Engineering Quality Management

Cornè Thirion & Jurie Steyn
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Introduction

Projects are often remembered for their cost overruns or delayed delivery, rather than the quality of their deliverables. Yet, it is the quality of those deliverables that dictates the potential financial gains or losses throughout its lifespan.

A project marred by subpar engineering and design is bound to cause long-term frustration for the owner. Meeting the project's quality requirements can prevent the dissatisfaction of both the owner and the operator.

This article discusses an Engineering Quality Management (EQM) approach that ensures the delivery of technical quality in engineering projects.

Project Quality Management

Opening remarks

This article centers on the quality management of engineering deliverables within projects, necessitating alignment with overall project quality management. The Project Management Institute (PMI, 2017) organizes project management processes into distinct knowledge areas, tailored to the specific knowledge needed. Among the ten defined interrelated knowledge areas, project quality management stands out, encompassing planning, managing, and controlling as its sub-processes.

Our consultancy endorses the integrated owner project management team approach, consisting of the project manager, business manager, operations manager, and engineering manager. This team embodies all the essential competencies needed to ensure the project's successful completion (van Heerden, 2018), as depicted in Figure 1.

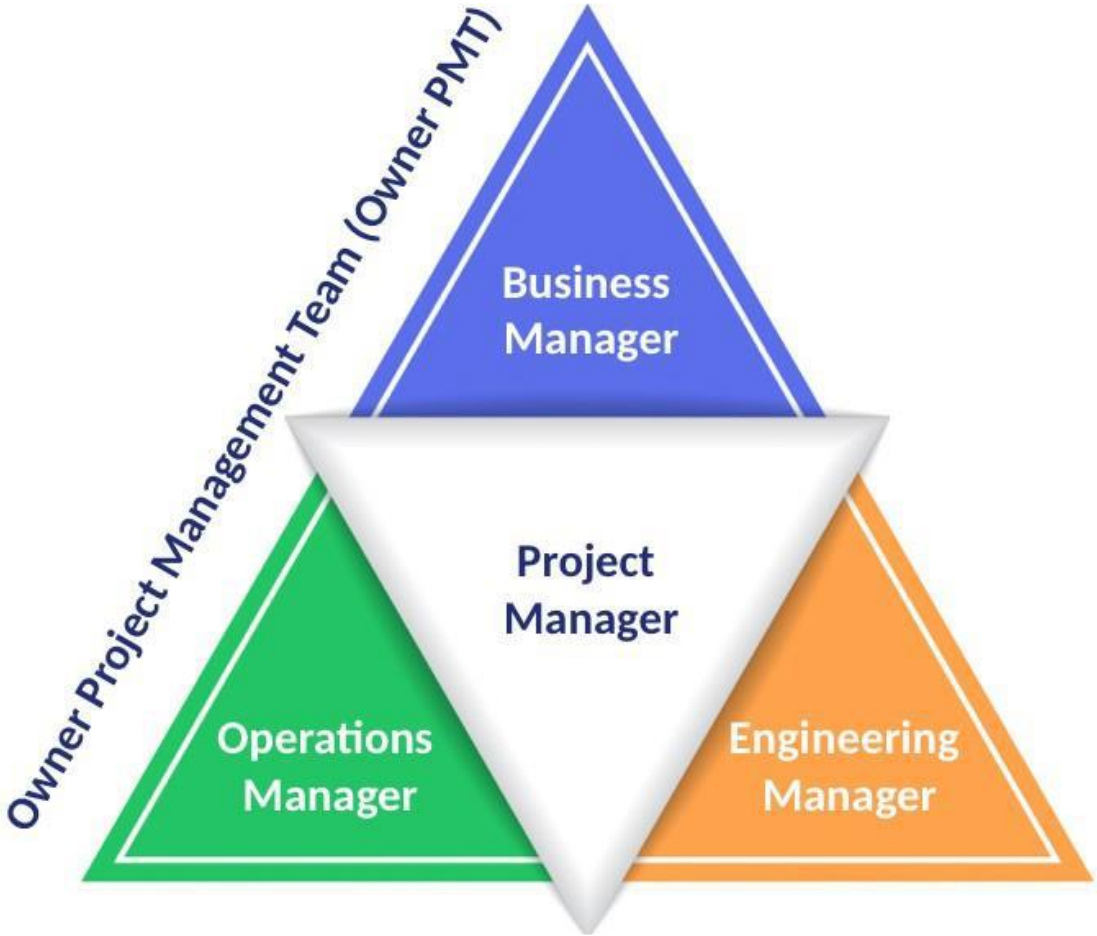

Figure 1: The Owner Project Management team (van Heerden, 2018)

The project manager is responsible for the Project Quality Plan, which is derived from the Project Execution Plan. The Engineering Quality Plan (EQP) is developed by the engineering manager, who also ensures the overall technical integrity of the project among other deliverables.

The engineering manager is assisted by a team of engineers from various disciplines, tailored to the particular needs of the project's scope and complexity. Within a functional organization, these disciplines are part of the Engineering Function, overseen by the Manager, Engineering.

Project Quality Management Philosophy

The project manager holds accountability for the overall quality management of the project, whereas the engineering manager oversees the quality of the technical outputs.

The complexity and scope of a project determine the method of execution. Typically, the owner's Project Management Team (PMT) selects an Engineering Contractor (EC) to oversee the project. The owner's PMT monitors the quality, while the EC guarantees

the quality delivered by contractors, sub-contractors, and manufacturers. Independent third-party inspectors and Approved Inspection Authorities (AIAs) conduct the quality verification. The interrelationships of quality management in a standard project are depicted in Figure 2.

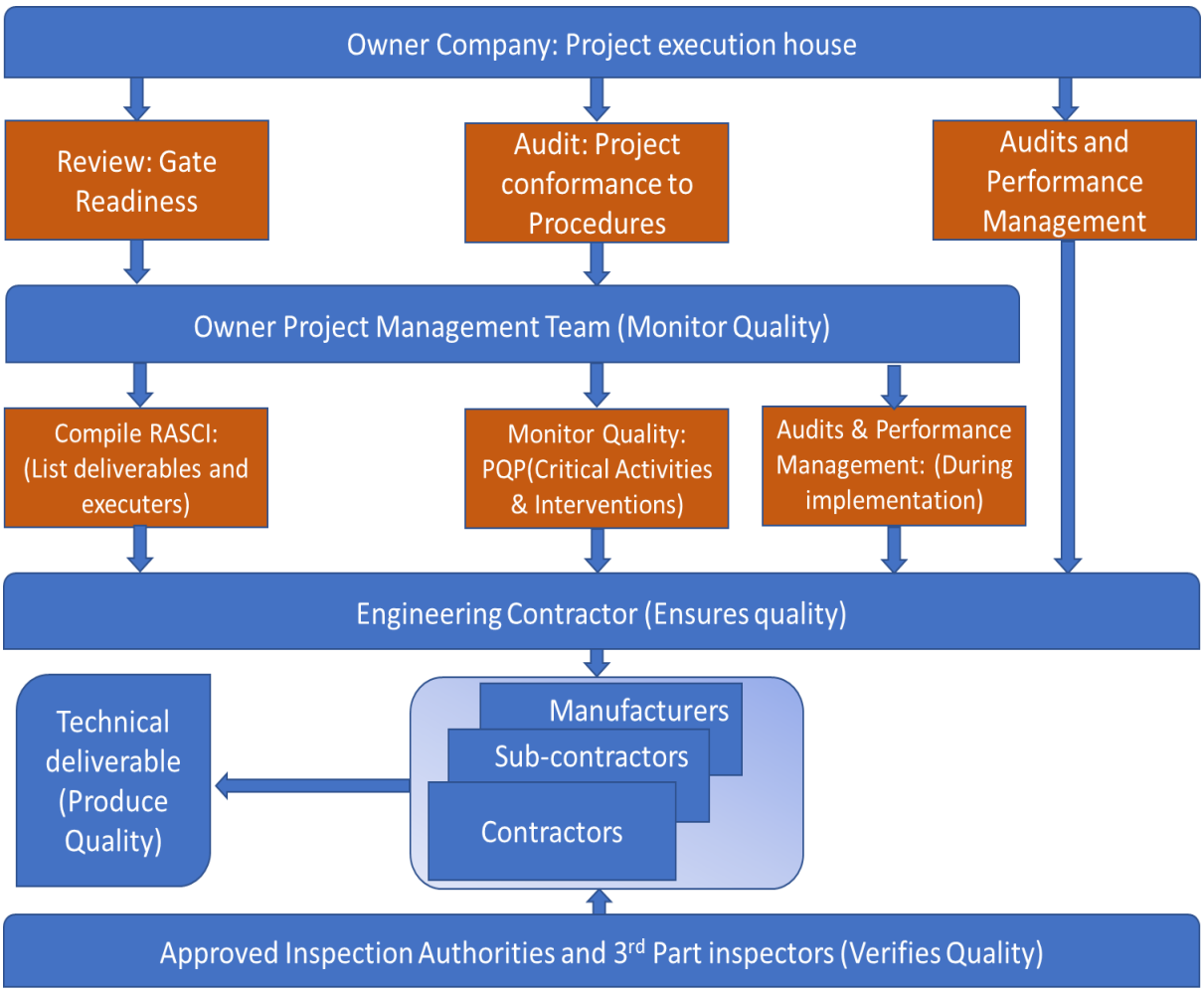

Figure 2: Different role-players and their responsibility towards quality

As the project execution strategy evolves, the roles in quality management may shift, with the owner's PMT taking on full responsibility for quality management when an EC is not present.

The quality requirements for a project should be clearly outlined in the Request for Quotation, and the contractor's Quality Management System (QMS) and Project Quality Plan ought to be assessed during the proposal evaluation phase as a crucial factor in selecting a contractor.

The role of the Engineering Function

Opening remarks

As previously stated, the engineering manager within the owner's PMT oversees a group of engineers tasked with ensuring the quality of a project's technical deliverables. These engineers are assigned from the Engineering Function.

Role of the Engineering Function in supporting project teams

The Engineering Function serves as the foundation for various engineering disciplines needed by the business type. These disciplines may include mechanical and piping, electrical, chemical, civil and structural, control and instrumentation, metallurgical, and welding engineering.

The Engineering Function's role in projects includes:

- **Requirements:** Establishing the technical requirements for engineering outputs.
- **Integrity:** Maintaining the technical integrity of engineering disciplines within projects.
- **Competency:** Developing and nurturing competent engineering personnel.
- **Specifications:** Creating and enforcing owner specifications, guidelines, and standard drawings.
- **Assurance:** Ensuring project compliance with codes and legislative mandates.
- **Availability:** Providing sufficient human resources for project teams.
- **Governance:** Implementing systems, governance, and structures to oversee the technical quality of engineering delivery in projects.

Quality of Engineering Support

The Engineering Function is responsible for tracking the performance of engineering support across various projects. Monitoring should cover areas such as:

- **Quality:** The quality of engineering and technical deliverables.
- **Human Resources:** The allocation of sufficient and competent engineers to projects, matching the project's complexity.
- **Knowledge Management:** The review of lessons learned from previous projects and the incorporation of new lessons into the knowledge database.

- **Risk Management:** The tracking and management of risks associated with engineering deliverables.

The outcomes of this performance review can be documented in various forms. For instance, a high-level summary might be presented as a heatmap, similar to what is depicted in Figure 3. The aforementioned focus areas are assessed for each project and within each engineering discipline. Critical areas are indicated in red, areas needing careful monitoring in yellow, and areas without identified or potential issues in green, thus spotlighting engineering-related problem areas within projects.

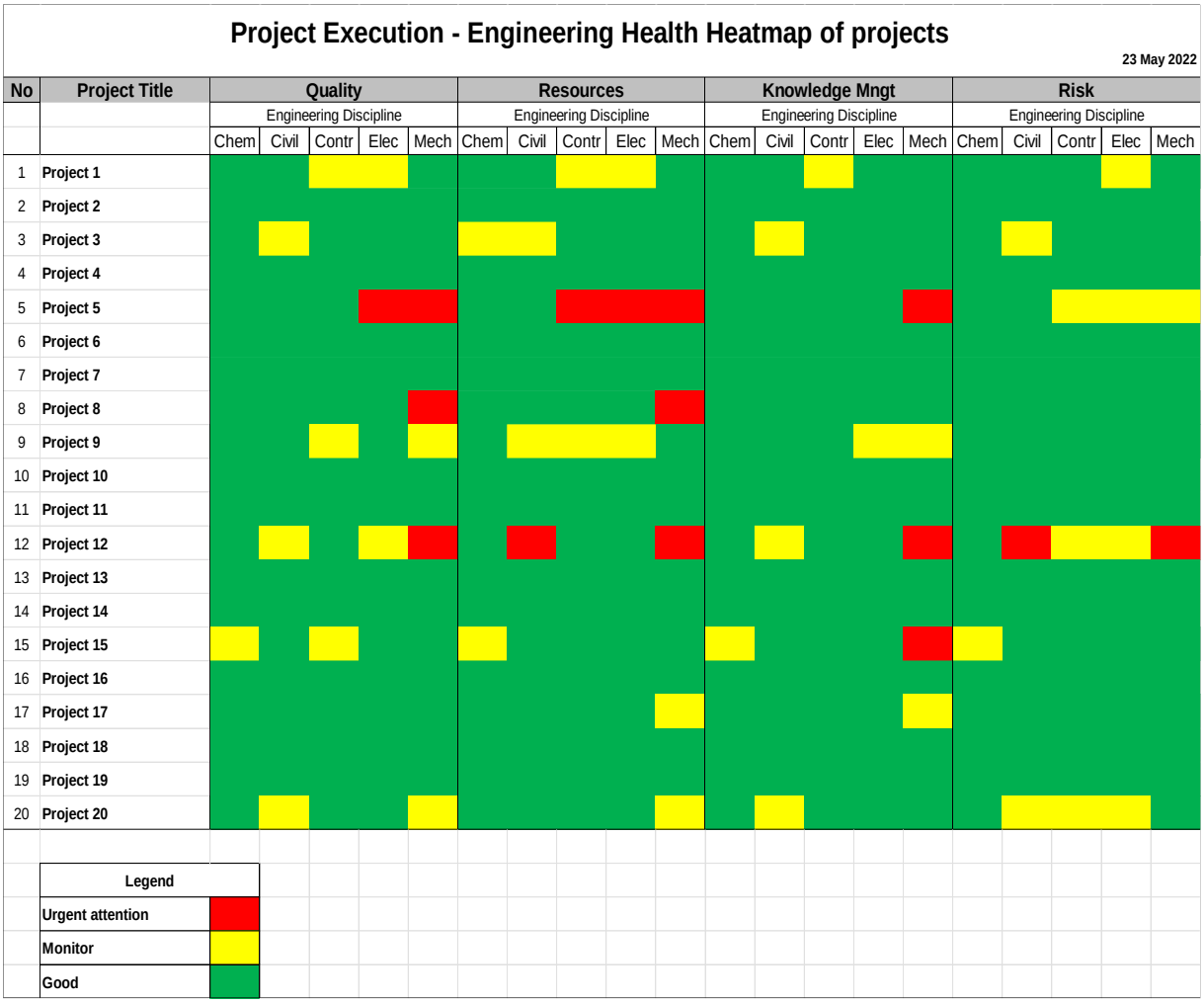

Figure 3: Heatmap of engineering health on projects

Engineering Quality Management

Opening remarks

The discussion will now focus on the quality management approach used to oversee the quality of technical engineering delivery in projects. It is preferable to prevent defects rather than detect them during inspections. Therefore, the emphasis should be on designing and constructing projects and products with quality in mind, instead of finding non-compliance during final product inspections.

Engineering Quality Plan

The Engineering Quality Plan (EQP) is a vital internal document that guides the engineering team's focus on essential activities and interventions necessary to maintain quality, thereby achieving the goal of fulfilling established requirements. Should the EQP be insufficiently detailed, it fails to emphasize the crucial elements, potentially resulting in the EC feeling disempowered or frustrated.

Minimum requirements of an EQP

The content of an EQP is dependent on many factors and every project should have a unique EQP. It is therefore not advisable to list “must” requirements, but the following could be considered:

- **Background**: Project background and quality management philosophy, objectives, scope, and purpose.
- **Interventions and activities:** Some activities such as model reviews are attended by most disciplines and should be listed separate from discipline specific activities such as review of single line diagrams or equipment data sheets. Describe activities in full detail to reflect intention, process, equipment, and expected outcome.
- **RASCI:** This describes the roles of the different participants in the project. All activities should be linked to an executer (person name), and the role of the person i.e., being Responsible, Accountable, Supportive, Consulted, or Informed.
- **Planning and control:** Link the planning of different actions to the overall project plan, project quality plan, as well as the EC’s schedule. The plan is also an input to resource planning and scheduling.

The EQP should be revised if the scope of the project changes. Each project phase will have a new EQP in terms of the typical stage-gate model for project execution, relevant to deliverables to be completed during a specific phase. Tracking of compliance is controlled and reported against the plan.

Factors that could influence the EQP

Stakeholders of the EQP play a crucial role in pinpointing factors that might affect the plan. The following generic items should be considered:

- **Business matters:** Business-related matters such as strategy, objectives, drivers, and the environment.
- **Complexity & maturity:** The complexity of the project, first of a kind technology, and maturity of technologies and licences used in the project.
- **Greenfield or brownfield projects:** Impact of latter on alignment, existing standards, codes, suppliers, and standardisation drive of the existing facilities.
- **Contractors & suppliers:** Contractors and suppliers selected based on experience in executing projects with the business, their culture, system and tools, competency and ability of team members allocated to the project.
- **Engineering resources:** The experience, competency, and availability of PMT members.
- **Project Contract Strategy:** The project contract strategy [Engineering, Procurement and Construction management (EPCM), or Engineering, Procurement and Construction (EPC)].

Although an EQP is agreed for a project phase, significant changes in any of the above could necessitate a revision during a phase.

Developing the EQP

The EQP is the accountability of the engineering manager, who is also responsible for compiling it. The first step is the identification and alignment of stakeholders like representatives from the plant (owner, maintenance, engineering, and production), the project manager, lead discipline engineers and, if required, engineering functional leaders. Alignment is best achieved by a facilitated alignment workshop.

The engineering manager kicks off the process by facilitating an EQP philosophy meeting, as well as listing specific requirements from the stakeholders. The first draft EQP is released, populated under headings as was discussed earlier under minimum requirements of an EQP. The Project Quality Plan of the EC is an important input to the development of the EQP, and it should be aligned with it.

The different discipline engineers develop subsections of the EQP, with special focus on activities and interventions required by them in monitoring the quality of project technical deliverables to satisfy the project objectives.

During the review cycle, before approval of the EQP, it is important to ensure that the content, level of detail and time spend on activities by different engineering disciplines

are aligned and on the same level, as is required by project objectives, risks, and other factors, as was discussed earlier.

RASCI

Communication and understanding your role and roles of other team members is of utmost importance during project implementation. A RASCI is developed as part of the EQP and lists roles and responsibilities of all team member, in relation to specific tasks of a project. The following roles are allocated in a RASCI:

- **Responsible:** This person is responsible to get the job done and there could be multiple persons for a task
- **Accountable:** This (one) person is answerable for a task; the buck stops with this person, and he/she takes final decisions.
- **Supportive:** These persons provide resources to the team, especially to those who are responsible or accountable.
- **Consulted:** These people are subject matter experts in their field and provide experience, advice, and wisdom when asked for.
- **Informed:** These people must be kept up to date on the project's progress, because of potential impact on them, or as a stakeholder.

The RASCI is not a project plan, it only lists major activities/deliveries for a project, and who, by name, participates in executing it.

Quality activity plan

A quality activity plan checklist is developed by each engineering discipline for every deliverable/equipment that will be monitored, and all activities are listed, as well as at what stage in the project lifecycle it must be executed. The status is updated as the work progresses. As an example, an activity is originally listed as review requested (X) and later updated to review completed (C), or review partially completed (PC). See Figure 4 for an example of a unit quality activity plan checklist.

Owner PMT	UNIT QUALITY ACTIVITY PLAN CHECKLIST

PLANT NUMBER (SYSTEM):												
PROJECT NAME: An Example								**Rev.**	**14**			
EC/TECHNICAL AREA/DISCIPLINE: Potential EC /Pumpstation/Electrical								**Date:**	**23-May-22**			
EQUIPMENT TYPE: High Voltage supply system								**Senior Electrical Engineer**				
STAGE OF PROJECT EXECUTION (TIME SEQUENCE)												
ITEMS/DETAILS TO BE APPRAISED	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**NOTES**
Switchgear Board 1 A/B	C	C	C	C	C	C	C	C	C	C	PC	
Switchgear Board 2 A/B	C	C	C	C	C	C	C	C	C	C	PC	
Automatic Transfer System	C	C	C	C	C	C	C	C	C	C	PC	
HV Variable Speed Drive	C	C	C	C	C	C	C	C	C	C	CP	
Protection, Metering & Control System	C	C	C	C	C	C	C	C	C	C	PC	
Substation Automation	C	C	C	C	C	C	C	C	C	C	PC	
Motor AA-2 (4,5MW)	C	C	C	C	C	C	C	C	C	C	PC	

EXECUTION STAGE ACTIVITY			
1	ECs Studies & Evaluations	7	Pre-award Meeting with Manufacturer
2	ECs Basis i.e used Standards/Specs./Calc. Methods	8	Manufacturer's Drawings & Calculations/Procedures (Testing etc.)
3	ECs Primary Drawings/Calculations	9	Manufacturer's Approved for Construction drawings
4	ECs Vendor List/Request for Quotation	10	Factory Acceptance Testing
5	ECs Final Drawings/Calculations	11	Site Acceptance Testing
6	ECs Bid Evaluation		

STATUS LEGEND			
X	Review Requested	**W**	**Waived**
C	Review Completed	**V**	**Vendor Visit**
PC	Partially Completed		

Figure 4: An example of a unit quality activity plan checklist.

All documents received for a review are tracked and returned to the EC by the project document control system and reviewers should complete reviews on time, as outstanding reviews may impact on the project schedule. The following review codes could be assigned after a review:

- **Code A/ Reviewed with no comment:** The EC may proceed with next activity after approval of document
- **Code B/Reviewed with comments:** The EC may proceed with next activity after approval of document, after incorporating the review comments
- **Code C/Revise and resubmit:** The design/solution is unacceptable, and it should be revised and resubmitted. No work may proceed before obtaining A or B revision status

- **Code D/Not reviewed:** The PMT selected not to review the project, the EC is not relieved from any obligations according to the Contract and may proceed with next activity.

There are two groups of reviews planned in most EQPs. The first group of reviews are attended by the engineering manager and most of the engineering disciplines. The second group of reviews are done by a single engineering discipline.

The first group of meetings/reviews typically include the following, although this is not regarded as an all-inclusive list:

- Project kick-off meeting.
- Project framing meeting.
- Process Flow Diagram review.
- Mechanical Flow Diagram review.
- Process & Instrumentation Diagram (P&ID) review.
- Plot plan review.
- Model review (30%, 60% and final) review.
- Hazard & Operability (HAZOP) review.
- Safety Integrity Level (SIL) review.
- Factory Acceptance Tests (FAT) of critical equipment.

For the single discipline reviews, the lead discipline engineer manages communication amongst engineers in the team, as well as integration with other disciplines. The engineering manager is accountable for overall integration and alignment. There are hundreds (depending on the size of the project) of items to be reviewed, the following are typical elements:

- Process design and intent definition (and adherence to it).
- Battery limit definition and documentation.
- Material and energy balances.
- Utility requirements (balance and composition).
- Single line diagrams.
- Network analysis studies.
- Hazardous area classification.
- Instrument process data sheet (material, turndown ratios, flow-, pressure- and temperature range).
- Shutdown systems.

- Equipment Data sheets (all disciplines).
- Piping isometrics drawings (process-, specification-, code requirements; standard drawings, line classes and routing plans).
- Compliance to national and local codes.
- Test results.
- End-of-job documentation.

The EC's QMS is reviewed during the bid evaluation phase, but subsequent audits (QMS and plans) are done during project development and implementation. Deep dives (audits) are also done by specialists on elements of the system and tools, which might have an impact on critical project deliverables. Spot checks are also done to confirm that specifications and procedures are applied.

Closing remarks

The adage that a chain is only as strong as its weakest link holds true in quality management as well. This implies that the success of a project hinges on the performance of each individual component. Should one component fail, it can lead to the failure of the entire project.

Engineering systems, procedures, standards, and the competency of engineers play a pivotal role in aiding the owner's Project Management Team (PMT) in their pursuit of quality in technical project deliverables. Their capacity to monitor quality, guaranteed by the Engineering Contractor (EC) and delivered by contractors and subcontractors, is bolstered by their understanding of the EC, subcontractors', and suppliers' strengths and weaknesses.

The remaining links in the chain pertain to the development and implementation of the Engineering Quality Plan (EQP). Selecting the essential few deliverables for review, along with the thoroughness of the review checklists and interventions, ensures that deviations are addressed early in the development process, rather than leading to the rejection of the deliverable at the final inspection stage.

References

PMI (Project Management Institute, Inc.) (2017), A guide to the project management body of knowledge (PMBOK® guide), Six Edition, PMI Book Service Centre, Atlanta.

van Heerden, F.J. (2018) *Introduction to Engineering Management.* Available from https://www.ownerteamconsult.com/introduction-to-engineering-management/| Owner Team Consultation. Accessed on 28 March 2024.