

RISK AND QUALITY MANAGEMENT IN INFRASTRUCTURE CONSTRUCTION PROJECTS

NAWAF MUBARAK JAMIL AL MUSHEIFRI

Email: PG24S2275@mec.edu.om

CPCM, Middle East College, Al Rusayl, Oman

ABSTRACT

The construction industry faces numerous risk management and quality management issues on every type of project. Many of these issues lead to negative impacts on project cost, schedule, safety, and the overall success of the project (Flyvbjerg et al., 2003; Zou et al., 2007). To reduce the potential for negative impacts on project cost, schedule, safety, and overall success, it is important to integrate risk management and quality management practices throughout the life cycle of a project. Integrating risk management and quality management practices into the project life cycle will assist in achieving successful project delivery, reducing construction defects, minimizing rework, and ensuring compliance with regulatory and industry standards (International Organization for Standardization [ISO], 2015, 2018). This research study will focus on the relationship between risk management and quality management practices in infrastructure construction projects. Specifically, the study will focus on identifying the main risk factors associated with infrastructure construction projects; evaluating current QA/QC practices used in infrastructure construction projects; and analyzing the interactions between risk management and quality management practices and their effect on project performance. There have been several studies conducted that have documented the various types of problems that occur during construction projects. Some of the most common problems include: lack of effective risk identification, poor project planning, changes in design, use of non-compliant materials, poor performance by contractors, and poor communication/coordination among all parties involved in the project (Love & Li, 2000; Zou et al., 2007). This research study proposes a mixed-methods approach to investigate current industry practices and find areas where improvements can be made. A mixed-methods approach will include a comprehensive literature review, survey questionnaires, expert interviews, and case studies to examine current industry practices and suggest areas for improvement. It is anticipated that the proposed risk and quality management system will provide practical recommendations for project managers, contractors, consultants, and policymakers to strengthen risk mitigation strategies, minimize quality-related issues, and achieve more reliable and sustainable outcomes in infrastructure construction projects.

Keywords: Risk Management, Quality Management, Infrastructure Construction, Project Performance, Quality Assurance, Quality Control.

INTRODUCTION

Risk management, an essential domain of project management in construction, is one of the most critical areas for ensuring that the project objectives are met (Hillson & Murray-Webster, 2007). With regard to construction projects, including those managed by Contractors, risks are inherent and have a great potential to affect key performance indicators such as cost, time, and quality (Iqbal et al., 2015). Risks can be considered threats as well as opportunities, depending on how they affect the project performance (PMI, 2017). For example, late delivery of material might be a threat, and adopting a creative construction approach might be an opportunity. Back in the 1980s, Terry (2011) and Olsson (2007) stated that identifying risks early in the project lifecycle helps firms to control variables, especially cost and schedule.

In the construction projects are full-fledged risk management process based on the latest practices. Tools used to identify and mitigate adverse outcomes included, but were not limited to, qualitative and quantitative risk assessments, stakeholder risk workshops, and continuous monitoring (Al-Bahar & Crandall, 1990). Risks have been ranked according to the established guide within the OQ risk register, both in terms of probability (high, medium, low) and severity (high, medium, low). The aim was to enhance project predictability and align with client expectations (Aven, 2016). Proactive identification and mitigation of risk have remained a key aspect of the project execution approach, especially when it comes to technically complicated and environmentally sensitive projects.

Quality management is a systematic process that helps in maintaining quality standards in projects and ensures customer satisfaction (Goetsch & Davis, 2016). A quality system, as defined by ISO 9001:2015, is the organizational structure, procedures, processes, and resources needed to implement quality management (International Organization for Standardization [ISO], 2015).

PROJECT IDENTIFICATION OF CONSTRUCTION RISKS

Identifying sources of risk is an essential and continual stage of the risk management process, especially in complex construction projects involving clients and contractors. During this phase, people involved in the construction projects could spot potential risks, understand their possible impacts, and create suitable plans to reduce them (Muhammed-Yakubu, 2023; Project Management Institute [PMI], 2017). If the risk is identified properly, it helps the project team to foresee problems before they arise and enhance decision-making (Hillson & Murray-Webster, 2007).

It is also important to note that risk identification is not a one-off process; the project life cycle needs constant review; new risks may arise, and previously identified risks may become redundant (Berends, 2011; Aven, 2016). Activities for risk identification were carried out by the project team of the contractor, comprising managers, engineers, and site supervisors at all major phases of the project, and the risks were recorded and updated in the Risk Register and Risk Mitigation Plan

Sheet. The practical part of this approach was maintaining the documentation updated and current, making it actionable, which is one of the suggestions in the industry for dynamic risk assessment (Kendrick, 2015).

The contractor used various industrial tools and techniques such as brainstorming workshops, expert interviews, root cause analysis, and checklists based on historical project data (Baldwin & Bordoli, 2014; Chapman & Ward, 2003) to ensure comprehensive risk identification. These approaches are recognized to improve the breadth and depth of risk identification by including qualitative and quantitative perspectives (Loosemore et al., 2006). Contractor also employed categorization as a fundamental aspect of their process, placing risks into buckets of technical, environmental, health and safety, financial, and contractual, then sub-categorizing those for even more detailed analysis (Hillson, 2002). Having this structured approach in place enabled the Contractor to identify and mitigate risks early, thus supporting the timely and cost-effective delivery of the project, such as the Project Risk Breakdown Structure Chart to identify the type of Construction Risks with Justifications and Project Fishbone Diagram.

Identified types of Construction Risks with Justifications such as;

1. Weather Risk.
2. Logistical Risk.
3. Design Risk.
4. Administrative Risk.
5. Financial Risk.
6. Political and Regulatory Risk.
7. Site-Specific Risk

PROJECT RESPONSE STRATEGIES

In-depth monitoring and tracking measures for risk response plans are a key driver of the success or failure of any project; many of them are supplementary for complex infrastructure projects, including buildings, roads, clean stormwater drainage, etc. The main response strategies include mitigation, avoidance, acceptance, and transfer of risks, which have varied consequences on the project (PMI, 2021).

Mitigation is the process of taking actions to minimize the likelihood or effect of a threat. For instance, Contractor could adopt advanced weather forecasting tools with flexible scheduling to reduce disruption going through monsoon conditions. Risk transfer is when responsibility is allocated to a third party (subcontractors or insurance-type organizations) who are in a better position to manage specific risks (Henjewe, 2019).

Conversely, risk acceptance is appropriate for risks with low impact that will not significantly interfere with cost, time, or quality, such as administrative delays owing to remote vs. on-site approvals. The last response to risk is avoiding a risk, which means changing the project plan in a

way that prevents the threat from happening at all. Such actions may involve altering the design of the project to mitigate clashes with underground services or rescheduling timelines to bypass the cyclone season (Hillson, 2020).

PROJECT RISK MITIGATION PLAN

Risk Avoidance: Throughout the construction projects, the Contractor project team took a proactive stance and made the conscious decision to avoid high-risk excavation operations, which could compromise sensitive infrastructure. This decision was made to prevent the project from being damaged and to avoid going outside environmental and safety margins.

Risk Transfer: The contractor transferred the risk associated with equipment failure, leading to a delay, to one of its specialized subcontractors under very clearly defined terms in the contract, and therefore, limiting the risk of direct exposure for the project to this threat.

Risk Prevention: The construction team took several measures, including timing construction to avoid inclement weather and strengthening temporary drainage structures, to lower the likelihood and impact of flood-related disruptions in this geographically sensitive location.

Risk Acceptance: Contractor's team concluded that risks associated with minor logistical delays involving materials transportation in the remote parts of the project site are tolerable. They decided to track the situation and react only if the delays crossed a pre-established threshold.

The organizational and strategic performance of the Contractor must develop a targeted risk response plan, Project Risk Ranking and Prioritization, and Project Risk Priority Score (RPS) Chart.

PROJECT QUALITATIVE RISK ASSESSMENT

A qualitative risk analysis method should be employed in construction projects, prioritizing the identified risks to enable the project to focus on the main or critical risks for further evaluation and treatment. In this approach, it will evaluate each risk through these two important dimensions: (1) Probability of occurrence, and (2) Impact on one or more of the project objectives, such as cost, schedule, and quality. The effect is usually classified as high, medium, or low, helping the project team to prioritize the most dangerous threats (Hillson & Murray-Webster, 2017).

The effectiveness of a qualitative analysis rests heavily on sound expert judgement and detailed estimates of both the likelihood and impact of each risk. The main goal is to predict future uncertainties that could impact schedules or costs, particularly in sectors prone to weather delays,

design changes, or administrative issues. Risk assessment. Once identified, the risks are documented and ranked in a risk assessment matrix that visually maps their severity and assists in making effective decisions (Safran 2019, PMI 2021).

This process allows the Contractor to mitigate the possible interferences caused by uncertainties in their projects through strategic resource allocation by using the Project Risk Probability Ranking, Project Risk matrix chart, and Project Probability and Impact chart.

PROJECT QUANTITATIVE RISK ASSESSMENT (QRA)

Quantitative risk analysis is a methodical process for assessing the estimated effects of severe risks by assigning a quantitative measurement to their probability and impact. When it comes to risk exposure, this method is vital in supporting decisions as it allows a tangible analysis of risk exposure, especially in large-scale engineering project execution for the Contractor. The success of quantitative risk analysis is contingent on several variables: the type of project itself, the amount and accuracy of historical and real-time data available, and the complexity of the risks that have been determined (PMI, 2017). Algebraic definitions of risk, when used effectively, can greatly improve an organisation's ability to manage its risks based on priority relative to risk exposure (Hillson & Murray-Webster, 2017). In the algebraic definition of risk, both the likelihood of a risk event occurring and the consequences of a risk event happening are defined as a numeric value, which allows for better prioritisation, resource allocation, refining risk mitigation strategies, and resultant project outcomes at Contractor.

The Full Monte software utilizes a Monte Carlo simulation chart to evaluate the time and cost impacts associated with approved project risks. Also, Optimistic Value, Most Likely Value, and Pessimistic Value can be obtained from the Monte Carlo simulation for the time and cost impacts chart.

PROJECT MONITORING AND CONTROL MEASURES

Using both qualitative and quantitative techniques, value drivers, such as key performance indicators (KPIs), are then organized and used as a basis for performance measurement, benchmarking, continuous risk monitoring, and control of sustainability initiatives. This phase safeguards that risks are managed within proportionate boundaries throughout the project timeline and also enables adequate modifications to be made as new unforeseen factors unfold. For Construction Projects, the project team consistently monitored known and potential risks, updating the risk register to mirror the changing state of affairs. Such monitoring helped the team to reassess existing mitigation plans and build adaptive plans for future phases of the project. In addition to this, a contingency plan was made to meet the project objectives and provide immediate corrective actions when there were deviations. Such an organized and responsive method is crucial

for ensuring the smooth implementation of projects and preventing potential setbacks (Project Management Institute [PMI], 2021).

PROJECT QUALITY MANAGEMENT PLAN DEVELOPMENT

What is Quality Management? Quality management is a systematic process that helps in maintaining quality standards in projects and ensures customer satisfaction (Goetsch & Davis, 2016). A quality system, as defined by ISO 9001:2015, is the organizational structure, procedures, processes, and resources needed to implement quality management (International Organization for Standardization [ISO], 2015). It comprises a wide range of managerial activities that determine quality policies and objectives, assign responsibilities, and ensure their execution. The major elements of quality management are quality planning, quality control, quality assurance, and quality improvement, and they fall under the structure of a quality system (Oakland, 2014).

PROJECT QUALITY MANAGEMENT PLAN DEVELOPMENT

The quality management plan is a guiding document that assists the project manager and project team in carrying out quality assurance and quality management activities (Project Management Institute [PMI], 2017). In the context of project management, quality refers to meeting the defined requirements and expectations of the project. Within a comprehensive project plan, the quality management strategy outlines the specific actions necessary to achieve quality objectives throughout the project lifecycle (Goetsch & Davis, 2016). Additionally, the quality management plan identifies the necessary resources to support effective implementation and continuous improvement (Oakland, 2014).

Here are the key Components of a Quality Plan

- **Quality Objectives:** Specific objectives clearly define desired outcomes in quality concerning the project.
- **Roles and Responsibilities:** Involves noting the various roles of different team members and stakeholders regarding accountability for quality management.
- **The quality standards and criteria:** The permissible standards and guidelines of the project.
- **Tools and Techniques:** Identification of methodologies, software, and best practices for quality management.
- **Human Resource Requirements:** Requirements for people, materials, and budget required for executing quality measures.
- **Continuous Improvement Plan:** actions for ongoing quality improvements, including lessons learned and process improvements. Machine Learning Sequence – how the machine learning solution will learn over time.
- **Compliant mechanism:** a system for monitoring and verifying the ideal outcome

❖ **Appropriate Roles, Responsibilities, and Authority**

The basis of the Quality Management Plan for this project is the quality organizational structure that will assign the responsibility of conducting quality performance monitoring and controlling to achieve the quality objectives and targets defined in the Quality Management System (QMS). A graphical overview of the organizational structure.

The framework defines the key team members on the project, outlines associated responsibilities, and clarifies the delegation of authority. Develop a team organizational chart that defines the obligations and responsibilities of each team member.

❖ **Project Quality Code and Standard**

Having a clear set of rules around quality also acts as a guarantee that the project will be executed as planned, since the deliverables are completed to meet these quality targets. This process also ensures that the project remains focused and consistent throughout its lifecycle.

The Contractor will perform the works in strict compliance with the specifications and all country-applicable regulations and design codes, as well as complete adherence to the Company and Project standards.

Project standards, specifications, standard drawings, and any other documents referred to therein will, collectively, be referred to as the project standards.

In the case of conflict between specifications, Contractor shall refer to the following hierarchy of documents to determine the applicable project requirements.

- A. Local Laws and Regulations of the country.
- B. National Standards
- C. Project Specification and Datasheets as applicable
- D. Codes and Standards and Industry and International
- E. All of these documents will be referred to collectively, and each will conform to all applicable requirements.
- F. Where standards, specifications, or regulatory requirements for Hearth Standards are inconsistent, conflicting, or differ in their requirements, the most stringent and safest requirement applicable to the project will apply.
- G. In the event of such conflicts, Contractor will issue a written interpretation for Company approval of the most stringent requirement. All such decisions are subject to the final discretion of the Company.

❖ **Project Quality Scheduling and Target**

For the project, the quality target is to achieve zero accidents during the project tenure and to complete the project on time and on budget. Additionally, it guarantees the accuracy of all tasks

from the start, eliminating the need for rework following the standard specifications. Moreover, all materials used in the project will comply with the specifications in the contract.

❖ **Project Manpower, Machines, and other required resources**

The Contractor will mobilize qualified manpower, specialized equipment, and basic supplies to accomplish this scope. The construction of projects requires skilled manpower, advanced equipment, and high-quality materials to execute the project safely, qualitatively, and environmentally.

This includes a schedule that details the manpower, machinery, and other resources necessary for the successful execution of the project.

Construction is a structured activity, in the sense that to accomplish the task, the Contractor needs to provide manpower, machinery, and utilities suitably to minimise wasteful execution. Here's a breakdown of the main requirements:

A. Manpower:

Skilled Manpower is critical to the success of any project. The personnel required include:

- Project Management and Supervision.
- Technical and Skilled Workers.

B. General Workforce.

C. Machinery and Equipment: Different construction tasks necessitate the use of specialized machinery, such as:

- Earthmoving machinery.
- Material Handling Equipment.
- Construction Machinery.

D. Common Construction Materials and Resources.

E. Construction Materials and Resources.

1. Project Quality Procedures.

Construction Quality Control Procedure allows a systematic method for observed assessment and renovation phases of buildings, from construction to damage and post-construction activities.

It is a complete quality management system that includes stringent inspection, quality assurance checklists, and quality assurance performance evaluations for specific work processes. This guarantees strict conformity with design specifications, regulatory compliance,

and industry best practices. The contractor's persistent devotion to quality in construction is preserved through systematic quality audits, defect prevention actions, and continual improvement processes.

In addition, the process focuses on forward-looking risk assessment, materials testing, and process optimization, aiming for enhanced durability, functionality, and sustainability. The contractor assures that each project accomplished not merely meets but surpasses the clients' demands, whilst complying with the highest international standards by creating an effective quality control system.

2. Project Inspection Test Plan (ITP)

A Project Inspection Test Plan (ITP) is a structured document that defines the criteria for inspections and tests relevant to particular construction activities within a project. The contractor sets quality levels for construction processes, materials, and workmanship, making it a leading contractor.

The ITP also specifies the approach to systematic quality control in each stage of inspection, laboratory testing, acceptance criteria, and responsible personnel. In a sense, it functions as a command meant to uphold compliance with contract requirements to ensure that the execution of construction activities is performed accurately and uniformly. The contractor ensures a quality that is lasting and dependable through various means such as frequent inspections, material tests, and state-of-the-art methodologies.

3. Project Quality Assurance Processes

Quality assurance (QA) is defined as a comprehensive framework of policies, procedures, systems, and practices that are adopted to achieve, maintain, and improve the quality outcomes (Elassy, 2015). The infrastructure construction projects in which the implementation of QA is done in such a way that all the construction activities conform to the contract requirements, client satisfaction, and International standards. Through these structured QA practices, the project team ensures that all facets of construction are delivered to possess good quality, consequently minimizing rework and contributing to overall customer approval

4. Project Quality Control

Contractor's quality control system for the construction process. A construction company needs to keep high standards of quality control to ensure customer satisfaction and compliance with all regulations in the market. The company adheres to quality control methods that guarantee that all deliverables are consistent with the agreed-upon scope and standards from the project start. Quality Control is thus quite different from quality assurance and refers to the strategies and processes that are implemented to create high-quality results (Mitra, 2016).

Construction Quality Control Issues: Maintaining Construction Quality control issues occur when aspects that prompt quality are not effectively recognized or proposed to change (Demski, 2022). Each construction phase must be closely monitored to pinpoint issues as early as possible. This would thus necessitate the company's quality control processes to engage in settlements, constant checking and testing for such discrepancies, and work towards rectifying these on an ongoing basis to ensure the project meets the specifications and regulatory requirements agreed upon.

Further, quality assurance would also be about establishing effective quality guarantee systems to ensure the contractor's quality is well ahead of industry standards as well as clients' expectations. This proactive approach allows the organization to prevent problems associated with quality from becoming crises, progress is measured, future challenges are anticipated, and dependable, impressive results are consistently produced.

5. Impact of Poor Project Quality

The Cost of Poor Quality (COPQ) is an alarming financial matter for an industry-leading construction business, encompassing costs incurred in producing products or services that do not conform to quality requirements. These costs are internal failure costs, like rework and material waste, as well as external failure costs, like warranty claims and damage to client relationships. Galfar needs to tackle COPQ to retain its industry reputation and exercise operational efficiency.

Poor work quality is a major problem in the construction industry, costing construction companies and their clients an astonishing \$625 billion a year on average to remedy (Cumulus Team, 2024). According to Sarkar (2017), COPQ can range between 5% and 15% of the total project cost in the construction industry due to (a) ineffective planning that results in (b) poor communication between owners and contractors and leads to (c) rework tasks in maintenance. Effective quality management approaches will enable contractors to detect and prevent possible quality failures, which will reduce COPQ and subsequently promote project success (Love & Li, 2000).

6. Project Quality Cost

The Cost of Quality (COQ) is an important methodology for a contractor to assess the total costs incurred to ensure the quality of the project and associated works throughout the lifecycle of the construction project. This covers both forms of conformance costs (prevention and appraisal), as well as non-conformance costs (internal and external failures). Tracking COQ also allows for better performance, reduced rework, and better utilization of resources according to the American Society for Quality (ASQ, n.d.).

Furthermore, embedding COQ within project planning enables businesses to recognize budgetary limits in the preliminary stages and implement data-informed interventions that minimize quality failures in the future. Research by Silva and Costa (2023) shows that the costs of internal and

external failures have the greatest influence on the total quality costs and indicates that investments in preventive actions have a return. Such COQ analysis is crucial for contractors working in complex and resource-intensive project environments to remain competitive and satisfy clients (Silva & Costa, 2023), and it is also at the forefront of (data-driven) methodologies to enhance project performance (Pavlovskaya, 2023).

7. Project Quality Basic Tools Used

In the construction projects, quality control (QC) takes the centre stage, particularly within infrastructure projects, where precision and compatibility with statutory standards are very crucial. QC verifies that workmanship, materials, and processes meet predetermined specifications while ensuring that problems are detected early to avoid expensive rework. To control

Category	QC Tool	Purpose
1	Check Sheet	Track and quantify defects during processes
2	Cause and Effect Diagram	Analyze root causes of problems
3	Flow Chart	Map and streamline sequential activities
4	Histogram	Visualize data distribution and detect patterns
5	Control Chart	Monitor process stability and detect variations
6	Scatter Diagram	Examine the correlation between the two variables
7	Data Collection & Reporting	Continuous quality monitoring and immediate issue escalation

8. Quality Legal Implications

Legal implications are the responsibilities that result when project activities overlap with applicable laws and regulations (Luenendonk, 2016). Construction projects typically begin with contracts that outline legal responsibilities. These implications will differ vastly depending on the nature and scale of the project and the specific actions or inactions of the parties involved. The implications of both these possibilities run the gamut, depending on the nature and scale of the project and the nature of the actions or inactions enacted by the parties (Fellows & Liu, 2015).

The scope of works was extremely large, and as the main contractor on construction works, the Contractor is subject to Country construction law, where the contractor has long-term liability for the structural integrity of the works and safety of the works. According to the Country Civil Code, the application of joint responsibility of the contractor and a consulting engineer lasts as long as ten years after the date of handover for any total or partial damage to permanent structures, which also includes storm water systems (Al-Busaidi, 2017). This also applies to any flaw that may affect the stability or security of the basic structures (Al-Busaidi, 2017).

If it neglects this project's quality control processes and legal standards, the consequences could be dire. These encompass conflict among project stakeholders, sanctions by regulators, or even litigation for non-compliance with regulations, as well as for safety breaches (McManus & Wu, 2019). Deficiencies in the project, such as poor workmanship, rework, or delayed testing that compromise safety, have the potential to reduce profits and prolong project duration, hence

contributing to the contractor's financial risk (Hwang & Ng, 2013). For damages suffered, compensation may be claimed, yet received only if legal culpability can be ascertained (Law, 2003).

However, the Contractor should maintain strict quality assurance and regulatory compliance at each project stage to minimize this risk, highlighting its commitment to "building it right the first time" (Fellows & Liu, 2015).

CONCLUSION

Risk management techniques included qualitative (e.g., risk matrices, expert opinion) and quantitative (e.g., Monte Carlo simulations, sensitivity analysis by software tools) approaches. These contributed to the establishment of a strong risk mitigation plan that focuses on key risks such as flooding, supply chain disruption, and worker safety.

In terms of quality, a comprehensive quality management plan was implemented, with a focus on quality assurance (QA) processes, including procedural reviews and contractor qualification checks, and quality control (QC) measures, such as inspections and material testing. The use of tools such as cause-and-effect diagrams (Fishbone) and control charts facilitated early identification and resolution of potential quality problems. It also covered the legal implications of substandard quality and stressed cost control through early intervention.

RECOMMENDATIONS

1. Improve Risk Monitoring and Communication

- Establish a central digital risk register linked to each project cycle and transparent for all authority figures.
- Schedule Regular Risk Review Approvals to truthfully review risk-based mitigation plans and respond according to the situation.

2. Commit to Training and Safety Education

- New training programs for site workers and management on risk identification and control must be improved, especially concerning stormwater handling and emergency response.
- Provide deliverables such as visual risk indicators (color-coded zone maps, etc.) to communicate hazards on-site.

3. Make Smart Use of Project Management Software

- Utilize commercial project management software more widely (such as MS Project with Risk add-ons) to run regular risk simulations and routinely revise cost-risk impact analysis.

4. Enhance Quality Culture

- Promote a “zero-defect” attitude through reward systems for teams meeting quality objectives.
- Implement independent quality audits and engage third-party quality consultants at key stages of construction.

5. Design Flexibility and Sustainable Options

- Review proposed design alterations or new proposals that include modular construction methods.
- Perform constructability reviews as early as the design to save time on rework and sequencing of construction.

6. Implement Structured Decision-Making Frameworks

- Use tools such as Multi-Criteria Decision Analysis (MCDA) and Cost-Benefit Analysis (CBA) in later phases to analyze and compare alternatives effectively.
- Log decisions in an accessible way to assist project audits and knowledge transfer.

7. Supervisory Control of Legal Compliance

- Enhance internal controls to seamlessly comply with local environmental, construction, and labor laws, especially related to stormwater management and fuel storage in proximity to sensitive ecosystems.

LIST OF REFERENCES

- Flyvbjerg, B., Bruzelius, N., & Rothengatter, W. (2003). *Megaprojects and risk: An anatomy of ambition*. Cambridge University Press.
- Love, P. E. D., & Li, H. (2000). Quantifying the causes and costs of rework in construction. *Construction Management and Economics*, 18(4), 479–490. <https://doi.org/10.1080/01446190050024897>
- American Society for Quality. (n.d.). What is cost of quality (COQ)? Retrieved September 29, 2026, from <https://asq.org/quality-resources/cost-of-quality>
- Zou, P. X. W., Zhang, G., & Wang, J. (2007). Understanding the key risks in construction projects in China. *International Journal of Project Management*, 25(6), 601–614. <https://doi.org/10.1016/j.ijproman.2007.03.001>

- El-Sawalhi, N., Eaton, D., & Rustom, R. (2007). Contractor pre-qualification model: State-of-the-art. *International Journal of Project Management*, 25(5), 465–474.
<https://doi.org/10.1016/j.ijproman.2006.11.011>
- Hatush, Z., & Skitmore, M. (1997a). Criteria for contractor selection. *Construction Management and Economics*, 15(1), 19–38. <https://doi.org/10.1080/014461997373088>
- Hatush, Z., & Skitmore, M. (1997b). Evaluating contractor prequalification data: Selection criteria and project success factors. *Construction Management and Economics*, 15(2), 129–147.
<https://doi.org/10.1080/01446199700000002>
- Cumulus Team. (2024, February 5). Unveiling the hidden cost of poor quality (COPQ) on construction and maintenance projects. Cumulus. <https://cumulusquality.com/unveiling-the-hidden-cost-of-poor-quality-copq-on-construction-and-maintenance-projects/>
- Love, P. E. D., & Li, H. (2000). Quantifying the causes and costs of rework in construction. *Construction Management and Economics*, 18(4), 479–490. <https://doi.org/10.1080/01446190050024897>
- Sarkar, S. (2017, July 12). Cost of poor quality in construction can negatively impact “quality”. LinkedIn. <https://www.linkedin.com/pulse/cost-poor-quality-construction-can-negatively-impact-sovan-sarkar>
- Abdullah Albogamy, D. S. (2013). ADDRESSING CRUCIAL RISK FACTORS IN THE MIDDLE EAST CONSTRUCTION INDUSTRIES: A COMPARATIVE STUDY OF SAUDI ARABIA AND JORDAN. *Sustainable Building Conference*. UK: Coventry University.
- AbdulLateef Olanrewaju, M. Z. (2022). Establishment of pre-qualification criteria for the selection of subcontractors by the prime constructors for building projects. *Journal of Building Engineering*, Volume 45. <https://doi.org/https://doi.org/10.1016/j.jobe.2021.103644>
- ABEKU, E. E. (2021). The Consequences of Public Procurement and Its Associated Irregularities in Ghana. *Academic and Applied Research in Military and Public Management Science*, 21. <https://doi.org/10.32565/aarms.2021.1.4>
- AMRI, T. A. (2019). CAUSES OF CONSTRUCTION PROJECT DELAYS AND COST OVERRUNS IN OMAN: A . *23rd International Congress on Project Management and Engineering Málaga*. Málaga. Retrieved from <https://creativecommons.org/licenses/by-nc-nd/4.0/>
- Author, S. (2023, June 18). *Building Construction Work in Oman: A Comprehensive Guide*. Retrieved from Shukran Oman: <https://shukranoman.com/building-construction-work-in-oman-a-comprehensive-guide/>
- Azungah, T. (2018). Qualitative research: deductive and inductive approaches to data analysis. *Qualitative Research Journal*, 18, 383-400. <https://doi.org/https://doi.org/10.1108/QRJ-D-18-00035>
- Baird, J. (2004). When Pre-Qualification of Contractors Is Not Enough . *the ASSE Professional Development Conference and Exposition*, (pp. ASSE-04-522-1). Las Vegas.

- Bhatia, N. (2014, February 23). *Construction Oman Rail sets challenging prequalification criteria*. Retrieved from Middle East Construction News: <https://meconstructionnews.com/7332/oman-rail-sets-challenging-prequalification-criteria>
- Bogacz, K. S. (2022). A Method for Stakeholder Mapping in Connection with the Implementation of a Development Project. *MDPI journals*, 1592. <https://doi.org/10.3390/en15041592>
- Chupryna, I. P. (2020). MODEL OF STRATEGIC ANALYSIS OF FORMATION AND ADMINISTRATION OF INVESTMENT ACTIVITY OF STOCKHOLDER CONSTRUCTION COMPANY. *Scientific Journal of Astana IT University*, 51–62. <https://doi.org/10.37943/AITU.2020.19.30.005>
- Dalia A. Kshaf, M. A.-D. (March 2022). The major problems between main contractors and subcontractors in construction projects in Egypt. *Ain Shams Engineering Journal*, <https://doi.org/10.1016/j.asej.2022.101813> ---- Volume 13, Issue 6.
- Doloi, H. (2009). Analysis of pre-qualification criteria in contractor selection and their impacts on project success. *Construction Management and Economics*, Volume 27, 1245-1263 . <https://doi.org/10.1080/01446190903394541>
- Flick, U. (2018). *The SAGE Handbook of Qualitative Data Collection*. SAGE Publications Ltd. <https://doi.org/10.4135/9781526416070>
- Hamzah Abdul-Rahman1, C. W. (2011). Project schedule influenced by financial issues: Evidence in construction industry. *Academic Journals*, 6, 205-212. <https://doi.org/10.5897/SRE10.989>
- Hesham A. El-khalek, R. F. (2019). Identification of construction subcontractor prequalification evaluation criteria and their impact on project success. *Alexandria Engineering Journal*. <https://doi.org/10.1016/j.aej.2018.11.010>
- Husam Helmi Alharahsheh, A. P. (2020). A Review of key paradigms: positivism VS interpretivism . *Global Academic Journal of Humanities and Social Sciences*,, 39-43 . <https://doi.org/10.36348/gajhss.2020.v02i03.001>
- Kallet, R. H. (2004). How to Write the Methods Section of a Research Paper. *RESPIRATORY CARE*, Vol. 49(Issue 10), 1229-1232.
- Kumaraswamy, E. P. (2001). Recent advances and proposed improvements in contractor prequalification methodologies. *Building and Environment*, 36, Pages 73-87. [https://doi.org/10.1016/S0360-1323\(99\)00069-4](https://doi.org/10.1016/S0360-1323(99)00069-4)
- Mangesh M. Kapote, A. A. (2023). Contractor Selection Approaches and Pre-qualification Criteria on Construction Projects: A Review. *National conference on Advances in Construction Materials and Management*. India: School of Civil Engineering.
- Menon. (2024, August 06). practical solutions based on recent studies recommendations for Pre-qualification process. (N. Mubarak, Interviewer)
- Qlik. (2024). *Qlik*. Retrieved from Qlik: <https://www.qlik.com/us/kpi>

R. E. Minchin Jr., G. R. (2001). *Quality-Based Performance Rating of Contractors for Prequalification and Bidding Purposes*. University Park, Pennsylvania.

Zsuzsa Varvasovszky, R. B. (2000). A stakeholder analysis. *Health Policy and Planning, Volume 15*(Issue 3), Pages 338–345. <https://doi.org/https://doi.org/10.1093/heapol/15.3.338> Contractor Pre-Qualification Platform (tiiny.site)

Bock, T., & Linner, T. (2016). *Robot-Oriented Design: Design and Management Tools for the Deployment of Automation and Robotics in Construction*. Cambridge University Press.

Hegazy, T., Elhakeem, A., & Ghosh, S. (2011). Contractor prequalification model using fuzzy logic. *Canadian Journal of Civil Engineering*, 38(12), 1365–1375.

Hatoum, M., Elseify, M., & Morkos, B. (2023). Leveraging NLP and AI in contract management: Risks and opportunities. *Automation in Construction*, 146, 104721.

Marzouk, M., & Ali, H. A. (2013). Assessing contractor performance using artificial neural networks. *Automation in Construction*, 30, 29–37.

