

Research Paper

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Impact of quality change management on civil engineering projects in India

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Abstract: The elimination of non-conformance is one of the goals of quality management, which can be accomplished by effectively managing and supervising the project. The excellent quality results in increased production and reduced costs, contributing to a rise in the competitive edge. The present body of research has examined the effect of quality management on the performance of building projects in the Indian industry. Different researchers have strived to identify the factors that affect the performance of construction projects. A structured questionnaire was floated to different professionals in the industry, that is, architects, engineers, consultants, developers and researchers, and >152 valid responses were received. The questionnaire asked respondents to respond on a Likert scale of 1–5. The questionnaire asked about the impact of quality on different aspects of the construction project's performance. Relative importance index (RII) are obtained to rank the elements in order of importance. According to the factor analysis results, three primary components account for 62% of the variance. The results show that the significant aspects of the project affected by quality are rate of rework, project performance, cost, safety, labour productivity and profitability with RII scores of 0.85, 0.82, 0.78, 0.76, 0.75 and 0.74, respectively.

Keywords: construction management, quality management, construction industry, factor analysis, construction productivity, relative importance index

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1 Introduction

The construction sector is undergoing consistent shifts due to the expanding variety of technologies, funding sources and development procedures. Currently, the complexity and difficulty that construction projects undergo are significantly higher than in the past. It was most common for project teams to deal with unprecedented amounts of change. The purpose of this investigation on the influence of quality management on project performance efficiency is to make projects more successful. In today's world, marketplaces are becoming more time and money-sensitive, which places pressure on businesses to produce their more intelligent products at lower prices and in shorter amounts of time. However, in the process, they sacrifice product quality in order to ship products more quickly and at a lower cost. It is essential to maintain quality as well. The quality department must prioritise the quality of work to avoid the need for subsequent rework, which would result in additional time, costs and potential delays in project delivery. Given the contractual obligations related to project timelines, it is imperative to address this issue promptly and with focus on the customer. Dixit et al. (2019).

The main goal of all organisations is to satisfy their shareholders and customers. All customers pay a high price for their desired products. When organisations fail to deliver quality according to the desire of the customer, they never deal with the same developer in the future (Guntuk and Koehn 2010 Tezel et al. 2010; Durdyev and Mbachu 2011; Jarkas 2015; Kazaz et al. 2015; Aarseth et al. 2017; Singh et al. 2018; Xu et al. 2018). Studies show that 85% of quality problems in construction projects happen due to a lack of commitment from the top management and the project team (Arashpour et al. 2014; Dixit and Saurabh 2019). If there is a quality issue, then rework is done, which subsequently increases the cost and duration of the project. In most cases, it comes under the responsibility of the project manager to prevent the project from cost overrun and time overrun due to poor quality.

Similarly, poor project performance may lead to numerous issues, as presented in Figure 1.

As a quality manager, it is wise to create systems and procedures and update the top management and all parties involved in the project team so that they have knowledge about the process. They should educate the project team about quality and its importance. Quality is a significant aspect of a construction project, and it helps the project manager to stay active and alert during all stages of the project. Maintaining the quality of the construction project is the project team’s responsibility. A project manager can prevent quality issues with effective quality policies. Otherwise, it can result in loss of the construction project performance and thus loss of future business and damage to their image in the market (Pignanelli and Csillag 2008b;

Bröchner and Olofsson 2012; Aziz and Hafez 2013; Ma et al. 2015; Gilbert Silvius et al. 2017; Pandey et al. 2017). Different problems that have been reported in the literature on construction project performance are as follows:

Budget overrun, unmatched timeliness, unsafe working condition, poor quality and dissatisfaction of clients (Ganesan 1987; Howell 1999; Zou et al. 2007; Nasir et al. 2012; Vereen et al. 2016; Nguyen and Watanabe 2017; Panas and Pantouvakis 2017).

In order to enhance the overall performance of construction projects, the construction industry must first determine the aspects that could contribute to the success or failure of individual projects. Throughout the years, a significant number of studies have been carried out to determine the factors responsible for the success or failure

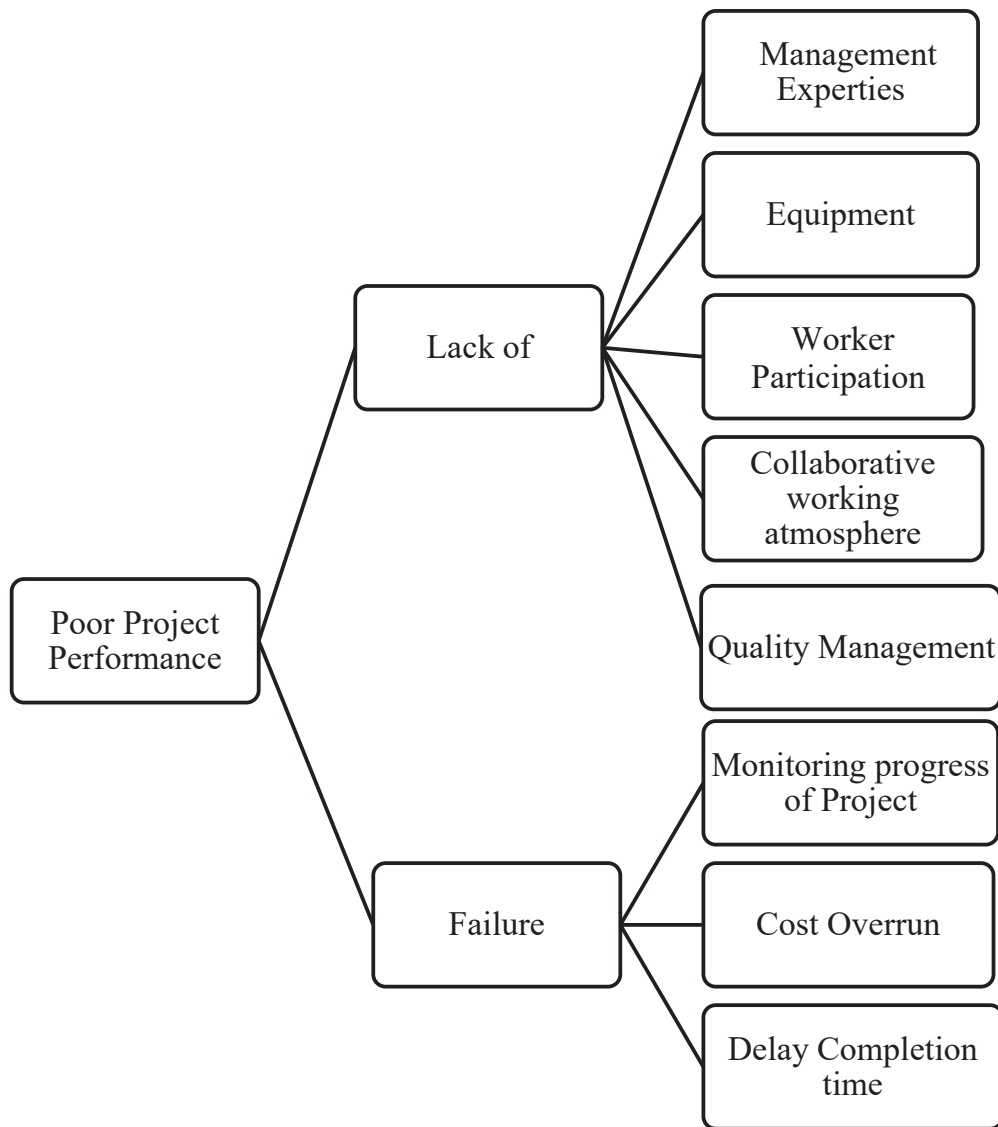


Fig. 1: Poor project performance leads towards high costs.

of construction projects. The factors affecting the success or failure of a project, which are described in different studies, are as follows:

- I. Project management techniques (ISO 31000, 2009; Nguyen and Watanabe 2017; Payne 2005; Shan et al. 2011; York Bigazzi and Rouleau 2017).
- II. Internal project factors such as the size of the project, complexity of the project, type of project and nature of the project (Lim and Alum 1995; Abdul Kadir et al. 2005; Frödell et al. 2008; Mirahadi and Zayed 2015; Vogl and Abdel-Wahab 2015; Molavi and Barral 2016; Tezel and Aziz 2017).
- III. External factors such as political and social factors, economic factors and technological innovations (Lim and Alum 1995; Abdul Kadir et al. 2005; Frödell et al. 2008; Alkaf et al. 2012; Arashpour et al. 2014; Kazaz et al. 2015; Mirahadi and Zayed 2015; Vogl and Abdel-Wahab 2015; Anvari et al. 2016; Molavi and Barral 2016; Tezel and Aziz 2017; Dixit and Saurabh 2019).
- VI. Procurement strategies, supply chain (Cooper et al. 1997; Berke and Satir 2011; Touboulic and Walker 2015; Tatoglu et al. 2016; Dallasega and Rauch 2017; Genovese et al. 2017; Saththasivam and Fernando 2017; Castillo et al. 2018).
- V. Culture of the organisation (Greed 2005; Sundaray 2011; Andrew and Sofian 2012; Barrett and Bourke 2013; McGregor 2016; Nguyen and Watanabe 2017) (Table 1).

1.1 Total quality management (TQM)

TQM is the representation of an organisation's attitude and culture, with the goal to satisfy the needs of the customer by using products and services of good quality (Mehta et al. 2014; Sadeh and Garkaz 2015; Sahney 2016). The organisation has quality in their culture, reducing waste and defects in its operations and with its process being done right the first time. TQM is a method in which all stakeholders are involved in the continuous improvement process of project development. It combines management with quality to improve the project's performance after eliminating rework and waste (Batty et al. 2012; Mahmood et al. 2014; Sadeh and Garkaz 2015; Kuraksin et al. 2017).

TQM is a management function that integrates engineering, design, development, finance and customer services to focus on completing the project with customer satisfaction. It involves implementing a management strategy that improves service and product quality to achieve sustainable growth with greater customer satisfaction.

It supports organisations by continuously improving their processes with the help of the project team's experience and knowledge. The objective of TQM is to do the right things the first time, every time (Zeithaml 2000; Shan et al. 2011; Sao et al. 2017; García-Onetti et al. 2018).

1.1.1 Factors in TQM

The following factors are essential in TQM:

- i. Commitment by the whole project team
- ii. Deliver the product as per the specification
- iii. Reduction in cycle time
- iv. Reduce cost
- v. Just in time (JIT)
- vi. Continuous improvement
- vii. Employee involvement
- viii. Benchmarking and goal-setting
- ix. Focus on process improvement plans

1.1.2 Principles of TQM

- i. Commitment of the management
 - Plan
 - Do
 - Check
 - Act
- ii. Empowerment of the employee
 - Training
 - Evaluation
 - Ratings and review
 - Recognition
- iii. Continuous improvement
 - Quality in place
 - Cross-functional process
 - Attain, sustain, improve
- iv. Customer focus
 - Supplier management
 - Do not compromise on quality

1.2 Continuous improvement

TQM is mainly about continuous improvement at all levels, from designing, planning and decision-making to the execution of the project. It guides continuously improving performance by improving processes, personnel skills, capabilities and technology. It should deal with increasing capabilities to improve performance rather than improving results. Technology, operations and people capability are the focus areas for increased capabilities.

Tab. 1: Selected attributes for analysis

Attribute codes	Attributes selected for the study	References
A1	Impact of quality on reduction in rework	Doloi et al. (2012) and Arashpour et al. (2014)
A2	Impact of physical environment of the site on the quality performance of project	Aziz and Hafez (2013), Banawi and Bilec (2014) and Sezer and Bröchner (2014)
A3	Impact of quality on project performance	Ikediashi and Ogwueleka (2016), Carvalho and Rabechini (2017), Dabirian et al. (2017) and Nguyen and Watanabe (2017)
A4	Impact of quality on safety	Yuen (2004), Zou et al. (2007), Gatti et al. (2010), Zou et al. (2012) and Pandey et al. (2017)
A5	Impact of continuous improvement in quality management on the performance of the construction project	Howell (1999), Mostafa et al. (2016), Sweis et al. (2016) and Tezel and Aziz (2017)
A6	Impact of competency of a subcontractor on the project performance	Iyer and Jha (2005a), Powl and Skitmore (2005), Bardhan et al. (2007) and Olaniran (2015)
A7	Impact of site management and supervision staff on the project performance	Aje (2012), Salunkhe and Patil (2014) and Karimi et al. (2017)
A8	Impact of effective quality assurance on quality performance of project	Iyer and Jha (2005b), Backes-Gellner and Veen (2009), Vogl and Abdel-Wahab (2015) and Dixit and Saurabh (2019)
A9	Quality increase in labour productivity	Kuykendall (2007), Minde (2012), Nasir et al. (2014) and Poirier (2015)
A10	Impact of quality on cost	Kannan and Tan (2005), Glavan et al. (2009), Aithal (2015) and York Bigazzi and Rouleau (2017)
A11	Role of employee training on quality management and control in construction project	Bertelsen (2004), Doloi et al. (2012) and Mishra et al. (2016)
A12	Impact of organisational culture on the quality performance of the project	Nasirzadeh and Nojedehi (2013), Poirier et al. (2015), Pheng et al. (2016) and Nima (2019)
A13	Impact of an effective safety programme on the quality performance of the project	Zou et al. (2007), Shan et al. (2011) and Chalker and Loosemore (2016)
A14	Impact of quality on profitability	Grau et al. (2009), Oral and Oral (2010) and Chancellor and Lu (2012)
A15	Impact of emphasising quality instead of price in the selection of supplier on the quality performance of the construction project	Xue et al. (2008), Aje (2012), El Refai et al. (2015) and Naganathan et al. (2015)
A16	Impact of management commitment on the quality performance of the project	Ruddock and Ruddock (2009), Arashpour et al. (2014) and Singh et al. (2018)
A17	Competency of the project management team	Abdel-Wahab and Vogl (2011), Ling et al. (2013) and Zhang and Chen (2016)

TQM believes people make mistakes, but poor systems and faulty processes cause them. Thus, they can be identified and eliminated by improving the capabilities and processes (Howell 1999; Ballard et al. 2002; Mostafa et al. 2016; Sweis et al. 2016). The three significant mechanisms of prevention are as follows:

- Prevent mistakes (mistake-proofing or poka-yoke).
- Identify them at early stages where they cannot be prevented and reduce their impact (inspection at source or by the next operation).

- Stop the work and improve the operation where mistakes occur frequently (stop in time).

After implementing TQM, the following advantages can be achieved:

- Easy to adapt to the changing market conditions and government policies
- Increase productivity
- Increase market value
- Decrease defects and waste

- Increase profitability
- Reduce cost
- Increase customer satisfaction
- Improve shareholder value
- Innovative processes

2 Literature review

Chan et al. (2004) studied a list of variables to identify the factors which affect the success of a construction project. Their paper aims to form a structure for concepts of critical success factors (CSF). They reviewed seven journals in the construction field to review previous studies related to the success of the projects. They identified project-related factors, human-related factors, external environment and project management actions and procedures as five significant independent variables affecting a construction project's success.

Doloi et al. (2012) analysed the factors affecting delay in the Indian construction project. They selected 45 attributes and identified key factors that impact delays in the Indian construction industry. They then established a relationship between the critical aspects and the factors affecting delays (Doloi et al. 2012). A questionnaire and personal interview formed the basis for this research. They have identified substandard contracts, improper planning, poor site coordination, lack of commitment, inefficient site management, communication gap and unclear project scope as the critical factors responsible for delays in construction projects. They formed a regression model, which indicates that architects' reluctance to change, slow decisions from clients, poor productivity and rework due to poor quality are the reasons for the delays in construction projects.

Pignanelli and Csillag (2008a) They studied the impact of quality management on profitability. They followed the evaluation of 31 firms recognised by the Brazilian National Quality Award for 10 years. They used statistical tools like regressions, parametric analysis and non-parametric analysis. These studies aimed to identify a sample of companies that have already implemented quality management and measure their performance by comparing it with those that do not use quality management models. The results show that the firms implementing quality management models achieved higher profitability and work performance. This study has some limitations about the size and profile of the sample. Regarding the sample, the study has another limitation, that is, the characteristics of the sample, as the only firms recognised by the Brazilian National Quality Award are selected.

2.1 Different theories in construction management given by different authors

The researchers who contributed the most to the quality management domain were Thomas and Lamouri (1998), Abdel-Galil (2012), Aziz and Hafez (2013), Mahmood et al. (2014) and Sen et al. (2018). They supported the idea that there is a connection between the financial performance of a firm by adopting the quality management system. Deming points out that to improve the quality of products and different services, reducing variations and uncertainties from the projects' production processes need to be undertaken. Deming has stated 14 principles as the fundamental elements to his idea. Kannan and Tan (2005) studied the three approaches supply chain management (SCM), JIT and TQM to understand their interconnection with each other and their impact on business performance. The JIT phenomenon simplifies the production process by eliminating waste. It reduces set-up time, controls material flows and emphasises preventive maintenance, and thus reduces excess inventories and utilises the resources more efficiently. TQM emphasises focus on the customer, continuous improvement, training and development of employee and improved decision-making processes. Alignment of customer expectations and product design and focus on quality at each stage of production can improve business performance. SCM improves the decision-making process by allowing the integration of suppliers and buyers. It can reduce lead times, and the cost and quality of materials. SCM, JIT and TQM improve the efficiency and effectiveness of organisations by improving their operational functions. Results show the many interconnections between SCM, JIT and TQM at both the strategic and operational levels (Kannan and Tan 2005). SCM and commitment to quality have a great influence on project performance. The factors identified and analysed by are listed below:

- I. JIT
 - Supply management
 - Flow of material
 - JIT commitment
- II. TQM
 - Design of product
 - Quality commitment
 - Capability of supplier
- III. SCM
 - Sharing of information
 - Integration of supply chain
 - Development of supply chain
 - Coordination of supply chain

Researchers have studied the scope of the Project Organisational Culture and its impact on the Performance of Construction Projects (Nguyen and Watanabe 2017). Due to its vital role in the project's success or failure, cultural influence has received the attention of academics. The purpose of their study is to analyse the influence of organisational culture on the performance of construction projects. For data gathering by structured questionnaire, they analysed 199 completed construction projects in Vietnam. The literature shows that satisfaction of participants and overall better performance can be achieved by worker orientation, commitment of contractor and reliance with goal alignment. Cooperative orientation and commitment of the contractor can improve the productivity of labour, whereas learning performance can be ensured by the commitment of the contractor with trust and goal alignment. Nguyen and Watanabe (2017). As per the above available literature the different project organisational culture dimensions are Empowerment orientation, Cooperative orientation, Reliance and goal alignment, Worker orientation and Commitment of contractor.

The literature shows that satisfaction of participants and overall better performance can be achieved by worker orientation, the commitment of contractor and reliance with goal alignment. Cooperative orientation and commitment of contractor can improve the productivity of labour. Learning performance continuous adaptive blending (CAB) is predicted by contractor commitment and goal alignment and reliance. With good results, this study also has some limitations. The first limitation is that the study is conducted on a small size sample. With the increase in sample size, the results may vary. The second limitation is about the nature of the respondents. The major respondents were contractors (85%). This lack of diversity in respondents might affect the results. David Waldman defined the influence of TQM on work performance (Waldman 1994). His findings show that TQM may result in continuous improvement and better project performance by cooperative efforts and better teamwork.

The identified key elements for TQM are as follows:

- I. The commitment of top management to place quality as the highest priority.
- II. Quality is defined as meeting customers' expectations at the lowest cost.
- III. Practices of institution of leadership towards TQM vision and values.
- IV. Development of a culture which adheres to quality.
- V. Empowerment and involvement of all members of the organisation for achieving improvements in quality.
- VI. Work procedures and employee capabilities can be improved by training and benchmarking with the commitment towards continual improvement.
- VII. Involvement of external suppliers and customers in TQM.
 - I. Person factors
 - Knowledge, abilities and skills
 - Motivation
 - II. System factor
 - Person enhancers
 - Systems demands

Mallawaarachchi and Senaratne (2015) studied the importance of quality for success of the construction project. They believed that a balance between quality, cost and time is important. At high cost, it is possible to achieve high quality in less time, and at longer duration it is possible to achieve high quality at low cost. A required level of quality at every stage is extremely important for success of a construction project. Finally, to have easy and smooth entry in the commissioning phase of a construction project it is important to have good construction quality and minimum defects. They reviewed the literature and processes at construction stages and concluded that quality is most important for a successful construction project. Prevention, appraisal and failure due to poor quality could increase the organisation's unnecessary cost. A proper quality management plan can be implemented at the stage of project inception where drawings, standards and constructability can improve the quality of the project. It is important for the organisation to have management commitment and support for continuous improvement. To lead towards success of construction project, awareness and training programme and collaboration of all parties involved is essential. Philip Barlow analysed the cost of poor quality in the American construction industry. According to him, the construction industry needs to decrease non-conformance to quality and cost of poor quality and understand the importance of good quality. Rework in commercial building costs around 5% of direct cost (Barlow 2009). In 2007, due to rework the construction industry in the U.S. wasted US\$62 billion of direct cost of poor quality from US\$1.246 trillion (Barlow 2009). Researchers have predicted that quality costs can go up to 20% of construction costs (Crosby 1980; Barlow 2009). The direct cost of rework in industrial construction projects can go up to 12% of the total cost (Barlow 2009). In commercial building construction, direct cost estimates from rework averaging about 5% are more conservative (Barlow 2009). The main concern of the Deming theory was to lower down the variability and achieve conformance to quality

and specification. Good quality leads to higher productivity and decreased cost and thus increases the competitive advantage. Measurement of quality is done through various methods. Seven dimensions of quality were described by Barlow (2009), which applies to performance of the construction project, reliability of project, conformance, durability of construction, serviceability of project, aesthetics of project and perceived quality of construction.

2.2 Cost of quality

Prevention cost: To prevent the issue of internal or external non-conformance of activities undertaken by the contractor, the following steps are essential:

- i. Planning
- ii. Training
- iii. Control of process.

Appraisal cost: To conduct an inspection, data collection and evaluation process by the contractor.

- i. Testing and equipment
- ii. Control of System
- iii. Survey.

Internal failure cost: These costs are due to Contractor's unsatisfactory (failure) results prior to acceptance of the building specification by the owner.

- i. Scrap
- ii. Rework
- iii. Expediting
- iv. Additional Material

External Failure Cost: These costs are due to poor quality (defect) by the contractor after acceptance of the building by the owner.

- i. Warranty cost
- ii. Litigation
- iii. Brand Image

Many researchers attempt to graphically depict the cost of quality. Barlow (2009) developed one such graph as shown in Figure 2.

Based on the literature review, researchers have identified specific attributes of quality management that significantly impact project performance. The selection criteria include the following:

1. **Relevance:** Attributes directly related to CSFs identified in previous studies.
2. **Impact:** Attributes that have shown a measurable impact on project performance metrics such as cost, time, quality and stakeholder satisfaction.
3. **Frequency:** Attributes frequently cited in the literature as influential factors in construction project outcomes.

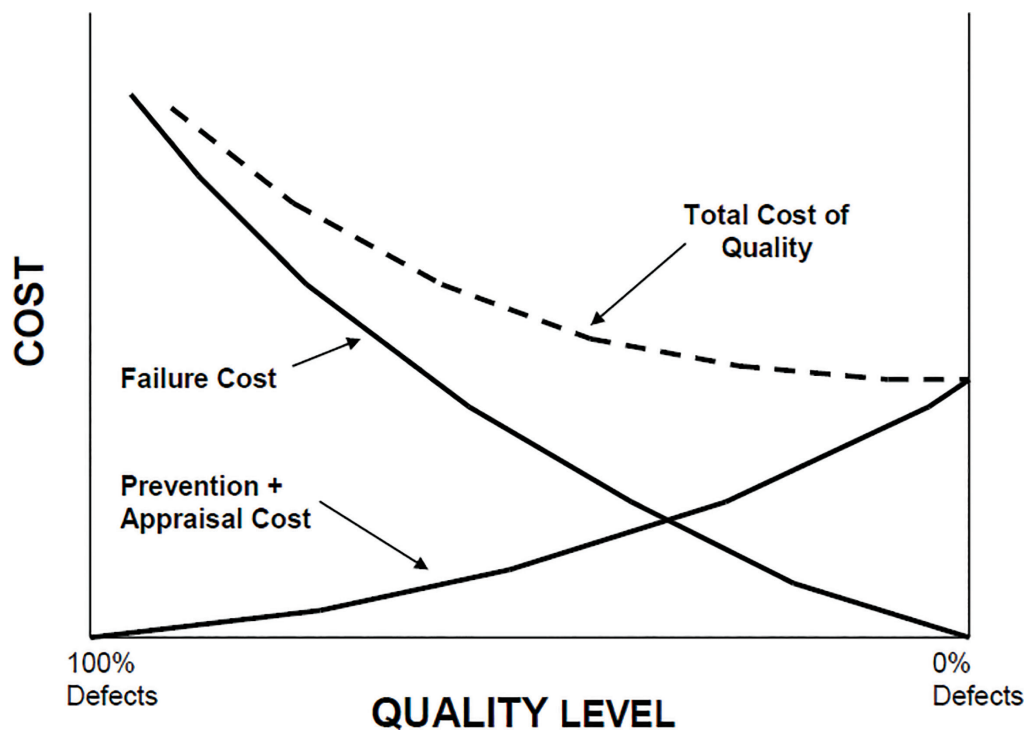


Fig. 2: Cost versus quality level (Barlow 2009).

2.3 Research objectives

- To identify the attributes of quality management that impact project performance.
- To analyse and find out the impact of quality management attributes on the performance of a construction project.

The literature highlights several critical factors influencing construction project success, such as effective quality management, organisational culture and addressing delays. However, while previous studies have identified numerous factors and established relationships between them, there is need for a comprehensive analysis that integrates these findings to form actionable insights for improving project performance. This study aims to fill this gap by systematically analysing quality management attributes and their impacts, providing a structured approach to enhancing construction project outcomes. The research question explores the relationship between specific quality management attributes and construction project performance. This involves the following:

1. Identifying key attributes: Review the existing literature to identify attributes that have been shown to significantly impact project performance, such as planning, process control, resource management and continuous improvement.
2. Analysing impact: Using quantitative and qualitative methods to assess how these attributes affect performance metrics, such as timeliness, cost-efficiency, quality and stakeholder satisfaction.
3. Developing strategies: Synthesising findings to provide practical recommendations for optimising quality management practices, thereby improving project outcomes.

By addressing these areas, the research aims to provide a comprehensive understanding of enhancing construction project performance through effective quality management.

3 Research methodology

Through extensive literature review and expert analysis, we were able to determine the aspects of quality management that affect the project's performance. With the support of discussions held with various industry experts, the various aspects of the project's performance

that are influenced by the quality management system have been determined. A structured questionnaire survey was used to collect industry data and find out the effect of quality management on the performance of projects in the Indian construction sector. Initially, a pilot study was conducted to check the consistency of the questionnaire, and after receiving the responses, the questionnaire was updated. This method is used broadly in various global research projects. Requests were made to the respondents to rate the impact of quality on different attributes of the project performance using a Likert scale of 1–5 (Hughes and Thorpe 2014); the respondents are different professionals working in the Indian construction industry. The responses received from the online questionnaire survey were analysed using different statistical tools (relative importance index [RII], reliability analysis, Kaiser–Meyer–Olkin (KMO) test and factor analysis).

3.1 Development of questionnaire

The questionnaire used in this study was developed through an extensive process involving a thorough literature review and expert analysis. This process identified the aspects of quality management that affect project performance. Additionally, discussions with various industry experts provided valuable insights into the various aspects of project performance influenced by the quality management system.

The initial version of the questionnaire underwent a pilot study to assess its consistency and reliability. Feedback from the pilot study participants was carefully analysed, and necessary modifications were made to enhance the questionnaire's effectiveness and relevance.

3.2 Description of target group and addressing bias

The target group for this study comprises professionals actively engaged in the Indian construction industry. This includes project managers, engineers, architects, contractors and other relevant stakeholders with expertise in construction project management and quality assurance.

To address potential biases in our sampling, we employed random sampling techniques to ensure representation from various construction industry sectors. Additionally, sensitivity analyses were conducted to assess the robustness of our findings and identify any potential biases that may arise from sample selection.

3.3 Data collection and analysis methods

Data collection was conducted through a structured questionnaire survey administered online to professionals in the Indian construction industry. Participants were requested to rate the impact of quality on different attributes of project performance using a Likert scale ranging from 1 to 5.

The responses collected from the questionnaire survey were analysed using a variety of statistical tools, including the RII, reliability analysis, KMO test and factor analysis. These analytical techniques provided insights into the relative importance of quality management attributes and their impact on project performance in the Indian construction sector.

4 Data collection

4.1 Respondent's profile

The respondents were selected from a diversified portfolio. The average experience of the respondents is 8 years. A structured questionnaire has been floated to different professionals in the Indian construction industry including but limited to architects, engineers, consultants, academicians, built environment professionals, developers and researchers. The questionnaire was shared with 370 respondents and after three reminder emails over a period of 2 months, a total of 152 valid completed responses were received with a response rate of 41%. The respondents were asked to rate the different aspects of construction project performance affected by quality management system on a Likert scale of 1–5 according to their influence. The values of Likert scale of 1–5 are defined as 1 = 'no Impact', 2 = 'very Low Impact', 3 = 'moderate Impact', 4 = 'high impact' and 5 = 'very high impact' (Dixit et al. 2017).

4.2 Reliability analysis

The reliability analysis is the measure of the consistency of data collected. Its value varies from 0 to 1, and a value of >0.5 is considered good for the study using structured questionnaire surveys (Dixit et al. 2019). For the current research project, the value is 0.81, which is excellent for the study as shown in Table 2. Cronbach's alpha is a measure of internal consistency reliability, indicating the extent to which items in a scale or questionnaire are correlated. In our study, a value of 0.81 was obtained for Cronbach's alpha, indicating excellent reliability for the

Tab. 2: Reliability analysis for the study

Cronbach's alpha value	No. of attributes	No. of samples
0.816	17	152

structured questionnaire used. This high level of reliability ensures that the data collected are consistent and dependable for analysis, contributing to the robustness of our study findings.

4.3 RII (R_{ii})

The respondents were asked to share their inputs on the attributes selected in the questionnaire on a Likert scale rating from 1 to 5 (Shah et al. 2019). RII is used to prioritise and rank the attributes on the basis of weighted average calculated using the below formula in which the number of responses and value of the Likert scale are used. From this positioning, elements were evaluated as having a direct or higher impact on project performance:

$$R_{ii} = \frac{\sum_0^1 r * n_r}{5N} \quad (1)$$

R = Rating on Likert scale

n_r = Number of respondents given rating r

N = Total respondents.

Eq. (1) is used for performing RII, while all considered attributes and their total respondents with relative scores are as listed in Table 3. Maximum (R_{ii}) value is measured as 0.85 for the attribute Impact of Quality on reduction in rework, while minimum (R_{ii}) value is measured as 0.62 for attribute competency of the project management team.

The attributes discussed were selected based on their RII scores and their relevance to key performance indicators in construction projects. The following criteria were used for the selection:

- High RII scores: Attributes with the highest RII scores were chosen as they indicate a greater perceived impact on project performance by the respondents.
- Relevance to key performance indicators: Attributes directly related to critical performance metrics such as rework, project performance, cost, safety, labour productivity and profitability were prioritised for detailed discussion.
- Comprehensive representation: The selected attributes represent a broad spectrum of quality management aspects, ensuring a holistic view of their impact on construction project performance.

Tab. 3: The impact of quality management system on different aspects of construction project performance

Attributes code	Total responses	Total score	RII	Variance	Range of validity	Attribute name
A1	152	637	0.85	0.12	0.78–0.92	Impact of quality on reduction in rework
A3	152	622	0.82	0.15	0.75–0.89	Impact of quality on project performance
A10	152	592	0.78	0.18	0.70–0.86	Impact of quality on cost
A4	152	577	0.76	0.14	0.69–0.83	Impact of quality on safety
A11	152	570	0.75	0.17	0.67–0.83	Role of employee training on quality management and control in construction project
A12	152	563	0.74	0.16	0.66–0.82	Impact of organisational culture on the quality performance of the project
A8	152	539	0.71	0.13	0.64–0.78	Impact of effective quality assurance on the quality performance of the project
A9	152	538	0.71	0.15	0.63–0.79	Quality increase labour productivity
A15	152	532	0.70	0.14	0.62–0.78	Impact of emphasising quality instead of price in the selection of supplier on the quality performance of the construction project
A16	152	524	0.69	0.16	0.61–0.77	Impact of management commitment on the quality performance of the project
A5	152	516	0.68	0.17	0.60–0.76	Impact of continuous improvement in quality management on the performance of the construction project
A13	152	509	0.67	0.15	0.60–0.74	Impact of an effective safety programme on the quality performance of the project
A14	152	509	0.67	0.18	0.59–0.75	Impact of quality on profitability
A2	152	494	0.65	0.14	0.58–0.72	Impact of physical environment of the site on the quality performance of the project
A6	152	478	0.63	0.19	0.54–0.72	Impact of competency of a subcontractor on the project performance
A7	152	471	0.62	0.13	0.55–0.69	Impact of site management and supervision staff on the project performance
A17	152	467	0.62	0.15	0.54–0.70	Competency of project management team

RII, relative importance index.

4.4 Impact of quality on rate of rework

The first aspect of construction project performance affected by quality is the rate of rework. It has a relative importance of highest index at 0.89. Poor quality of work is not accepted by the owner or management and cannot satisfy the customer too. The poor quality of work also decreases the safety of the tenant in the project in the later stage of building use. Poor quality of work leads to rework or rectification of work. It incurs the cost of additional material and generated waste. Good quality of work is essential to reduce the rate of rework. Good quality of

work satisfies the owner and management and majorly reduces the rate of rework.

4.5 Impact of quality on project performance

The second and major aspect of construction affected by quality is the project performance RII score at 0.88. Good quality of work leads to lesser rework and defects handling in the future of the building. Good quality of work also increases the satisfaction of the customer, owner and management team. With a satisfied customer, the owner

can get higher profitability and a good market image. Good construction quality also leads to less number of maintenance issues in the project in use stage and increases the performance of the building.

4.6 Impact of quality on cost

The third aspect of construction project affected by quality is that the cost has an RII score of 0.8545. Rework in a commercial building costs around 5% of direct cost. The construction industry in the U.S. spent US\$1.246 trillion in 2007 and among that US\$62 billion is dissipated from the direct cost on rework due to poor quality (Barlow 2009). Quality costs can go up to 20% of construction costs (Barlow 2009). The direct cost of rework in an industrial construction project can go up to 12% of the total cost (Barlow 2009). In commercial building construction, direct cost estimates from rework averaging to about 5% are more conservative (Barlow 2009). The cost of quality can be divided into four major parts: Prevention cost and Appraisal cost as good quality costs, and Internal failure cost and External Failure cost as poor quality costs.

4.7 Impact of quality on safety

The fourth aspect of construction project affected by quality is safety, with an RII score of 0.85. Safety of the workers during the construction of the project and safety of the tenant after the construction of the project are major aspects which are affected by the quality of work. Poor quality of work increases chances of failure and decrease in the level of safety. Good quality of work increases the level of safety as there are lesser chances of failure. There are enough number of examples available which show that the failure of a building is due to poor quality of work and lack of commitment from the management team and contractor towards the implementation of quality management systems.

4.8 Impact of quality on labour productivity

Another aspect of construction project affected by quality is labour productivity, with an RII score of 0.82. Good quality of work leads to the satisfaction of the owner and management team and increases the level of safety by decreasing the chances of failure. Good quality of work increases profitability as it decreases the internal and external failure costs. The worker is rewarded and encouraged by the contractor as well as the management team

for their good quality of work. Workers also feel safe if the quality management systems and effective quality assurance plans are in place. These will increase the productivity of the workers.

4.9 Impact of quality on profitability

The final aspect of the construction project affected by quality is profitability, with an RII score of 0.76. The desired quality reduces non-conformance and the cost incurred to reduce the non-conformance, which are appraisal cost, prevention cost as good quality costs, and internal failure cost and external failure cost as poor quality costs. The cost of implementing the quality management system is not more than the cost incurred due to rework and additional cost of the material. A similar type of study reported the impact of quality management on the profitability of the project studied. The results show that the firms that implemented quality management models achieved higher profitability and higher work performance (Pignanelli and Csillag 2008b).

5 Different factors affecting quality management

Factor analysis is a very useful tool to reduce the number of dimensions and to group the attributes into constructs/factors on the basis of covariance in between the attributes. A number of researchers used factor analysis to group the attributes into respective factors (Dixit et al. 2017; Dixit and Saurabh 2019). For this study, the principal component analysis with Varimax rotation is used. A total of three factors having an eigenvalue of greater than one were considered for this study. The overall contribution of all three attributes are presented in Figure 3 as per 100% scale as well as the accurate values.

All three factors explain a cumulative variance of 62%. The first factor (project quality management factor) explains a variance of 32.1% and has the following attributes: Impact of Quality on reduction in rework, Impact of Quality on Project Performance, Impact of Quality on cost, Role of Employee training on quality management and control in construction project, Quality Increases the labour productivity, Impact of emphasising quality instead of price in selection of supplier on quality performance of the construction project, and Impact of Quality on profitability having a factor loading of 0.515, 0.75, 0.72, 0.825, 0.51, and 0.56 respectively. The variation in factor

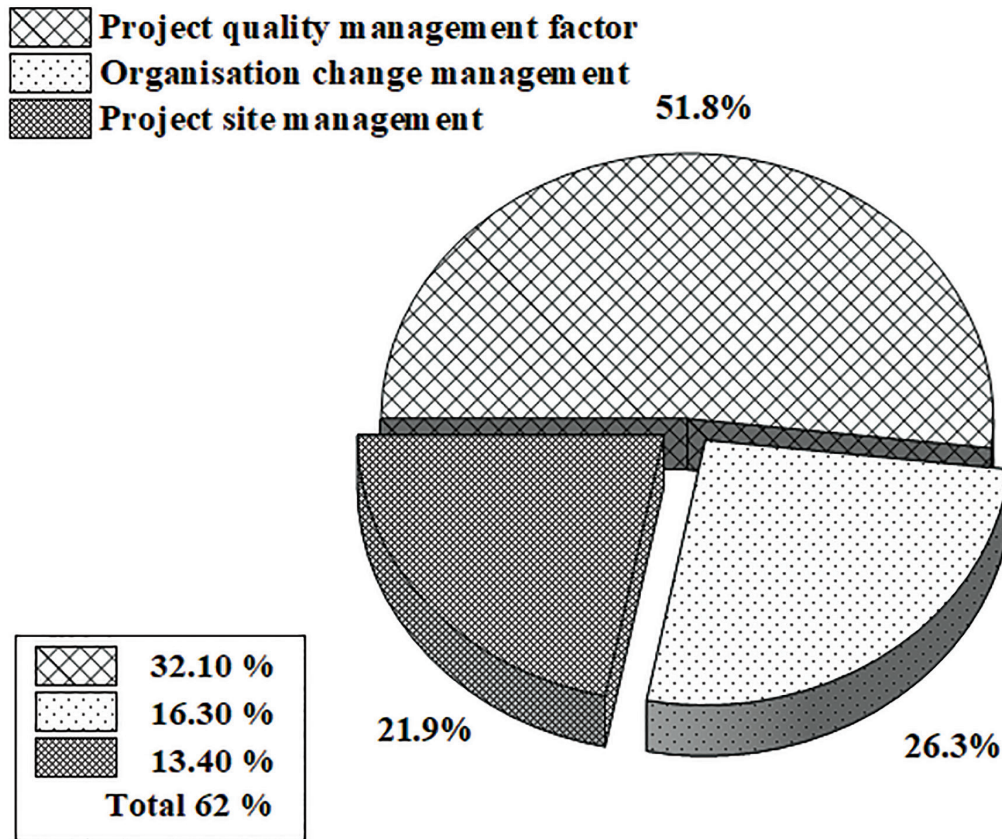


Fig. 3: Overall contribution of all three attributes.

loading on the basis of project quality management factor is presented in Figure 4.

Factor 2 (Organisation change management) explains a variance of 16.3% and has the following attributes: Impact of Quality on safety, Impact of Organisational Culture on quality performance of project, Impact of effective quality assurance on quality performance of project, Impact of management commitment on quality performance of project, Impact of effective safety programme on quality performance of project and Competency of project management having a factor loading of 0.53, 0.49, 0.54, 0.47, 0.62 and 0.409, respectively. Variation in factor loading on the basis of organisation change management is presented in Figure 5.

Factor 3 (Project site management) explains a variance of 13.6% and has the following attributes: Impact of continuous improvement in quality management on performance of the construction project, Impact of Physical environment of site on quality performance of project, Impact of competency of subcontractor on the project performance, and Impact of site management and supervision staff on the project performance having a factor loading of 0.6, 0.52, 0.481 and 0.56. Variation in

factor loading on the basis of project site management is presented in Figure 6.

The analyses have been performed on all three characteristics, and the results are tabulated in Table 4. It is shown that the impact of management commitment had the smallest loading factor on the quality performance of the project, while the role of employee training in quality management and control in construction projects had the largest loading factor. The highest possible factor loading was 0.825, while the lowest possible factor loading was 0.47. On the contrary, the qualities that deal with project site management are the least impacted factors and have the least percentage variance of explained (13.6%), whereas the elements that deal with project quality management have a high degree of influence or the largest percentage variance of explained (32.1%).

6 Discussion and Conclusion

‘The construction industry needs to experience two true paradigm shifts; one moves the industry from resources spent on quality non-conformance to resources spent on

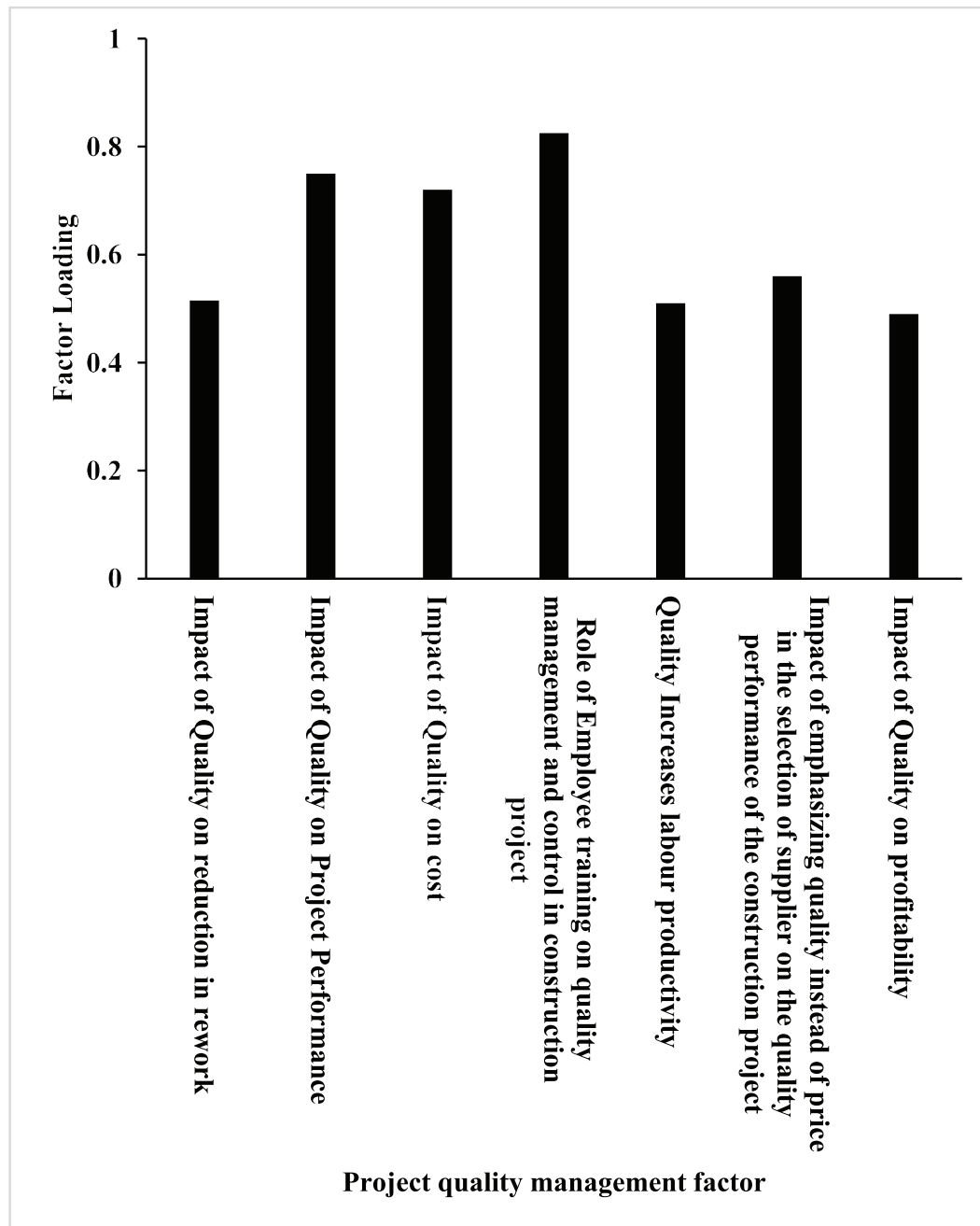


Fig. 4: Variation in factor loading on the basis of project quality management factor.

quality conformance, and one moves the construction business perspective from thinking in quality compliance mode to actual quality performance mode' (Barlow 2009). The research by Olaniran (2015) concluded, as reasonably expected, that 'the more you invest in prevention and appraisal, the less you will have to spend on internal and external failures'. Additionally, the findings 'demonstrate that there is a balance to be struck between the proactive cost of quality and the resulting cost of non-quality'. The cost of quality for conformance, which

is used for prevention and appraisal, are known amounts and they can be managed. The other cost of quality for non-conformance, which is used as internal and external failure cost, cannot be managed. In addition, the common consent among many is that the determinable cost of non-conformance is just a tiny part, representing only a small portion of all hidden costs (Zou et al. 2012; Ma et al. 2015; Durdyev and Ismail 2016; Ikediashi and Ogwuel-eka 2016; Molavi and Barral 2016). Indeterminable external failure costs such as the loss of future business and

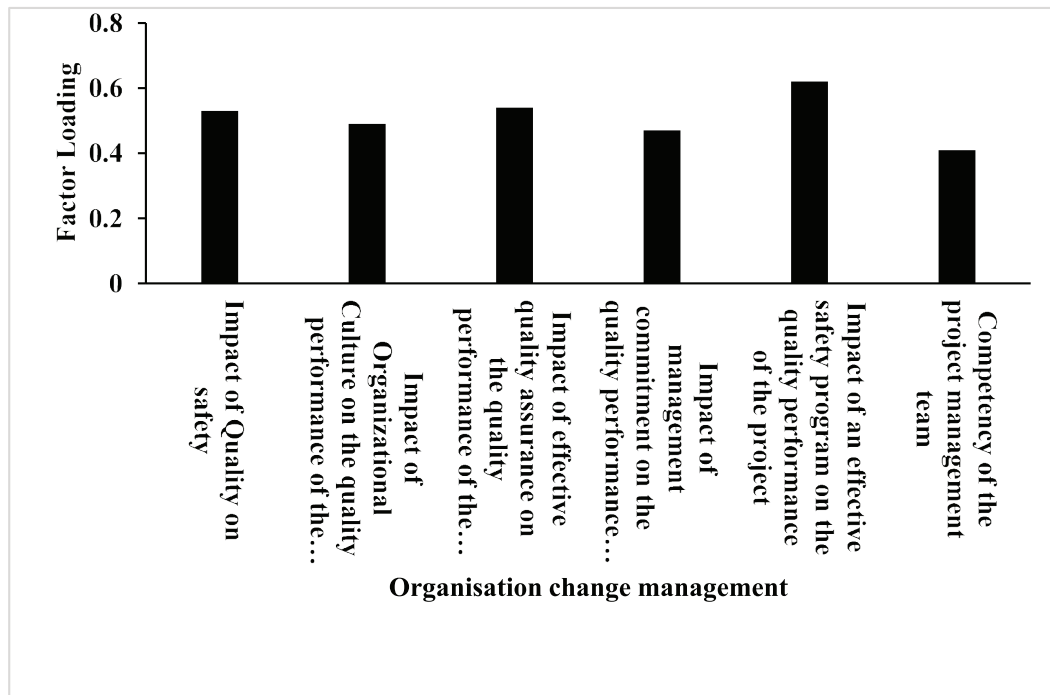


Fig. 5: Variation in factor loading on the basis of organisation change management.

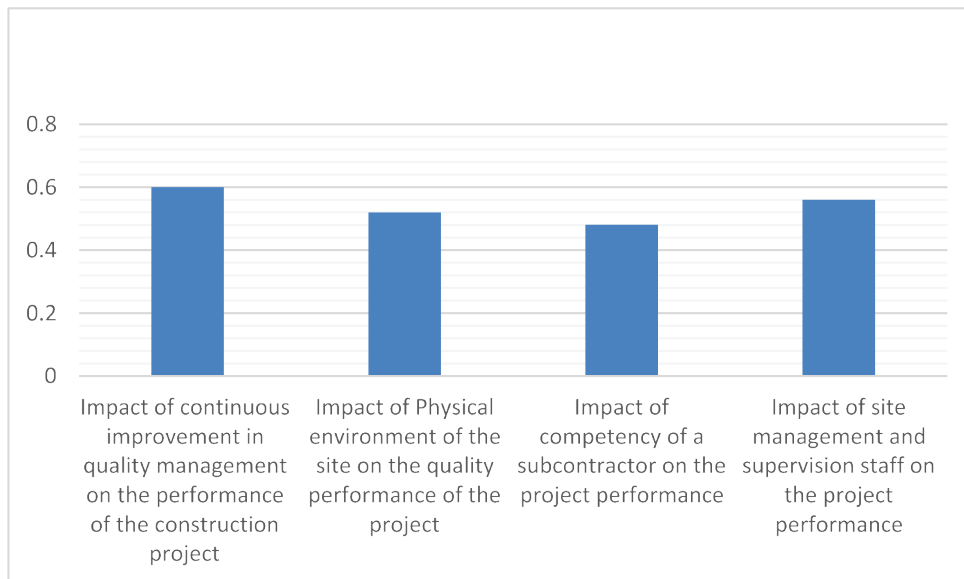


Fig. 6: Variation in factor loading on the basis of project site management.

damage to image are steep (Pignanelli and Csillag 2008b). The management can eliminate non-conformance by properly managing and controlling the project. Crosby (1980) says, ‘Quality is free, it’s not a gift but free, what costs money is the un-quality things – all the actions that involve not doing jobs right the first time’. After reviewing all the above research papers, it is observed that quality

management has a positive impact on project performance. Many other researchers have studied these, but there is no data available about the effect of quality management on the performance of a construction project.

TQM may result in continuous improvement and better project performance by cooperative efforts and better teamwork (Waldman 1994). The firms that implemented

quality management models achieved higher profitability and higher work performance (Pignanelli and Csillag 2008b). There is an improvement in the financial performance of the firm after adoption of the quality management system. SCM and commitment to quality have a great influence on project performance (Nguyen and Chileshe 2015). The satisfaction of participants and overall better performance can be achieved by worker orientation, commitment of contractor and reliance with goal alignment. Cooperative orientation and commitment of contractor can improve the productivity of labour. Learning performance CAB is predicted by contractor commitment and goal alignment and reliance (Nguyen and Watanabe 2017). To lead towards success of a construction project, awareness and training programme and collaboration of all parties involved is essential (Mallawaarachchi and Senaratne 2015). Internal and external failure costs can be reduced by investing more in the prevention and appraisal costs. A proper quality management plan can be implemented at the stage of project inception where drawings, standards and constructability can improve the quality of the project. The cost of quality for conformance, which is used for prevention and appraisal, are known amounts and they can be managed. This study is based on 152 valid responses from a structured questionnaire. The respondents gave their responses on a Likert scale of 1–5 based on their experience of various aspects of construction project being affected by quality. Various factors were analysed and prioritised based on their score in RII. The major aspects of the project affected by quality are the rate of rework, project performance, cost, safety, labour productivity and profitability. They have RII scores of 0.85, 0.82, 0.78, 0.76, 0.71 and 0.67, respectively. The quality management system can be implemented with the help of various factors. They are Employee Training, Organisational Culture, Effective Quality Assurance Plan, Continuous improvement, Effective Safety Programme and Physical Environment of Project site. These factors have RII scores of 0.75, 0.74, 0.71, 0.68, 0.65 and 0.63, respectively. With the help of these factors, quality management system can be implemented in construction projects and performance can be improved.

6.1 Interaction between quality management attributes

The interaction between the various attributes of quality management and their impact on project performance is critical for understanding the holistic effect of quality management practices. Our study, based on a structured questionnaire survey with 152 valid responses, provides

insights into these interactions. The major aspects of construction project performance affected by quality management are the rate of rework, overall project performance, cost, safety, labour productivity and profitability. These aspects have RII scores of 0.85, 0.82, 0.78, 0.76, 0.71 and 0.67, respectively.

The higher RII scores for rate of rework and overall project performance indicate that quality management significantly reduces rework and enhances the overall performance of construction projects. These findings are consistent with previous studies that emphasise the importance of investing in quality conformance to reduce costs associated with non-conformance (Barlow 2009; Olaniran 2015).

6.2 Attributes affecting quality management

This study has identified several key attributes that affect the implementation of quality management systems in construction projects. They include the following:

- Employee training (RII = 0.75): Proper training ensures that employees are well-versed in quality standards and practices, reducing the likelihood of errors and rework.
- Organisational culture (RII = 0.74): A culture that prioritises quality can significantly improve project outcomes by fostering an environment where quality is everyone's responsibility.
- Effective quality assurance plan (RII = 0.71): Implementing robust quality assurance processes helps in early detection and correction of issues, thereby minimising defects.
- Continuous improvement (RII = 0.68): Commitment to continuous improvement ensures that quality management practices evolve and adapt to new challenges and technologies.
- Effective safety programme (RII = 0.65): Safety and quality are closely linked, as poor quality can lead to unsafe conditions. An effective safety programme enhances overall project quality.
- Physical environment of project site (RII = 0.63): The physical conditions of the construction site can impact quality. Proper site management and supervision are crucial for maintaining high-quality standards.

6.3 Reliability measures and validation

To ensure the reliability of the collected data, we conducted a reliability analysis using Cronbach's alpha,

which resulted in a value of 0.816. This high value indicates excellent internal consistency of the data. Furthermore, the RII was used to prioritise and rank the attributes based on their weighted average scores.

6.4 Key findings and implications

Our study highlights the significant positive impact of quality management on various aspects of construction project performance. By focusing on quality conformance and proactive quality management practices, construction firms can reduce rework, improve overall project performance, enhance safety, boost labour productivity and increase profitability.

In conclusion, the study provides empirical evidence that quality management practices have a substantial impact on the performance of construction projects. The implementation of a comprehensive quality management system, supported by key attributes such as employee training, organisational culture and continuous improvement, can lead to significant improvements in project outcomes. Future research should focus on exploring the long-term effects of quality management practices on construction projects and identifying additional factors that may influence the effectiveness of these practices. By continuing to refine and enhance quality management systems, the construction industry can achieve higher levels of performance and success.

7 Limitation

The current study contains some important results; however, it has highlighted some drawbacks as well. The construction project performance was a topic that was queried about in the questionnaire, along with the limiting variables that were affecting it. There is room for additional research in the topic of putting the Quality Management system into practice in the construction industry; however, these studies do not provide any precise data about active construction projects across the industry, thus they are not very useful. The importance of this study is directly proportional to the significance of the responses provided by those working in the construction business as respondents. These findings could be used in additional research in the sector and to enhance the performance of construction projects within the Indian construction industry.

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