

## **RESEARCH PAPER**

# **Quality Management System Implementation and Timely Completion of Building Projects: Evidence from Rwanda**

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### **Abstract**

The construction industry in rapidly developing economies is expanding in scale and complexity, placing greater pressure on contractors to deliver projects efficiently while maintaining quality standards. Where quality control systems are weak, defects and rework frequently translate into schedule overruns and reduced performance. Rwanda's fast-growing construction sector faces similar challenges, raising questions about whether structured Quality Management System (QMS) implementation can improve project timeliness. This study investigates the relationship between QMS implementation and the timely completion of building projects in Rwanda. A quantitative correlational design was used, from a dataset of 45 building projects executed by 15 construction firms between 2013 and 2024. QMS implementation was classified into four levels—full compliance, near compliance, minimal compliance, and non-compliance—based on documented quality control practices. Data analysis involved descriptive statistics, chi-square tests, Pearson correlation, and binary logistic regression to assess associations and predictive effects. Projects with full QMS compliance achieved the highest on-time completion rate (87%), compared with 50% among non-compliant projects. The Pearson correlation showed a weak positive relationship between QMS implementation and timely completion ( $r = 0.286$ ,  $p = 0.057$ ). However, logistic regression identified QMS level as a significant predictor of schedule performance ( $\beta = 0.92$ ,  $p = 0.048$ ), with higher compliance increasing the likelihood of on-time completion by approximately 2.51 times. Frequent inspections and continuous material testing were also linked to lower defect rates and shorter project durations. The findings indicate that systematic quality control practices—particularly inspections, documentation, and staff training—enhance schedule reliability and support staged QMS adoption in emerging construction environments.

**Keywords:** Construction Performance, Logistic Regression, Project Timeliness, Quality Management System, Rwanda Construction Industry

## **1. INTRODUCTION**

The construction sector is widely recognized as a key driver of economic growth, infrastructure development, and employment generation, particularly in developing economies. In Rwanda, sustained public and private investment has contributed to steady expansion of the construction industry, increasing its contribution to national output and urban development (Rugambwa et al., 2025). As project scale and complexity continue to grow, effective Quality Management Systems (QMS) have become increasingly

critical for ensuring compliance with specifications, minimizing rework and improving project delivery timelines (Kwapong & Pipaliya, 2022).

Despite this growth, evidence from practice and prior studies indicates that construction projects in Rwanda continue to suffer from persistent quality-related problems. Defects such as structural cracks, poor finishing, plumbing leaks, and electrical faults frequently emerge during construction or within the defects liability period. This often necessitates remedial works that disrupt planned schedules and contribute directly to project delays (Aline & Samuel, 2025; Umuhoza & An, 2024). From a project management perspective, ineffective quality management manifests not only as technical defects but also as schedule slippage, cost escalation, and loss of stakeholder confidence (Enyinna et al., 2024). These recurring issues suggest that quality management practices are either inconsistently implemented or insufficiently enforced across projects.

While international literature extensively documents the benefits of Quality Management System (QMS) implementation in reducing rework, improving productivity, and enhancing schedule performance, empirical evidence within the Rwandan construction context remains limited. Existing local studies primarily address general construction challenges, project delays, or overall quality performance, with little emphasis on quantitatively assessing how specific QMS components—such as inspection frequency, testing practices, compliance levels, and documentation rigor—influence timely project completion (Aline & Samuel, 2025). Despite the acknowledgement of QMS benefits for project outcomes, empirical studies quantifying the influence of specific quality management components on schedule performance in Rwanda are scarce, with much of the existing work focused on descriptive relationships rather than predictive modelling of schedule outcomes (Patrick et al., 2025)

In response to these limitations, this study advances a more rigorous and focused investigation of QMS implementation within Rwanda's construction sector. The novelty of the study lies in its project-level analytical approach and the combined application of correlational analysis, chi-square testing, and binary logistic regression to isolate QMS implementation as a predictor of schedule performance while controlling for firm size and project type. By disaggregating QMS into measurable components and linking them explicitly to completion outcomes, the study extends existing construction management literature and provides context-specific empirical evidence relevant to developing-country settings.

Against this background, the study evaluates the level of QMS implementation across selected construction projects in Rwanda and examines how these practices relate to project completion outcomes. It further investigates the strength and direction of the relationship between QMS implementation levels and project completion timelines and determines whether QMS implementation significantly predicts timely project completion when relevant project and firm characteristics are accounted for. Through this approach, the study seeks to clarify the role of QMS as a practical tool for improving schedule performance in Rwanda's growing construction industry.

## 2. LITERATURE REVIEW

Niyigena et al. (2016) found that only 56% of public buildings surveyed in Kigali met technical specifications. Non-compliance was a significant reason for project delays. Rugege and Maturu (2019) reported that only 18% of construction firms had ISO certification, while those that implemented quality management systems (QMS) saw notable improvements in operational consistency and scheduling. Similarly, Uwizeye et al. (2018) noted that weak quality control and poor planning were major causes of rework and delays in 20 completed building projects. Makuza and Bahala (2019) further pointed out that projects with regular inspections and material testing performed better on schedules than those with lax quality enforcement. A review of current literature shows a common conclusion: poor quality management practices (QMPs) significantly contribute to delays in building and infrastructure projects. Conversely, adopting QMS offers a promising way to enhance time performance. In Rwanda, a recent study by Tuyishime and Gathiru (2023) found that quality planning accounted for about 80.4% of the performance differences in energy sector projects ( $R^2 = 0.804$ ) among 96 participants. Additionally, Zigirumugabe and Kwena (2023) conducted an extensive study on project quality management in a large educational project in Kigali. They concluded that weak QMPs were closely linked to delays, increased costs, and poor outcomes. At a larger scale in Africa, a 2024 study of the Nigerian construction industry by Okonta et al. (2024) found that only 34.8% of firms held ISO certification, and 60.9% lacked formal QMS frameworks. Notably, 71.4% of respondents cited a lack of commitment from top management as the main obstacle to implementing QMS.

These findings show that in developing economies, simply adopting formal systems is not enough. These systems need to be part of the organizational culture and supported by leadership commitment. In Rwanda, these insights are particularly significant because the industry continues to face scheduling challenges. A 2025 study of public construction projects in Gasabo District found strong connections between decision-making, scheduling, supply chain factors, and project performance ( $R = 0.797$ ;  $R^2 = 0.635$ ) (Umurangamirwa & Bazimya, 2025). Moreover, research on Monitoring & Evaluation (M&E) practices in road construction projects in Musanze by (Twagirumukiza & Amolo, 2024) revealed that robust M&E systems, which serve as proxies for quality assurance, dramatically improved project outcomes. Overall, the evidence stresses the importance of structured QMS frameworks that include formal inspections, testing routines, leadership commitment, and processes for continuous improvement. These components help reduce rework, defects, and schedule delays.

The underlying mechanism is that a well-designed QMS creates systems for quality planning, control, assurance, and feedback. This integration weaves inspections, material testing, tracking non-conformity, and corrective actions into the entire project lifecycle instead of treating them as separate tasks. Projects that follow such systems are less likely to encounter unexpected defects or change orders, which helps uphold schedule integrity. Studies like the one by Bouzidi et al. (2023) in Algeria demonstrate that when QMS knowledge and implementation are weak, construction firms experience greater inconsistencies in quality and time performance.

While having a formal QMS and ISO certification provides a sound framework, they do not guarantee good schedule performance on their own. The success of these systems depends on their integration into organizational practices. In the earlier-mentioned Nigerian study, low certification rates and weak commitments to QMS among firms were linked to higher incidences of building failures and delays. In Rwanda, although there are few direct studies connecting ISO certification or formal QMS to schedule performance in building projects, emerging evidence (Tuyishime & Gathiru, 2023; Zigirumugabe & Kwena, 2023) suggests that firms that integrate quality planning and control from the beginning, rather than relying solely on paperwork, achieve better schedule outcomes.

However, it is important to understand that just implementing a QMS doesn't ensure improved schedule performance. Scholars caution that systems can become focused more on documentation than on actual performance, leading to an emphasis on paperwork and certification over workmanship, testing, and organizational culture. The Nigerian study by Okonta et al. (2024) pointed out that insufficient support from top management, poor communication, and limited training can undermine the advantages of QMS. Similarly, in the Rwandan educational project study (Zigirumugabe & Kwena, 2023), following quality management procedures did not always lead to better time performance, showing the risk of superficial adoption. In developing economies, additional challenges like limited resources, a shortage of skilled labor, and traditional procurement methods (especially design-bid-build) further weaken the effectiveness of QMS implementation.

Despite recent advancements in understanding quality planning and management practices in Rwanda (Tuyishime & Gathiru, 2023; Zigirumugabe & Kwena, 2023), and international evidence linking formal Quality Management Systems (QMS) to improved schedule and cost outcomes (Okonta et al., 2024), a critical research gap persists. Current literature lacks building project-level studies within the Rwandan context that isolate specific QMS variables—such as certification status, inspection and testing frequency, and continuous improvement processes—to quantitatively determine their impact on schedule adherence metrics like timely completion or the magnitude of delays. Consequently, the relationship between standardized quality interventions and the mitigation of schedule risks remains unverified at the local industry level.

Furthermore, literature from Rwanda, Africa, and beyond consistently shows that systematic QMPs and formal QMS implementation are related to fewer delays, improved schedule performance, and reduced rework. At the same time, critics argue that certification and documentation alone are insufficient unless backed by leadership, cultural change, and effective quality control processes. New evidence from African contexts highlights that although the benefits of QMS are recognized, context-specific challenges—particularly in developing economies—must be addressed for these systems to achieve timely completion. Therefore, closing the identified gap by generating in-depth, context-specific evidence on QMS and project schedule performance in Rwanda's building construction sector remains a critical research priority.

### **3. RESEARCH METHODOLOGY**

This study adopts a structured methodological framework based on the research onion model, progressing from research philosophy through to data analysis techniques to ensure methodological rigor and transparency. The selected analytical methods enable project managers and policymakers to assess not only association but also the predictive value of QMS implementation for timely project delivery.

#### **3.1 Research Philosophy**

The study is grounded in a positivist research philosophy, which assumes that relationships between Quality Management System (QMS) practices and construction schedule performance can be objectively measured and statistically tested. Positivism is appropriate because the study relies on observable variables, numerical data, and hypothesis testing to establish empirical relationships rather than subjective interpretations.

#### **3.2 Research Approach**

A deductive research approach was adopted. The study builds on established theories and prior empirical findings that suggest quality management practices influence construction project performance. From this theoretical foundation, testable hypotheses were formulated regarding the relationship between QMS implementation and schedule adherence, which were subsequently examined using quantitative data.

#### **3.3 Research Strategy**

The research employed a quantitative survey strategy. This strategy was selected because it allows for the systematic collection of standardized data from multiple construction projects and supports statistical generalization within the study context. The survey approach is consistent with prior construction management studies that investigate organizational and project-level performance relationships.

#### **3.4 Time Horizon**

The study followed a cross-sectional time horizon, whereby data were collected at a single point in time from completed or near-completion construction projects. This design was considered appropriate given the objective of assessing existing QMS practices and their association with schedule performance within a defined study period.

#### **3.5 Unit of Analysis and Study Population**

The unit of analysis for this study is construction projects executed by registered construction firms in Rwanda. While data were obtained from project managers, site engineers, and quality officers, responses were structured to reflect project-level quality practices and schedule outcomes. The study population comprised 120 registered construction firms, from which eligible construction projects were identified for inclusion.

#### **3.6 Sampling Technique and Sample Size Determination**

A purposive sampling technique was used to identify construction projects that met predefined criteria, including firm registration status and project execution within the study period. The sample size was determined using Slovin's formula, as follows:

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

Where:  $n$  is the sample size;  $N$  is the total population (120 firms), and  $e$  = margin of error (0.05, or 5%).

This yielded a sample size of 45 construction projects drawn from 15 firms. This sample size was considered adequate for the applied statistical analyses, including logistic regression, consistent with similar construction management studies.

#### **3.7 Data Collection Methods and Instruments**

Primary data were collected using a structured questionnaire designed to capture measurable QMS components, including inspection frequency, testing practices, documentation rigor, and compliance

procedures. The questionnaire also captured project schedule performance outcomes. The instrument design was informed by prior QMS and construction performance literature to ensure content validity.

### 3.8 Data Analysis Techniques

Data analysis was conducted using descriptive and inferential statistical methods. Descriptive statistics were used to summarize respondent and project characteristics. Correlation analysis examined the strength and direction of relationships between QMS variables and schedule performance. Chi-square tests assessed associations between categorical variables, while binary logistic regression analysis was employed to isolate QMS implementation as a predictor of on-time project completion. Statistical significance was evaluated at the 5% level. Table 1 summarises the statistical analysis techniques applied, their specific purposes within the study, the governing mathematical formulations, and definitions of key parameters.

**Table 1.** Statistical analysis techniques, specific purposes, corresponding formulas, and parameter definitions used to evaluate the relationship between QMS implementation and construction project schedule performance.

| Analysis Technique              | Purpose / Application in Study  | Statistical Formula   | Definition of Parameters  |
|---------------------------------|---|---|---|
| Chi-Square Test of Independence | Assesses the association between QMS categories and project completion status.  | $\chi^2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$  | $\chi^2$ : Chi-square statistic; $O_{ij}$ : observed frequency in cell (i,j); $E_{ij}$ : expected frequency in cell (i,j)                     |
|                                 |   | $E_{ij} = \frac{R_i \times C_j}{N}$   | $R_i$ : row total; $C_j$ : column total; $N$ : grand total of observations  |
| Pearson Correlation Analysis    | Examines the linear relationship between QMS levels and project completion timelines.   | $r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$ | $r$ : Pearson correlation coefficient; $n$ : number of observations; $x, y$ : paired data values  |
| Binary Logistic Regression      | Predicts the probability of timely project completion based on QMS implementation while controlling for firm size and project type. | $\ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$               | $P$ : probability of project success; $P/(1-P)$ : odds of success; $\beta_i$ : estimated regression coefficients; $X_i$ : predictor variables |

### 3.9 Methodological Contribution

By integrating correlational analysis, chi-square testing, and logistic regression within a single analytical framework, this study advances methodological practice in construction management research and enables a more nuanced evaluation of QMS impacts on schedule performance.

## 4. RESULTS AND DISCUSSION

### 4.1 Profile of the Construction Projects: Demographics, Operational Experience, and Quality Compliance Status

The study analyzed 45 completed building projects from 15 construction firms executed between 2013 and 2024. Local firms accounted for 53% of the sample, followed by multinational contractors (27%) and government-owned firms (20%). Approximately 40% of firms had operated for 5–10 years, and one-third reported annual revenues below USD 1 million, reflecting a mix of emerging and established market players. Table 2 provides a summary of sample demographics and project characteristics, including QMS compliance levels.

The dataset is dominated by local firms (53%), which primarily handle routine construction projects, while multinationals (27%) and government contractors (20%) focus on large-scale and public infrastructure works. Most firms (40%) have been operating for 5–10 years, reflecting recent sectoral growth and consolidation. Younger firms (<5 years, 33%) represent emerging players, whereas older firms (>10 years, 27%) indicate established but fewer long-term operators. Mid-sized firms with annual revenues between \$1M–\$5M form the majority (40%), balancing resources and capability. Smaller firms (<\$1M)

struggle with technological and operational constraints, while larger firms (>\$5M) manage complex, quality-oriented projects requiring advanced management systems.

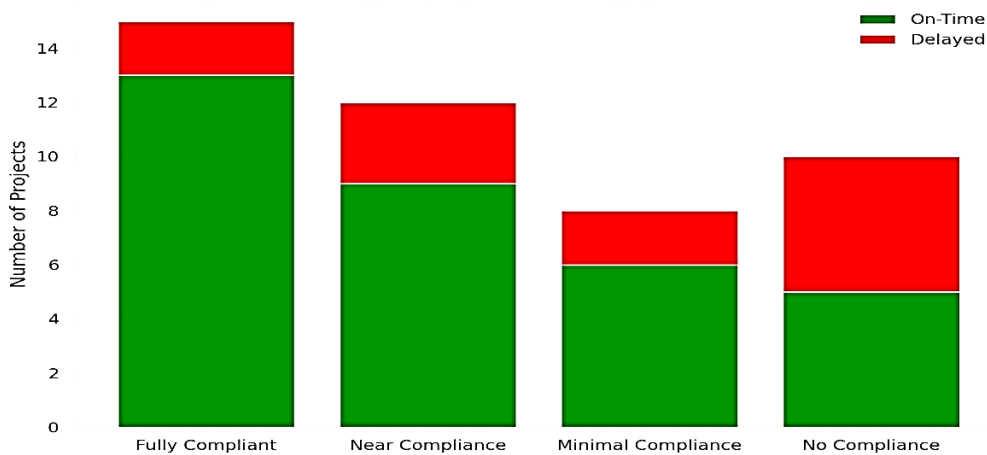
**Table 2.** Summary of Sample Demographics and Project Characteristics, Including QMS (2013–2024)

| Category           | Subcategory                 | Count | %   | Key Insights   |
|--------------------|-----------------------------|-------|-----|--|
| Firm Type          | Local                       | 8     | 53% | Dominant, primarily manages routine projects           |
|                    | Multinational               | 4     | 27% | Handle large-scale projects                            |
|                    | Government Contractors      | 3     | 20% | Focus on public infrastructure                         |
| Years in Operation | < 5 Years                   | 5     | 33% | Indicates recent market entrants                       |
|                    | 5–10 Years                  | 6     | 40% | Reflects sector growth over last decade                |
|                    | > 10 Years                  | 4     | 27% | Shows limited long-term experience                     |
| Annual Revenue     | < \$1M                      | 5     | 33% | Smaller firms face scale & tech challenges             |
|                    | \$1M–\$5M                   | 6     | 40% | Middle-tier dominates                                  |
|                    | > \$5M                      | 4     | 27% | Handle complex, quality-managed projects               |
| Project Duration   | < 1 Year                    | 15    | 33% | High turnaround  |
|                    | 1–2 Years                   | 18    | 40% | Majority complete within this period                   |
|                    | > 2 Years                   | 12    | 27% | Affected by delays from weather, finance, or approvals |
| Quality Compliance | Fully Compliant (ISO + RBS) | 15    | 33% | High-quality standards achieved                        |
|                    | Near Compliance             | 12    | 27% | Best practices applied but lacking certification       |
|                    | Minimal Compliance          | 8     | 18% | Irregular QC implementation                            |
|                    | No Compliance               | 10    | 22% | Risk of defects and safety issues                      |

Project durations mainly span 1–2 years (40%), marking this as the typical completion period, while 33% finish within a year, indicating strong operational efficiency. Longer projects (27%) often face delays from external conditions like financing or regulatory approval. Quality compliance is evenly spread, with 33% achieving full compliance (ISO + RBS), demonstrating robust quality systems. Near Compliance (27%) firms implement best practices but lack certification, while Minimal Compliance (18%) firms apply irregular quality checks. The remaining 22% operate without compliance frameworks, posing higher defect and safety risks, underscoring the importance of institutionalized QMS adoption.

#### 4.2 Relationship Between Quality Management System (QMS) Compliance and Project Success Rates

Figure 1 is a stacked bar chart that visualizes the absolute number of projects that finished On-Time versus those that were Delayed, segmented by their level of Quality Management System (QMS) compliance.

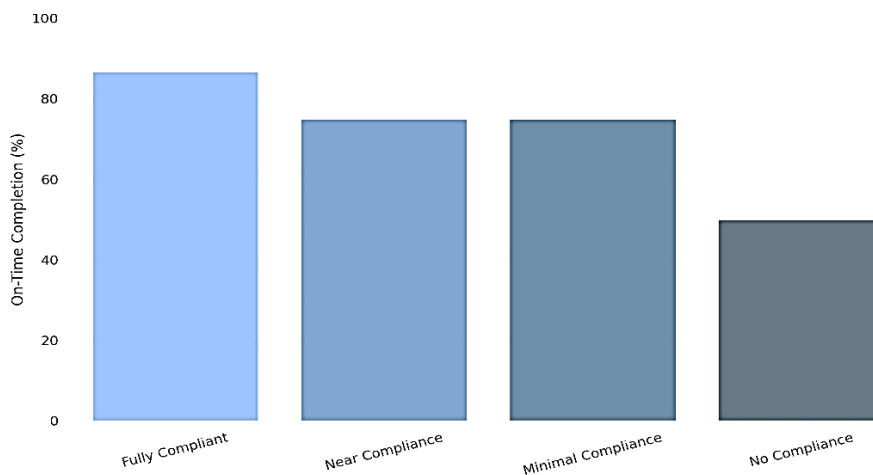


**Fig. 1** Project Completion Status (On-Time vs. Delayed) Across Different Quality Management System (QMS) Compliance Levels.

Analysis of QMS compliance from Fig. 1, revealed that 33% of projects were fully compliant, 27% near-compliant, 18% minimally compliant, and 22% non-compliant. The analysis further showed a clear correlation between QMS compliance and project delivery performance. Fully Compliant projects recorded the best outcomes, with about 15 total and 13 (87%) delivered on time, indicating minimal delays. Non-Compliant projects performed worst, with half (50%) of their 10 projects delayed, revealing significant schedule risks. Intermediate compliance levels—Near and Minimal—achieved roughly 75% on-time completion, confirming that even partial adherence to QMS principles significantly improves project timeliness and reliability compared to complete non-compliance. Overall, the findings demonstrate that rigorous implementation of quality management systems directly enhances delivery efficiency and reduces the likelihood of project delays across construction operations.

### 4.3 Comparison of On-Time Project Completion Rates by QMS compliance level

Figure 2 is a bar chart illustrating the relationship between a project's level of compliance to a Quality Management System (QMS) and its resulting on-time completion rate.



**Fig. 2** Quality Management System (QMS) Compliance Levels and On-Time Project Completion rates

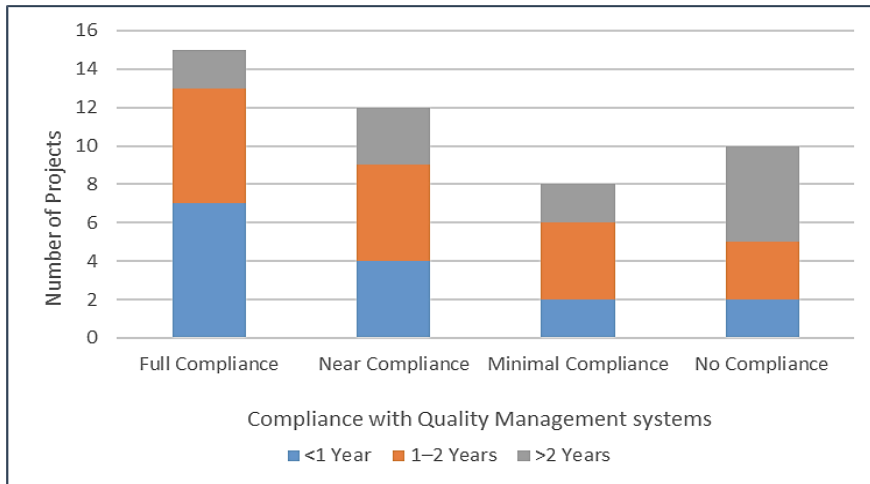
The data presented in Fig. 2 establishes a clear, positive correlation, i.e., higher QMS compliance generally leads to a higher probability of project completion on schedule. Projects with Full Compliance achieved the highest on-time completion rate (87%), followed by Near Compliance (75%) and Minimal Compliance (75%). Non-compliant projects recorded the poorest schedule performance, with only 50% delivered on time. Projects that are Near Compliance and Minimal Compliance show similar, intermediate performance, both settling around 75% on-time completion. This suggests that once a certain baseline of QMS implementation is met, marginal improvements from "Minimal" to "Near" compliance may not yield substantial gains in scheduling performance. The most significant difference in performance lies between the "Fully Compliant" projects and all other categories, and critically, between projects with any level of formal QMS implementation (even Minimal) and those with No Compliance. The dramatic drop to 50% for the "No Compliance" group demonstrates that adhering to a structured QMS is a critical factor for schedule reliability in a project environment.

### 4.4 Analyzing the Link between QMS Compliance and Project Completion Timelines

Figure 3 is a stacked bar chart illustrating the duration of projects categorized by their level of compliance with Quality Management Systems (QMS).

The chart in Fig. 3, illustrates how project duration varies with the level of Quality Management System (QMS) compliance across 45 projects. Full Compliance recorded the highest number of projects (15), followed by Near (12), No (10), and Minimal (8). Short-term projects (<1 year) dominate in higher compliance categories—7 in Full and 4 in Near Compliance—indicating faster delivery. Conversely, long-term projects (>2 years) are more frequent in lower compliance levels, accounting for half of Minimal and most No Compliance projects. Overall, strong adherence to QMS correlates with quicker project completion, while weak or absent compliance is linked to extended durations and inefficiency. These

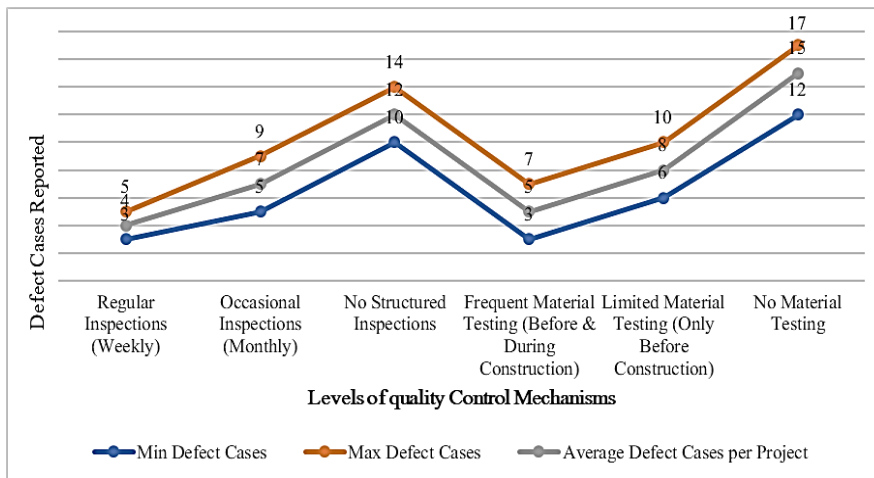
patterns indicate a clear positive association between QMS implementation and adherence to planned timelines.



**Fig. 3:** Distribution of Project Duration (in Years) Across Different Levels of Quality Management System (QMS) Compliance.

#### 4.5 Correlation Between Inspection/Testing Frequency and Reported Defect Rates

Figure 4, visualizes the relationship between the Levels of Quality Control Mechanisms employed in construction projects and the resulting Defect Cases Reported. The data is presented using three series: Minimum Defect Cases, Maximum Defect Cases, and Average Defect Cases per Project.



**Fig. 4** Relationship between the Levels of Quality Control Mechanisms and Reported Defect Cases

Figure 4 indicates a strong inverse relationship, indicating that inspection frequency strongly influenced project outcomes. Projects with weekly inspections recorded the lowest defect rates (3–5 defects/project) and contributed only 10–15% of total defects. This indicates high predictability and immediate identification/correction of issues. Monthly inspections produced moderate results (5–9 defects/project), while projects with no structured inspections exhibited the highest defect rates (10–14 defects/project) and the greatest delays, thus highlighting the increased risk of failure when inspections are not mandated. This underscores the importance of systematic monitoring and documentation in reducing rework and safeguarding schedule performance.

Further inference from Fig. 4 indicates that the rigor of material testing exerts a decisive influence on defect containment and overall construction quality. Projects without material testing exhibit the highest defect rates, averaging 15 cases and peaking at 17, underscoring the critical role of quality assurance. In

contrast, frequent testing conducted both before and during construction achieves superior outcomes, reducing defects to an average of 5 and a minimum of 3 cases, comparable only to weekly inspections. Limited testing performed solely before construction proves inadequate, averaging 8 defects and failing to prevent on-site errors. These findings confirm that continuous material verification is essential for reliable performance and durability.

#### 4.6 Statistical Analysis of Project Timelines: Testing the Independence of QMS Compliance and Project Duration

Table 3 presents the raw project data used for the statistical analysis, categorized by QMS Compliance Level (Full, Near, Minimal, No Compliance) and Project Duration (<1 Year, 1–2 Years, >2 Years).

**Table 3.** Observed and expected frequencies of project duration categories across different QMS compliance levels

| QMS Level          | Project Duration by QMS Level |           |          |  |           |          |
|--------------------|-------------------------------|-----------|----------|--|-----------|----------|
|                    | Observed Frequency Table      |           |          | Expected Frequency Table (Chi-Square Test) |           |          |
|                    | <1 Year                       | 1–2 Years | >2 Years | <1 Year                                    | 1–2 Years | >2 Years |
| Full Compliance    | 7                             | 6         | 2        | 5  | 6         | 4        |
| Near Compliance    | 4                             | 5         | 3        | 4  | 4.8       | 3.2      |
| Minimal Compliance | 2                             | 4         | 2        | 2.67                                       | 3.2       | 2.13     |
| No Compliance      | 2                             | 3         | 5        | 3.33                                       | 4         | 2.67     |

The analysis compares observed and expected project frequencies to test the relationship between QMS compliance and project duration. Observed data (Table 3) shows that Full Compliance projects are predominantly shorter—7 completed in under one year, 6 between one and two years, and only 2 exceeding two years. In contrast, No Compliance projects skew heavily toward longer durations, with 5 lasting over two years. Expected frequencies, derived under the assumption that compliance and duration are independent, serve as a baseline for  $\chi^2$  testing. For instance, the model predicted 4 long-duration projects for the Full Compliance group, yet only 2 were recorded. This deviation suggests that QMS compliance and project duration are statistically related rather than independent.

The Chi-Square Expected Frequency Table establishes a theoretical benchmark for project duration assuming no relationship with QMS compliance. Deviations from this baseline reveal performance differences across compliance levels. Fully Compliant projects outperform expectations, recording only two long-duration projects versus the expected four, indicating superior schedule control. In contrast, the No Compliance group underperforms significantly, with five long-duration projects compared to an expected 2.67, reflecting schedule inefficiency. These non-random deviations between observed and expected outcomes highlight a clear statistical association between strong adherence to Quality Management Systems and improved project timeliness. The results affirm that rigorous QMS implementation enhances operational performance and minimizes the likelihood of extended project durations.

Table 4 presents the results of the Chi-Square Test of Independence, which is used to determine if there is a statistically significant relationship between the two categorical variables (QMS Compliance Level and Project Duration).

**Table 4.** Chi-Square Test Results for Independence

| Statistic                         | Value           |
|-----------------------------------|-----------------|
| Chi-Square Statistic ( $\chi^2$ ) | 5.02            |
| Degrees of Freedom (df)           | 6               |
| p-value                           | 0.5411          |
| Significance Level ( $\alpha$ )   | 0.05            |
| Result                            | Not Significant |

From the Chi-Square Test results (Table 4), no statistically significant association was observed between QMS level and project duration ( $\chi^2 = 5.02, p = 0.5411$ ). This statistical outcome suggests that, based on the sampled data, there is no statistically significant evidence to conclude that the two categorical variables examined (QMS Level and project duration) are related or dependent. While descriptive analysis may show observable differences (as seen in previous project tables), the Chi-Square test confirms that these differences are likely due to random sampling variation and not a true, non-random association.

### 4.7 Linear Association between QMS Adherence and Project Performance

Table 5 presents the key metrics from a Pearson Correlation Analysis, used to assess the strength and direction of the linear relationship between two continuous variables (QMS Compliance Level and On-Time Project Delivery).

**Table 5.** Relationship between Quality Management Systems and On-Time Project Delivery

| Metric                              | Value         |
|-------------------------------------|---------------|
| Pearson Correlation Coefficient (r) | 0.286         |
| p-value                             | 0.0567        |
| Significance Level (α)              | 0.05          |
| Strength of Correlation             | Weak Positive |
| Statistical Significance            | Borderline    |

The Pearson correlation coefficient ( $r = 0.286$ ) indicates a weak positive linear relationship between QMS compliance and project on-time completion—suggesting that higher compliance slightly improves timeliness. The p-value (0.0567) is marginally above the 0.05 significance threshold, meaning the result is statistically borderline. Although the data hint at a positive association, the correlation is weak and not significant at the 95% confidence level. Practically, this implies that while better QMS adherence tends to align with improved schedule performance, the evidence is insufficient to confirm a strong, consistent relationship in the wider population, and the observed effect may be due to random variation.

### 4.8 Regression Modeling of Project Success Likelihood by QMS Level, Firm Type, and Operational Experience

Table 6 displays the output of a Binary Logistic Regression model used to determine which factors best predict a dichotomous outcome (project success (on-time completion) or failure/delay). The predictors tested are QMS Level, Firm Type, and Years of Operation. The key metrics for interpretation are the Coefficient ( $\beta$ ), the Odds Ratio ( $\text{Exp}(\beta)$ ), and the p-value.

**Table 6.** Results of the Binary Logistic Regression Analysis Predicting Project Success Based on QMS Level and Firm Characteristics

| Predictor                  | Coefficient ( $\beta$ ) | Odds Ratio ( $\text{Exp}(\beta)$ ) | p-value |
|----------------------------|-------------------------|------------------------------------|---------|
| QMS Level                  | 0.92                    | 2.51                               | 0.048   |
| Firm Type (F.T.)           | 0.47                    | 1.60                               | 0.201   |
| Years of Operation (Y.Op.) | 0.35                    | 1.42                               | 0.274   |

The information in Table 6 is expressed in a regression equation as follows:

$$\text{Project Success} = \beta_0 + 0.92(QMS) + 0.47(F.T.) + 0.35(Y.Op.) \tag{2}$$

Where,  $\beta_0$  the model's Constant (or Intercept),  $QMS$  is the level of QMS compliance,  $F.T.$  is the Firm Type and  $Y.Op.$  is the Years of Operation.

The regression equation shows that project success depends primarily on QMS Level, with secondary influences from Firm Type and Years of Operation. The coefficient for QMS Level (0.92) is the strongest, indicating that each improvement in compliance level more than doubles the likelihood of project success (a 151% increase in odds). It is the only statistically significant predictor ( $p = 0.048$  at the 5% level). Firm Type ( $\beta = 0.47$ , odds ratio 1.60,  $p = 0.201$ ) and Years of Operation ( $\beta = 0.35$ , odds ratio 1.42,  $p = 0.274$ ) have smaller, positive effects, raising success odds by roughly 1.6 and 1.4 times, respectively, but lack statistical significance.

Overall, the model highlights that rigorous adherence to Quality Management Systems is the most decisive factor in determining successful project outcomes, while organizational type and experience contribute minimally to performance variation. From a project management standpoint, this implies that incremental improvements in QMS maturity substantially increase the probability of meeting planned schedules.

## 4.9 Discussion

The analysis of 45 completed building projects from 15 construction firms between 2013 and 2024 reveals a sector dominated by local contractors (53%), followed by multinationals (27%) and government entities (20%). The industry demonstrates a maturation trend, with 40% of firms possessing 5 to 10 years of experience, while emerging and established players account for 33% and 27% respectively. Mid-sized firms with revenues between \$1 million and \$5 million emerged as the most prevalent (40%), suggesting they possess the necessary balance of operational agility and technical capacity. Crucially, the data identifies a significant performance gap tied to Quality Management System (QMS) adherence; projects with full compliance (33%) achieved an 87% on-time completion rate, whereas non-compliant projects (22%) fell to 50%. These findings align with Tuyishime and Gathiru (2023), Zigirumugabe and Kwena (2023), Makuza and Bahala (2019), and Okonta et al. (2024), reinforcing the premise that rigorous inspections, meticulous documentation, and management oversight are essential for reducing rework and capturing operational efficiencies.

Project timelines were substantially shorter for entities maintaining high QMS compliance, with fully compliant projects typically concluding in under one year, whereas non-compliant counterparts often exceeded two years. This confirms the longitudinal patterns identified by Uwizeye et al. (2018) and Niyigena et al. (2016) regarding the delay-mitigation effects of quality protocols. Technical interventions, specifically weekly inspections and material testing, served as primary drivers for quality, reducing defect rates to 3–5 per project compared to 10–14 in uninspected projects. These results corroborate the findings of Makuza and Bahala (2019) and Tuyishime and Gathiru (2023), suggesting that proactive error detection is a critical determinant of project health. Although statistical analysis revealed a weak positive Pearson correlation between QMS adherence and on-time delivery ( $r = 0.286$ ,  $p = 0.0567$ ) and a non-significant Chi-Square association ( $X^2 = 5.02$ ,  $p = 0.5411$ ), these results point toward the influence of external systemic factors such as financing and regulatory bottlenecks, as noted by Terziovski et al. (2003) and Fotopoulos and Psomas (2009). However, binary logistic regression confirmed that QMS Level is the most potent predictor of project success ( $\beta = 0.92$ , Odds Ratio = 2.51,  $p = 0.048$ ), far outweighing firm type or years of operation.

Ultimately, the effective implementation of a multi-faceted QMS—integrating inspections, testing, documentation, and leadership involvement—is indispensable for improving delivery speed and lowering defect rates. This study contributes an innovative perspective by operationalizing QMS maturity as a measurable, non-binary predictor of timeliness, offering a scalable framework for gradual adoption in resource-constrained environments. The measurable advantages of even partial compliance suggest that quality management should be viewed as a spectrum of continuous improvement rather than a static certification. These findings emphasize that structured systems and committed leadership remain the cornerstones of successful project delivery, echoing the foundational work of Sambasivan and Soon (2007) and Chan and Chan (2004).

### 4.10 Research and Policy Implications

This study offers important methodological, regulatory, and industry-level implications for construction management research and practice in Rwanda and comparable developing economies. Methodologically, the study demonstrates the value of combining descriptive statistics, correlational analysis, chi-square tests, and logistic regression to isolate Quality Management Systems (QMS) as a predictor of schedule performance. This integrated analytical approach advances existing literature, which has largely relied on descriptive or single-method analyses, and provides a replicable framework for future empirical investigations of construction project performance.

From a policy perspective, the findings highlight the need for regulatory agencies such as the Rwanda Housing Authority and Rwanda Standards Board to move beyond prescriptive quality requirements toward performance-oriented monitoring of QMS implementation. Emphasis on measurable elements—such as inspection frequency, testing rigor, and documentation compliance—can support evidence-based enforcement and improve schedule adherence across public and private projects.

For industry stakeholders, the results underscore that even partial or incremental QMS implementation can yield tangible schedule benefits. Contractors and project managers can leverage structured inspections, systematic documentation, and routine testing practices to reduce rework and enhance time performance, even where full QMS certification is constrained by resource or capacity limitations.

## 4.11 Limitations

This study is constrained by its purposive sample of 15 firms and 45 projects, limiting generalizability across Rwanda's broader construction industry. The reliance on secondary data sources such as firm records and audit reports introduces potential reporting bias and data gaps. The operational definition of timely completion ( $\leq 2$  years), while practical for comparative analysis, may not fully capture differences across large-scale or phased projects. Additionally, the modest sample size may have reduced the statistical power of some tests, explaining the borderline significance of the correlation results.

Future research should involve larger datasets, longitudinal designs, and multi-country comparisons to improve external validity. Including qualitative insights from project managers and quality control officers could also enrich understanding of how QMS practices interact with contextual factors such as resource constraints and regulatory enforcement.

## 5. CONCLUSION

This study examines the relationship between Quality Management System (QMS) implementation and the timely completion of building projects in Rwanda, providing project-level empirical evidence that QMS—through compliance levels, inspection frequency, and firm characteristics—functions as a significant managerial lever for improving schedule performance in the construction industry. Using data from 45 completed projects and applying correlation, chi-square, and logistic regression analyses, the study achieved its objectives by quantifying the impact of QMS adherence on schedule reliability and project success. Based on the findings, the following conclusions are drawn:

1. **QMS Compliance as a Decisive Predictor:** Logistic regression results confirm that QMS adherence is the most potent predictor of project success; each unit increase in QMS maturity ( $\beta = 0.92$ ;  $p = 0.048$ ) more than doubles the likelihood of timely completion (Odds Ratio = 2.51).
2. **Performance Variance by Adherence Level:** Quantitative evidence shows a clear hierarchy of outcomes, with full and near QMS compliance yielding on-time completion rates of 87% and 75% respectively, while non-compliant projects saw performance drop to 50%.
3. **Impact of Technical Controls:** High-frequency quality controls are critical to operational efficiency, as weekly inspections and continuous material testing reduced defect rates to a range of 3–5 per project, significantly lower than unmonitored sites.
4. **Correlation and Process Discipline:** While a positive association exists between QMS adherence and on-time delivery ( $r = 0.286$ ), the lack of impact from firm type or years of operation reinforces that consistent process discipline—rather than organizational size or longevity—is the primary driver of reliability.

## 6. RECOMMENDATIONS

Based on the findings and conclusions of this study, the following recommendations are proposed to enhance the effectiveness of Quality Management Systems (QMS) and improve project delivery performance in Rwanda's construction industry:

1. **Institutionalize QMS compliance across the sector:** The Rwanda Housing Authority and national regulatory bodies should make QMS certification (e.g., ISO 9001) a prerequisite for contractor registration and public project bidding.
2. **Strengthen internal quality assurance practices:** Construction firms should adopt a staged pathway toward full QMS compliance, prioritising inspection regimes, documentation systems, and staff training as high-impact interventions.
3. **Enhance management commitment and capacity building:** Senior management should allocate resources for continuous staff training and QMS audits to reinforce a culture of quality and accountability.
4. **Promote integration of QMS in project planning:** Quality objectives should be embedded in project schedules, procurement strategies, and supervision frameworks to ensure quality and time performance are managed concurrently.
5. **Encourage digitization of quality processes:** Adoption of digital tools for real-time monitoring, documentation, and defect tracking will improve traceability, reduce delays, and ensure continuous improvement in construction quality control.

6. Establish an independent quality oversight body: A national construction quality board should periodically audit QMS compliance across firms and projects to maintain industry-wide standards and transparency.

## 7. AREAS FOR FUTURE STUDY

To deepen understanding of QMS effectiveness and strengthen empirical evidence, future research should address the following areas:

1. Longitudinal analysis: Conduct multi-year studies to track how sustained QMS implementation affects performance trends over time, including cost, safety, and sustainability indicators.
2. Cost–benefit evaluation: Analyse the financial implications of QMS adoption, balancing implementation costs against savings from reduced delays and rework.
3. Link between QMS maturity and sustainability performance: Examine how advanced QMS frameworks contribute to environmental, social, and governance (ESG) outcomes in construction projects

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