

The Three Pillars of Quality: The Role of Three-Phase Control System in Construction Quality Management ¹

Yamanta Raj Niroula, PMP

Abstract

In the dynamic world of construction projects, ensuring quality is a fundamental objective that directly impacts the project's success, site safety, and stakeholder satisfaction. Quality management plays a vital role in maintaining high standards throughout the project lifecycle, from design and construction to completion and beyond. As construction practices continue to evolve, new technologies and methodologies emerge to streamline processes and enhance project outcomes. One such powerful tool in the construction industry is the three-phase control system.

Given the lack of detailed information in the literature on three-phase control systems, this paper aims to fill the gap by providing a detailed overview of the subject. It discusses the importance of the system and how it can improve quality management in construction projects. The system comprises three phases - preparatory, initial, and follow-up. Each phase of the system has its own set of activities, inspections, and tests. By using this system, construction professionals can identify and address quality issues early in the process, which can help to reduce rework and ensure that projects comply with the specified quality standards.

Keywords: Quality, Quality control, Quality assurance, Quality management, Construction, Three-phase control system, Preparatory phase, Initial phase, Follow-up phase, Definable feature of work, Concrete, Checklists, Specifications, Shop drawings, Submittals, Materials, Testing, Inspection, Corrective action, Continuous improvement

1. Introduction

1.1 Quality

When we talk about quality, we mean a product or service that is fit for purpose and meets or exceeds our expectations. These expectations are based on the intended application of product or service and its corresponding cost (Besterfield, 2013).

According to ISO 9000:2000, quality is "the degree to which a set of inherent characteristics fulfills requirements". In other words, quality is about how well something meets the needs of its users. This can be defined in terms of specific features, such as durability or performance, or terms of more general qualities, such as usability or aesthetics.

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The pursuit of quality has been a driving force in human history, catalyzing innovation, progress, and the desire for excellence in all aspects of life. From the craftsmanship of ancient artisans to the modern industries of today, the notion of quality has played a fundamental role in shaping societies and influencing their development. Quality has been a long-standing concern for human civilization (Rumane, 2018). The historical context of quality is essential to understand its value and the ongoing initiatives to guarantee high-quality standards in a variety of sectors, including construction.

The theory of quality has evolved over time. In the early 20th century, quality was viewed as a matter of inspection, with an emphasis on identifying problems after they occurred. In the mid-20th century, quality began to be seen as a way to prevent problems from happening in the first place. Today, the emphasis is on strategic quality management, which involves integrating quality into all aspects of an organization's operations (Kerzner, 2017). The emphasis on customer satisfaction and continuous quality improvement has led to a global focus on quality, with the development of systems and standards to help organizations improve their products and services (Mitra, 2021).

Quality in construction projects involves ensuring that the facility is completed to the owner's satisfaction, within budget, and according to the specified schedule, while also considering total management approach and adherence to the scope of work (Badiru & Osisanya, 2013). In its renowned publication titled "Quality in the Constructed Project: A Guide for Owners, Designers, and Constructors", the American Society of Civil Engineers (ASCE) defines construction quality as the delivery of products and services that meet or exceed the expectations of the owner, design professional, and constructor. It includes meeting all contract requirements, industry standards, and applicable codes, laws, and licensing requirements (American Society of Civil Engineers, 2012).

Quality in construction involves many factors, including:

- **Use of high-quality materials:** Using materials that are durable, long-lasting, and that meet the project's quality requirements.
- **Adherence to specifications and quality standards:** Following the plans and specifications that have been created for the project, as well as any applicable quality standards.
- **Compliance with safety and environmental regulations:** Following all applicable safety and environmental regulations to ensure the health and safety of workers and the public.
- **Achievement of functional and aesthetic objectives:** Creating a structure that meets the project's functional requirements, such as being able to withstand the elements or accommodate the intended use, while also achieving aesthetic appeal.

The construction industry has made significant progress in improving quality standards in recent years. This is due to the development of new techniques and management practices. As a result, construction projects are now more likely to meet or exceed the expectations of stakeholders.

1.2 Quality Assurance and Quality Control

Quality Assurance (QA) and Quality Control (QC) are two distinct but interconnected processes within the realm of quality management. While both processes aim to ensure the delivery of high-quality outcomes, they have different focuses and activities.

Quality Assurance (QA)

According to the American Society for Quality (ASQ), quality assurance is a comprehensive and organized activity that is implemented within a quality system to provide assurance that a product or service will meet the specified quality requirements. The term "quality assurance" refers to all formal activities and managerial procedures used to ensure that goods and services are of the required standard of quality (Kerzner, 2017).

Quality assurance in the construction industry refers to the processes and systems put in place to ensure that quality control measures are effective and efficient (Hendrickson & Au, 1989). This involves various management activities such as planning, implementation, evaluation, reporting, and continuous improvement, all aimed at ensuring that processes, products, or services meet the project requirements.

QA focuses on preventive measures and processes aimed at ensuring that the project is planned, executed, and controlled in a way that meets the required quality standards. It involves creating and implementing systems, procedures, and guidelines to prevent defects and non-conformities. The emphasis is on preventing issues before they occur rather than identifying and correcting them afterward.

QA activities for construction projects include:

- Developing a Quality Management Plan that outlines quality objectives, criteria, processes, responsibilities, and resources required to achieve and maintain quality standards for the construction project.
- Conducting periodic Quality Audits to assess compliance with quality standards and effectiveness of quality management processes for the construction project. Audits ensure proper adherence to procedures and identify areas for improvement.
- Establishing a framework of Quality Control processes and guidelines tailored for the construction project. This ensures appropriate QC activities are performed and results are documented.
- Reviewing and approving quality-related documentation including Quality Control Plans, Inspection and Test Plans, and Quality Control procedures specific to the construction project. This ensures necessary documentation guides QC activities.
- Providing training and education to the construction project team to ensure common understanding of quality requirements and competence in executing quality-related tasks.

Quality Control (QC)

QC, on the other hand, is concerned with verifying that the project outputs meet the specified quality requirements. It involves a set of activities that are performed during the project execution phase to identify and correct any defects or non-conformities. QC is reactive in nature and aims to identify and eliminate issues to ensure that the final deliverables meet the required quality standards.

Quality control is the use of techniques and activities to achieve and sustain the quality of a product or service (Besterfield, 2013). Quality control involves a range of activities and methods used to ensure that products and services meet customer expectations. These activities include monitoring processes, identifying, and eliminating problems, and using statistical methods to reduce variability (Kerzner, 2017).

In construction, quality control typically comprises ensuring that the facility performs according to its design by verifying compliance with minimum standards for materials and workmanship. These standards are included in technical specifications (Hendrickson & Au, 1989). This control ensures that the work performed meets necessary standards and durability by conducting inspections throughout the entire process, starting from material source to the completion of final product (Salvi & Kerkar, 2020).

QC activities for construction projects include:

- Conducting inspections, tests, and checks at various stages of the construction project to verify deliverables meet quality criteria. This may involve visual inspections, measurements, material testing, performance testing, and functional testing.
- Identifying defects, non-conformities, or deviations from quality standards for the construction project. Implementing corrective actions to rectify issues and bring deliverables back to required quality level.
- Taking samples and subjecting them to rigorous analysis such as lab testing or statistical analysis to ensure construction materials/components meet specifications.
- Documenting non-conformities, defects, or deviations from quality standards for the construction project. Using documentation to analyze root causes, take corrective action, and prevent future issues.
- Verifying construction project outputs meet predetermined requirements and specifications by comparing deliverables against defined quality criteria and validating fitness for intended purpose.

In summary, QA centers on proactive measures and establishing rigorous processes, procedures, and guidelines to ensure the construction project is executed with a focus on quality from the outset. QC, on the other hand, involves the systematic inspection, testing, and verification of project outputs throughout the construction process to identify and rectify any defects or non-conformities. While QA aims to prevent quality issues, QC detects quality problems and enacts corrective actions to achieve the desired level of quality in final deliverables.

The goal of QC is to satisfy established quality requirements and deliver construction outputs free of defects whereas QA provides confidence that standards are met through comprehensive reviews, audits, and inspections of quality management practices. QA procedures emphasize proactive prevention of deficiencies rather than relying solely on inspections and rework. Construction projects can achieve optimal quality outcomes by combining rigorous QA planning with active QC measures.

1.3 Quality management

Quality management is a system for implementing a quality program within an organization or a project. It encompasses all facets of quality management practices within an organization, aiming to enhance customer satisfaction (Lim, 2020) and all control and assurance activities instituted to achieve the quality established by contract requirements (US Army Corps of Engineers, 1995). The performing organization implements its quality management system by using quality planning, quality assurance, and quality control processes. Continuous improvement initiatives are carried out throughout the project. Similar to safety and environmental management, quality management ensures that the project management system includes all necessary processes to meet project requirements, with a focus on incorporating quality (Project Management Institute, 2016).

Quality management involves establishing processes, procedures, and guidelines that span the entire project lifecycle, from planning and design to execution and delivery. By combining quality assurance, which focuses on prevention, with quality control, which implies monitoring and correction, quality management intends to provide a comprehensive approach to managing and improving quality throughout the project lifecycle. It outlines project-specific procedures for both quality control and quality assurance (U.S. Army Corps of Engineers, 2021).

2. Three-phase control system

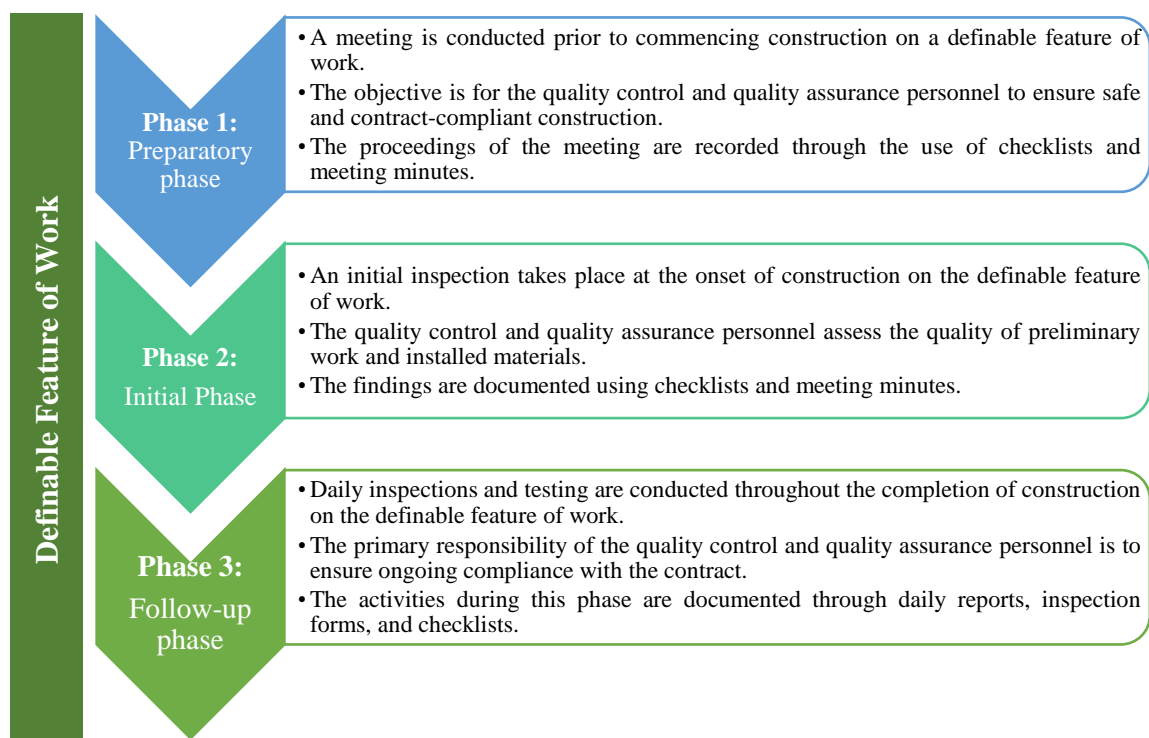
Three-phase control system is a quality control framework developed by US Army Corps of Engineers (USACE) with the aim of assisting its contractors and quality assurance personnel in detecting and avoiding construction deficiencies. It is based on the knowledge and insights gained from various construction initiatives, including large-scale infrastructure developments. It involves dividing the construction process into three distinct phases - *preparatory*, *initial*, and *follow-up*. The system emphasizes proactive prevention and early identification of deficiencies to minimize rework and ensure that the final product meets required quality standards. It requires various measures such as planning, documentation, inspections, testing, and coordination among stakeholders to effectively control and manage quality in construction projects.

The contractor and client are both responsible for ensuring the quality of a construction project. They share the common goal of delivering a high-quality product that meets the specifications of the contract. The contract documents set the standards for quality, and the contractor is responsible for upholding those standards. The client, on the other hand, is responsible for verifying that the contractor meets the standards (Bennett, 2003).

The three phases of control form the core of construction quality management system (US Army Corps of Engineers South Atlantic Division, 2008). This systematic approach comprises three phases:

- Phase 1: Preparatory phase
- Phase 2: Initial phase
- Phase 3: Follow-up phase

Each phase serves a specific purpose in ensuring quality control throughout the construction project.



The three-phase control system

2.1 Preparatory phase: Setting the quality foundation

Preparatory phase sets a foundation for quality in construction projects. It ensures proper coordination, planning, and adherence to specifications, thereby laying a groundwork for successful project execution and achieving desired quality outcomes.

The preparatory phase marks the initial stage of the three-phase quality control system utilized in construction projects. This phase focuses on establishing a robust foundation for quality by ensuring all necessary preparations are completed prior to commencing each definable feature of work.

Definable features of work refer to distinct tasks within the overall construction project scope that require dedicated quality control measures (US Army Corps of Engineers, 1995). To

promote effective coordination and planning, preparatory meetings are held for each construction crew undertaking specific definable features of work.

Prior to starting any definable feature of work, preparatory phase meetings are conducted to ensure proper coordination and planning among all parties. These meetings take place for each construction crew undertaking the specific tasks, including when new crews rotate in. To promote effective communication, preparatory checklists outlining quality control requirements are developed for each distinct feature of work. These checklists are circulated among the project team members to establish shared understanding of deliverables.

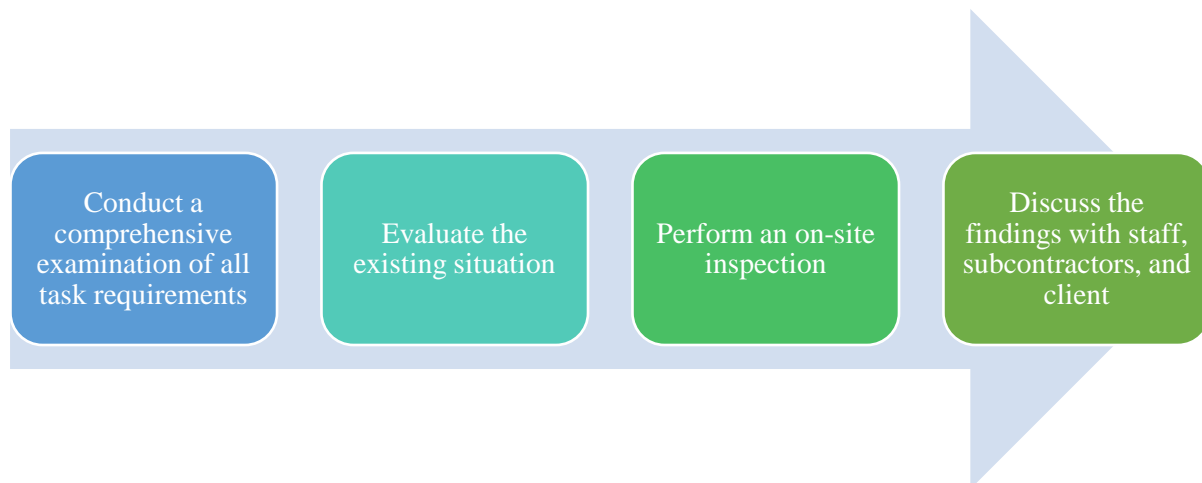
The discussions during preparatory phase meetings cover several important aspects. First, there is a review of applicable specifications to confirm that all quality requirements are well understood by the project team. This step helps in establishing a common understanding of standards and expectations that need to be met. Next, the team reviews applicable plans and shop drawings to verify that they align with the project objectives and accurately represent the design intent and scope of work. This validation process ensures that construction activities are executed in strict compliance with approved plans.

Another crucial aspect of preparatory phase is the verification of related submittals, shop drawings, and materials. The team checks whether these items have been properly tested and approved, ensuring that only compliant materials are used in construction. The team reviews inspection reports for received materials and verifies that they conform to contractual requirements. Additionally, they ensure that the materials are appropriately stored to prevent any damage or deterioration.

The project team also discusses the detailed sequence of work. This includes outlining the steps and procedures involved in carrying out a definable feature of work, considering factors such as dependencies, access, and resource availability. The objective is to establish a well-planned approach that optimizes efficiency and quality. Testing procedures and their frequency are also deliberated during the preparatory phase meeting. The team identifies any specific tests required to monitor quality at various stages of the project and ensures their timely execution at required intervals.

A thorough inspection of work area is conducted to verify the completion of all preliminary tasks in accordance with plans and specifications. This ensures that the site is ready for next phase of construction and that any necessary groundwork, such as site preparation or foundation work, has been completed to required standards. Site health and safety plan is reviewed to ensure that all safety precautions and regulations are being followed. The team verifies that all required safety equipment are on site and accessible to all personnel involved in the project. This is done to create a safe working environment for everyone involved.

In the preparatory phase, it is essential to define expected deliverables and required level of workmanship for each definable feature of work. This step plays a crucial role in establishing clear expectations regarding the quality of work and the necessary documentation to be provided upon completion.



Phase 1: Preparatory phase

2.2 Initial phase: Implementing quality control

During initial phase, the quality control measures are applied to ensure that the work being carried out meets the standards required by the project. This phase begins with initial inspections, which are conducted at the start of each definable feature of work and whenever new workers or crews are assigned to a task.

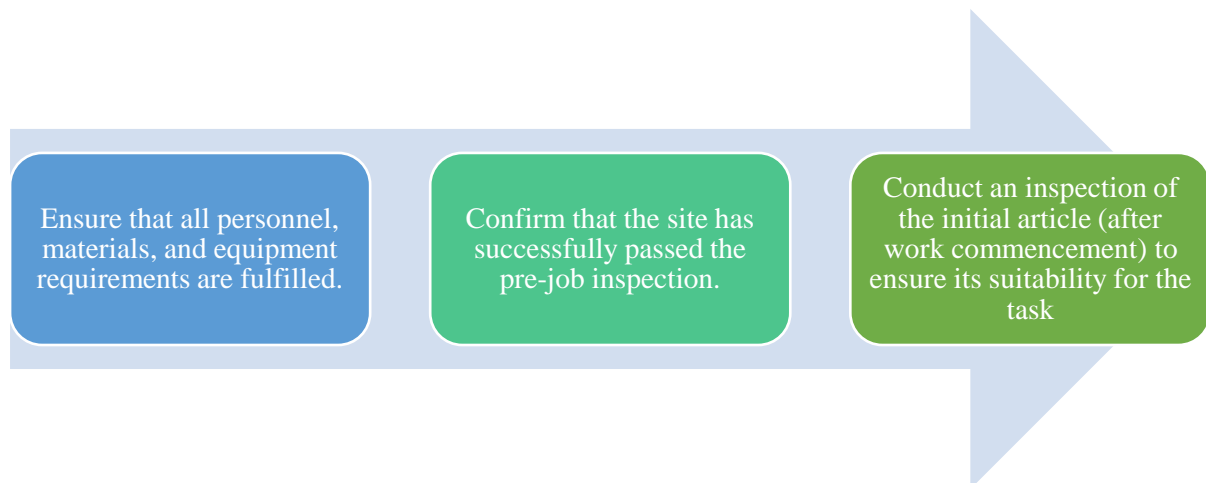
Initial inspections are conducted to review the minutes of preparatory phase meeting and ensure that the work aligns with design and specifications, including submittals and shop drawings. Any variations or inconsistencies that are identified during these inspections are promptly addressed to ensure continued adherence to the required standards.

In addition, the initial inspections verify that inspection and testing procedures are adequate. This entails ensuring that the appropriate level of inspection and testing is being carried out to monitor the quality of work. Inspections also establish the level of workmanship required, in terms of skill level and the number of skills involved.

During initial inspections, documentation of previous inspections of the work area is provided. This allows for a comprehensive understanding of progress made and any issues encountered. The work area is then re-examined to ensure ongoing compliance with specifications and quality requirements.

Detailed meeting minutes are recorded during initial inspections, documenting discussions, decisions, and actions taken. These meeting minutes serve as an important record of inspection process and valuable documentation for future reference, ensuring transparency, accountability, and traceability of quality control activities.

The initial phase ensures that necessary control measures are implemented from the beginning of each definable feature of work, promoting adherence to quality standards and facilitating effective communication and coordination among project stakeholders.

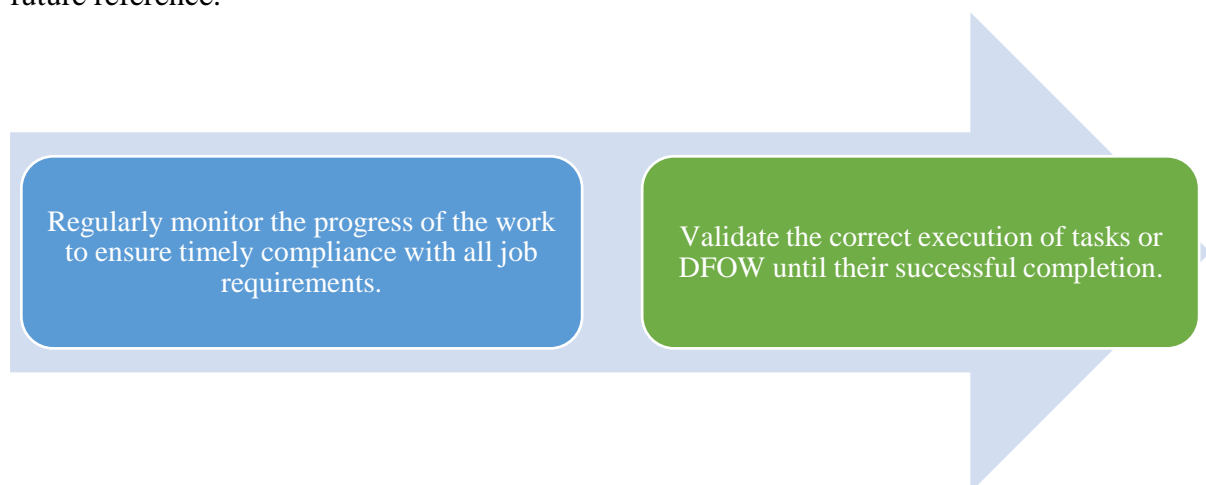


Phase 2: Initial phase

2.3 Follow-up phase: Sustaining quality

Follow-up phase is the final stage of three-phase control system, focused on sustaining quality throughout the duration of a construction project. During this phase, regular monitoring, inspections, evaluations, and audits are conducted to ensure that established quality control measures are being consistently implemented and that the final product aligns with contractual requirements.

Daily construction activities are carefully inspected, and findings are documented in daily reports. If any installation or testing activities are found to be non-compliant with the requirements, they are recorded in a non-conformance report for further action and resolution. All inspection and testing documents generated during this phase are filed and maintained for future reference.



Phase 3: Follow-up phase

3. An example of three-phase control system: Concrete works

Three-phase-control system is a versatile approach that can be applied to various types of construction works. One such application is in the context of concrete works, where the three phases of control play a critical role in ensuring quality and adherence to project requirements.

3.1 Preparatory phase

During preparatory phase, both consultant and contractor's teams thoroughly review specification requirements related to excavation, formwork, reinforcement, and embedded fixtures. Tests are conducted on concrete ingredient materials, including cement, aggregates, and water, to ensure they meet the desired standards. Concrete mix design is carried out to determine the appropriate proportions of ingredients for desired concrete properties. This phase establishes necessary parameters for quality control and ensures the suitability and compatibility of constituent materials of concrete.

3.2 Initial phase

During the initial phase, the same team continues to monitor the progress of concrete works. Close monitoring is done for every concrete operation, including batching, mixing, transportation, placement, compaction, and curing.

3.3 Follow-up phase

After concrete has been placed and consolidated, specially prepared concrete cubes or cylinders are tested to determine their compressive strength. Any deficiencies or deviations from the requirements are identified and corrected. Before proceeding with additional features of work, final follow-up checks are conducted to verify that all previous deficiencies have been addressed.

It is important to note that while this example uses concrete works, the three-phase control system can be adapted and used in a variety of other construction activities.

4. Advantages of three-phase control system

The three-phase control system in construction projects offers numerous advantages and plays a crucial role in ensuring quality and successful project outcomes. Some of key benefits and impacts of implementing this system are:

4.1 Effective quality control

The systematic approach of the three-phase control system enables effective quality control by ensuring that all necessary preparations, inspections, and follow-up measures are conducted at each phase. This reduces the likelihood of errors, deficiencies, and non-compliance with project requirements, resulting in improved overall quality of construction work. This systematic

approach guarantees that the final deliverables meet or exceed expectations, resulting in a higher quality outcome (Caldeira & Gatlin, 2019).

4.2 Improved communication

The three-phase control system promotes clear communication and coordination among project stakeholders, including consultant, contractor, quality control personnel, and other involved parties. Preparatory meetings, initial, and follow-up inspections provide opportunities for discussing project specifications, addressing concerns, and resolving any discrepancies, leading to a better collaboration among team members. An effectively implemented quality control program ensures that all project staffs have a clear understanding of their roles and responsibilities pertaining to quality. This fosters a seamless and efficient project execution, satisfying the expectations of all stakeholders involved (Caldeira & Gatlin, 2019).

4.3 Timely identification and resolution of quality issues

The proactive nature of the three-phase control system allows for an early identification of quality issues, non-conformities, and deviations from project requirements. By applying quality control measures at project's outset, the need for rework and repairs can be significantly reduced (Caldeira & Gatlin, 2019) leading to significant time and cost savings.

4.4 Increased client satisfaction

By consistently implementing a three-phase control system, construction projects can deliver high quality results that meet or exceed client expectations. An adherence to established quality standards, proper documentation, and regular inspections instill confidence in clients that their requirements are being fulfilled, leading to greater client satisfaction and positive project outcomes.

4.5 Cost savings and efficiency

Effective quality control measures implemented in the three-phase control system contribute to cost savings and improved project efficiency. By identifying and resolving issues early on, the need for rework and corrective measures is reduced, leading to optimized resource utilization, and minimized project delays and cost overruns.

4.6 Mitigation of risks

The systematic approach of the three-phase control system helps to mitigate risks associated with poor quality, non-compliance, and project delays. By carefully planning, thoroughly inspecting, and proactively following up, potential risks and deficiencies can be identified and addressed early, which can reduce the prospect of costly reworks and project delays.

In summary, the three-phase control system offers a range of benefits and exerts a positive influence on construction projects. By ensuring enhanced quality control, effective

communication, timely issue resolution, client satisfaction, cost savings, and risk mitigation, this system significantly contributes to the success of construction projects.

5. Challenges and mitigation strategies

Despite rigorous and coordinated efforts to manage the quality in construction, construction projects aren't immune to challenges such as poor quality of work and documentation. Effectively managing quality becomes challenging due to a multitude of factors including, but not limited to, inadequate planning, changes and delays, lack of resources etc.

Construction is a complex process that requires the expertise and coordination of different people, including owners, architects, contractors, and vendors. This complexity can make it difficult to achieve required quality, as it can lead to communication barriers and a lack of coordination. To overcome these challenges, it is essential to maintain open channels of communication and to ensure that all stakeholders are working together towards a common goal.

This section discusses some of the most common challenges faced in quality control, as well as some strategies for mitigation.

5.1 Improper planning and documentation

One of the main challenges in quality control is the lack of proper planning and documentation. This can lead to ambiguities, miscommunication, and inadequate allocation of resources, which can compromise quality.

To address this challenge, it is essential to develop a comprehensive quality control plan. This plan should outline necessary procedures, responsibilities, and documentation requirements for each phase of project. Quality control plan should be developed collaboratively by the contractor and consultant and approved by the client or project owner.

The contractor is responsible for implementing quality control plan. This includes executing the work in a skillful manner that adheres to contractual requirements, coordinating and scheduling tests as specified, and employing appropriate means and methods of construction.

Clear communication and regular updates on the quality control plan can ensure that everyone involved understands their roles and responsibilities, leading to effective quality control.

5.2 Compliance with specifications and standards

Another major challenge in quality control is ensuring compliance with specifications and standards. Construction projects often involve multiple contractors, subcontractors, and suppliers, each with their own processes and procedures. This diversity can make it difficult to maintain consistent quality across different parts of project.

To address this challenge, it is important to establish clear expectations and standards from the beginning and communicate them to all involved parties. Regular inspections and quality audits should be conducted to assess compliance and identify any deviations. Non-compliance should be addressed promptly through corrective actions, such as rework or replacement of materials.

5.3 Project changes and delays

Construction projects are often subject to changes and delays, which can have a major impact on quality control. Changes in design, scope, or schedule can disrupt the quality control process. To mitigate this challenge, it is essential to establish a change management system to allow for proper documentation, evaluation, and approval of changes. It is also important to assess the impact of changes on quality control and adjust the quality control plan accordingly.

Delays in project timelines can affect the availability of resources and may lead to rushed or compromised quality control activities. Mitigation strategies for managing delays include proactive schedule management, resource allocation, and re-allocation. These strategies can help to ensure that quality control activities are given adequate time and attention.

5.4 Lack of skills and resources

Construction projects are often subject to tight schedules, limited budgets, and resource constraints. If these constraints are not managed effectively, it can lead to poor quality, delays, or the removal of essential activities from project's scope. When time and resources are limited, inspections can be rushed, testing can be inadequate, and quality control processes can be compromised. This can lead to sub-standard work and poor project oversight.

To address these challenges, it is crucial to invest in training and development programs for quality control staff. Regular training sessions on quality control practices, construction techniques, and relevant regulations can enhance the skills and knowledge of the workforce. Additionally, ensuring access to the necessary resources, tools, and equipment is essential to facilitate effective quality control.

By taking these steps, construction projects can improve their quality and reduce the risk of costly rework and repairs.

5.5 External factors and environmental conditions

Construction projects are often subject to external factors that can impact the quality control process. These factors can include weather conditions, regulatory changes, and differing site conditions etc. To mitigate the risks associated with these factors, it is important to conduct regular risk assessments, monitor external factors closely, and have contingency plans in place. Flexibility and adaptability are key to addressing unexpected challenges and ensuring that quality control is maintained despite external influences.

6. Conclusion

Quality in construction projects is not something that happens by chance. It requires careful planning and control throughout the project lifecycle. While adopting a three-phase quality control system poses challenges, the benefits can be realized through proper preparation, clear communication, strict adherence to specifications, adaptive change management, and investment in skilled resources.

A thoughtfully developed project management plan forms the critical foundation for successful three-phase control system implementation. This plan must comprehensively address quality, procurement, risk, and contingency measures for any deviations. Proactive mitigation of uncertainties is essential even before execution commences.

Correctly instituted quality control processes ensure construction progresses as planned. With a holistic quality management strategy, defect-free, high-quality construction is no longer a pipe dream.

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About the Author



Yamanta Raj Niroula, PMP

Kathmandu, Nepal



Yamanta Raj Niroula is a seasoned engineering and project management professional with over 15 years of experience in overseeing all phases of construction and infrastructure programs.

He has overseen engineering and infrastructure programs across eight countries, including Nepal, Maldives, Singapore, Afghanistan, Philippines, Nigeria, Yemen, and Sudan.

His skill set includes design management, procurement, construction management, quality assurance/quality control, monitoring and evaluation, and close-out of construction projects. He holds a Master's degree in Rural Development and Bachelor's degree in Civil Engineering. He obtained his Project Management Professional (PMP) certification in January 2011. Currently located in Kathmandu, Nepal, he can be reached at niroulayr@gmail.com.