within a structured quality management framework. • Introduce performance incentives to encourage high-quality outcomes.	Project Manager, Quality Control and Assurance Team, Engineering Department, Procurement Department, Quality Manager, Client, Designers, External Consultants
Resource Management	• Accurately assess manpower and equipment needs early. • Allocate resources based on skills and availability. • Encourage multi-skilled teams to adapt to shifting demands.	• Strengthen HR development with dedicated training and support policies. • Implement standardized onboarding aligned with project plans. • Address morale and turnover through root cause analysis and targeted actions.	Project Manager, Human Resources Department, Training Providers/Consultants, Corporate Management/Executive Leadership, Project Team Members, Client
Communication Management	• Define communication protocols early (channels, frequency, roles). • Foster two-way communication for early issue detection. • Keep documented records of major decisions and changes.	• Foster clear and consistent communication among all project participants. • Standardize key project documents and reports to improve information flow and understanding across teams.	Project Manager, Project Team Members, Clients, Contractors/Subcontractors, Designers, Regulatory Agencies/Government Authorities, Document Control Team, Communication Team
Risk Management	• Start and maintain a comprehensive risk register. • Engage experts and stakeholders in identifying diverse risks. • Prepare response strategies and review risks regularly.	• Develop clear risk management plans and mitigation procedures. • Assign a dedicated risk management owner responsible for oversight. • Train all stakeholders in risk awareness and management practices. • Incorporate bid contingencies based on thorough risk assessments.	Project Manager, Project Team Members, Safety and Quality Assurance Teams, Contractors/Subcontractors, Client, Senior Management, Regulatory Agencies, External Consultants/Advisors, Legal Counsel, Estimators/Quantity Surveyors, Procurement Team

Table 4. Cont'd

Procurement Management	• Prequalify suppliers for compliance with local standards. • Draft detailed contracts with clear expectations and penalties. • Maintain active communication and performance tracking with vendors.	• Establish long-term strategic agreements with adaptable key suppliers and subcontractors. • Streamline procurement processes with all stakeholders, including client involvement, to shorten project duration. • Develop procurement KPIs and conduct regular performance evaluations. • Ensure continuous engagement between procurement and project control for alignment with project activities.	Project Manager, Legal Counsel, Finance Department, Procurement Team, Project Control Team, Suppliers and Contractors
Stakeholder Management	• Identify key stakeholders early and map their influence. • Use transparent updates and negotiations to manage expectations. • Align stakeholder strategies with risk management plans.	• Ensure key stakeholders understand and support project control reports. • Develop stakeholder management plans early to address needs, influences, and interests throughout the project. • Explore incentives or bonuses from the Client to motivate EPCM contractors for better performance. • Identify key stakeholders clearly and engage them effectively to meet project requirements.	Project Manager, Project Control Team, Client, Communication Team, Regulatory Agencies, Local Residents, Project Team Members
HSSE Management	• Implement a certified HSSE system with independent audits. • Maintain continuous improvement in safety and emergency planning.	• Define and clearly communicate corporate safety objectives and HSE vision throughout the project. • Company leadership must actively support and promote a strong safety culture. • Develop a system to monitor leading safety indicators, identify gaps, and implement corrective actions promptly.	Senior Management, Project Manager, Health and Safety Department, Project Team, Client, Construction Personnel
Financial Management	• Practice regular financial reporting and cash flow management. • Reconcile budgets during project closure for performance assessment. • Keep stakeholders informed of financial strategies and risks.	• Allocate sufficient time at project start to fully understand the cost budget per account. • Thoroughly study local taxes and levies during project initiation. • Align cash flow calculations whenever the project's forecast budget is updated.	Project Manager, Finance Department, Procurement Department, Project Controls Department, Legal Team, Government Authorities, Consultants/Advisors

identified as critical enablers of cross-functional integration, real-time decision-making, and coherence across procurement, finance, and risk management activities. Moreover, the experience, adaptability, and leadership of project managers—especially in communication, coordination, and stakeholder engagement—proved instrumental in operationalizing management frameworks.

Beyond empirical validation, the study presents several practitioner-oriented recommendations. These include expanding digital integration tools, developing structured training and upskilling pathways, and prioritizing leadership development as a strategic project resource. Collectively, these interventions are not only operationally beneficial but essential for navigating volatility and complexity in modern construction environments.

For construction executives and project leaders, the results underscore the importance of adopting a systems-oriented approach to project management. While the strength of core knowledge areas like cost, schedule, and quality management reinforces the need for disciplined planning and control, the findings also point to opportunities for strengthening stakeholder and risk management through more integrative governance and proactive coordination. Rather than reiterating their underperformance, this study highlights the need to transform these domains into strategic enablers of collaboration, foresight, and organizational learning. To achieve this, managers should institutionalize stakeholder engagement protocols, implement risk governance frameworks that emphasize early identification and shared accountability, and deploy ERP and communication platforms that support timely, transparent decision-making. Developing leadership capacity and fostering a culture of continuous learning will further enhance adaptability and resilience in project environments. Though grounded in a single-case context, these insights offer scalable strategies for managing similarly complex construction initiatives.

Notwithstanding its contributions, this study is subject to several limitations. The single-case design, focused on a large-scale, government-funded airport delivered under an EPCM model, restricts generalizability to other contract types and governance arrangements. The EPCM structure, with its unique distribution of authority and interface dynamics, may yield different results compared to EPC, Design-Build, or CM-at-Risk models. Geographic and regulatory context also influence performance outcomes, and the limited interview sample—while targeted at senior stakeholders—may not reflect broader organizational experiences. Furthermore, the six-month data collection period during construction execution may not fully capture dynamics present in earlier planning or later operational stages.

Future research should build on this foundation through multi-case comparative studies across sectors, contract types, and regions to identify universal and context-dependent performance factors. Cross-regional analyses can help disentangle regulatory and cultural influences, while longitudinal studies can track how the importance of knowledge areas evolves across the project lifecycle. Further exploration of digital integration—through ERP systems, BIM platforms, and real-time dashboards—can clarify their role in enhancing coordination and accountability. Finally, deeper investigation into team dynamics, leadership behavior, and communication networks would enrich understanding of the “soft systems” that underpin successful project delivery in large-scale, multi-stakeholder environments

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Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Ethics Committee Permission

The authors received ethical approval for this study from the Boğaziçi University Human Research Ethics Committee for Science and Engineering (FMINAREK) on July 4, 2024 (registration number 2024/19).

Conflict of Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix A

Interview questions.

Project Integration Management
- Is there awareness about the need or importance of project integration management in your organization's and Project Management team? - Had the project got support from senior management during the project life cycle? - What is the level of application of integration management in your organization? - What are the key performance indicators used in your company? - What is the level of ERP application of Integration management in your organization? - What kind of tools were being used to manage different knowledge areas in your project? - Is there deficiency or overlaps in the processes, templates, tools, reports and procedures of project management? - Do the processes such as developing project plan, definition of project objectives and benefits, preparation of project organizational structure and developing of responsibility matrix performed in your project? - The main role of a PM is integration. Do you agree? What do you think is most important to integrate the project and why?
Project Scope Management
- Is there awareness about the need or importance of project scope management in your organization's and Project Management team? - What is the level of application of scope management in your organization? - Was there a formalized acceptance of the project in every project phase? - What systems/tools do you currently use to manage your project scope? - How is scope of a project developed and is formal customer approval obtained? - Does the organization have a standard way to gather and document business requirements? - What kind of documents do you provide to your customers for project scope management? - How is the scope document used? - Is there any effort of monitoring and controlling scope in your project? - Is there a defined process for project close out? - Are work results reviewed or inspected to ensure or verify that all scope of the work is complete?
Project Schedule Management
- Is there awareness about the importance of project schedule management in your organization's and project management team? - What is the level of application of schedule management in your organization? - What type of documents do you use for time management? - What type of tools (software / systems) do you use for time management? - At what level of detail is a typical project planned? - Is WBS used when defining the schedule activities? - Are relationships among activities identified and the activities sequenced? - Is there a process of schedule buy-in / sign-off that involves the key stakeholders? - Who ultimately approves the project schedules? - Do the project schedules clearly identify the deliverables? - Are baseline schedules maintained for the project? - Are schedules published and accessible to all team members easily? - Are project meetings held to review and status project schedules? - Are schedules ever revised based upon risk assessment? - Do you integrate your timing plans across functional departments / organization? - Do you require schedules from your suppliers? - Is progress of project activities continuously monitored and controlled?

Project Cost Management
- Is there awareness about the importance of project cost management in your organization? - What is the level of application of cost management in your organization? - What is included in the project budgets? - What systems / tools do you currently use to manage your project Cost? - Who prepares proposal cost estimates, are the assumptions for project cost documented? - Do budgets tie to WBS or to separate Cost Accounts? - Are all purchased items and subcontract costs coded to budget "buckets" and tracked? - How often are budgets re-forecasted and re-baselined? - Is project cost tracked against the baseline on regular update cycle? - What kind of documents do you provide to your customers for project cost control? - Does the estimate detail cost of labor, material, and machinery separately? - Does the budget show the amount allocated for resources by category? - Is the project cost tracked against the baseline on regular update cycle?
Project Quality Management
- Is there awareness about the importance of Project Quality Management in your organization's and project management team? - What is the level of application of quality management in your organization? - What systems / tools do you currently use to manage your project Quality? - Are quality goals methods and systems established for the project? - How are quality improvement goals communicated? - What kind of documents do you provide to your customers for project quality management? - Do you use customer satisfaction metrics? - How does project quality track to work quality? - Does your organization have quality management policies, procedures and guidelines? - Is quality audit done in your project? (a review to determine whether project activities comply with policies, processes, and quality requirements) - Does your project/organization inspect and control quality of subcontractors or suppliers to ensure compliance with quality requirement? - Is there quality department or employees specializing in quality management?
Project Resource Management
- Is there awareness about the importance of project resource management in your organization's and project management team? - What is the level of application of resource management in your organization? - Are your Project management practices and process consistent across divisions and functional groups? - Are roles of Project Managers, Planners, Budget Analysts, Team Members clearly defined? - Does the training provide lead to professional certification? - What are the required criteria of staff efficiency on your organization? - Is there any planning for acquisition and management of human resource? - Is project organization chart prepared for your project? - Does your organization have resource allocation policy that guides acquisition, use, and replacement decisions? - Is resource management performed in your project or organization? - Is computer software used in resource equipment planning, assignment and tracking? - Is there a procedure for resource equipment sharing among projects of the organization? - Is there any effort of tracking and monitoring performance of the project equipment, their productivity, maintenance cost, time worked etc.?

Project Communications Management
- Is there awareness about the importance of project communications management in your organization's and project management team? - What is the level of application of communications management in your organization? - Do you prepare and use team rosters for project communication? - Does IT provide support through the ERP system to customize reports and formats to standardize across divisions, departments? - Is there a common management reporting requirement defined by your company? - Does your project Manager have a process in place to share lessons learned? - What kind of reports and key performance indicators are being used to manage projects and to whom are these reports and indicators visible to? - Is there something that could/should be automated in terms of reporting?
Project Risk Management
- Is there awareness about the importance of project risk management in your organization's and project management team? - What is the level of application of risk management in your organization? - Are areas of risk identified for each project along with risk avoidance and mitigation plans? (time risk / cost risk etc.) - What systems / tools do you currently use to manage your project Risk? - Are any risk metrics used to monitor trends? - What kind of documents do you provide to your customers for project risk management? - Assuming that you have identified a number of risks in the project, how would you prioritize them? - Is there any effort of identifying and documenting risks in your project? - Is risk response strategy developed for the prioritized risks? (example : avoid, transfer, mitigate, accept) - Is the risk response plan and strategy continuously updated? - Is contingency time allowed in project schedule for potential risk impact? - Is contingency budget reserved for potential risk impact?
Project Procurement Management
- Is there awareness about the importance of project procurement management in your organization's and project management team? - What is the level of application of procurement management in your organization? - Are contracting approaches, vendor lists developed for projects? - Are schedules and cost targets available during the purchasing process? - Is planning done for procurement of goods and services needed for your project? - Are major and/or special supply items (such as: those required in large quantity, or those requiring special manufacturing or long lead-time etc.) identified and special attention given for them? - Does your project/organization have standard procurement documents? (such as standard purchase order, standard sub contract / supplier agreement) - Does your organization use preferred supplier/subcontractor or prequalify them? - Does your project/organization have a documented contract management/administration process? - Does your project/organization have a staff trained in contract /procurement management? - Does your project monitor and control progress of subcontractors and suppliers? - Does your project have a clear defined process for contract closing?

Project Stakeholder Management
- Is there awareness about the importance of project stakeholder management in your organization's and project management team? - What is the level of application of stakeholder management in your organization? - How would you define the interaction of Project Stakeholders and their roles and responsibilities within the project? - Could you inform regarding the motives of the project stakeholders in the interest of project? - Is there awareness about the importance of stakeholder management in your organization's and project management team? - Is a stakeholder management plan prepared (is there a devised strategy on how to handle the stack holder's needs and expectations)? - Is there any continuous effort of communicating and working with stakeholders to influence their expectation, address their concern and resolve issues? - Is a strategy developed for managing each key stakeholder's expectation?
Project Health, Safety, Security, and Environmental Management
- Is there awareness about the importance of health, safety, security, and environmental stakeholder management in your organization's and project management team? - What is the level of application of health, safety, security, and environmental stakeholder management in your organization? - Does your project/organization have organizational policies, procedures and guidelines for Safety management? - Is Safety planning performed in your project? (determining safety standards and requirements, and devising actions plan/strategies) - Is Hazard Analysis performed for activities of your project? - Is Safety audit done in your project? (a review whether project activities comply with policies, processes, and procedures and safety requirements) - Does your organization provide Safety training for workers? - Does your project provide Personal Protective Equipment for site employees? - Is Safety control process implemented in your project? (inspecting whether project products and activities comply with relevant Safety standards plans) - Is safety surveillance and audit (control) performed in your project?
Project Financial Management
- Is there awareness about the importance of financial management in your organization's and project management team? - What is the level of application of financial management in your organization? - Is a Financial plan prepared for the project? - Are effects of change in exchange rate, escalation of labor and material cost etc. considered in your financial plan? - Is project cash flow analysis performed for the project? - Is there any effort to control the project finance to ensure that money is spent appropriately as planned and with proper authorization? - Does the project/company have clear expenditure authorization policy and procedure? - Is financial audit done in your project? - Are Financial Reports prepared regularly for the project? - Does the project have an established system/procedure for creating and handling financial documents? - Are computer systems used in filing and retrieval of financial information in your project?

Project Management Performance & Project Success
- In your opinion, how important is the project manager to the success of the project? - According to your view, how can the Project Manager work be simplified, eased and supported more? - How effective are project management knowledge areas in achieving project success? - What is project teams' knowledge in understanding the application of project management knowledge areas? - What is the most frequently applied Project Management Knowledge Areas within organization in order to achieve Project Success? What are some of the key outputs of each process group? - What are the key performance indicators used in the project? - What are some of the typical challenges project teams face during each of process groups? - Briefly describe what happens in each of the five project management process groups (initiating, planning, executing, monitoring and control-ling, and closing). On which process should team members spend the most time? Why? - According to your view, how can the Project Manager work be simplified, eased and supported more? - How effective are project management knowledge areas in achieving project success? - What is the performance measurement approaches used in the project? - What do you think about the effect of Project Management Standards on project duration? - What do you think about the effect of Project Management Standards on project cost? - What do you think about the effect of Project Management Standards on project productivity? - What do you think about the effect of Project Management Standards on customer/stakeholder satisfaction? - Which issues in a project do you think are most difficult to handle? Which of the knowledge area helps in resolving the most difficult issue and why? - What are the performance drivers in your job role and why?