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# Development of A Quality Management Framework for Installation of Electrical works in Residential Settlements

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## Abstract

The main objective of this research was to develop a bespoke Quality Management Framework (QMF) tailored specifically for residential electrical works to address and mitigate quality enforcement challenges. Background issues in residential electrical installations, such as inadequate planning, poor materials, insufficient supervision, and regulatory compliance, significantly impact project quality and safety. Grounded in Total Quality Management (TQM) theory, this study employed a mixed-methods approach, integrating both quantitative and qualitative methodologies to comprehensively analyze these challenges. The research targeted a population of 242 industry professionals and residential dwellers with a sample size of 150 respondents. Significant results indicated that key factors contributing to quality issues include insufficient project planning (62.50% of respondents), poor quality materials (41.66%), and inadequate supervision (50%). The proposed QMF incorporates essential components like comprehensive training programs, site inspections, technology integration, and quality assurance, which collectively enhance safety, compliance, efficiency, and customer satisfaction. The study highlighted the critical need for a structured QMF to standardize practices, ensure regulatory compliance, and improve project efficiency and effectiveness. Recommendations include developing specialized training programs in home automation, enhancing compliance with industry standards, and strengthening inspection mechanisms. The study's contributions to the body of knowledge encompass the detailed identification of challenges in residential electrical installations, empirical data on contractor perspectives, and practical recommendations for improving quality and safety in electrical projects.

**Keywords:** Quality Management Framework, Residential Electrical Works, Total Quality Management, Project Planning, Regulatory Compliance, Skilled Labor, Quality Assurance

## 1. Background of the study

The construction industry is a critical driver of economic development, contributing significantly to national income and infrastructure growth, particularly in developing countries where it accounts for approximately 3–8% of GDP (Khaertdinova et al., 2021; Igorevich, 2023). Despite its importance, the sector continues to face persistent challenges, including weak regulatory frameworks, skills shortages, financing constraints, and quality management deficiencies, which hinder the effective delivery of infrastructure projects (Moavenzadeh, 2022; Serohina & Vishnia, 2022).

Within the construction industry, the energy subsector plays a vital role in supporting economic productivity and social welfare. Recent advancements such as digitalization, distributed energy systems, and renewable energy integration have transformed energy production and distribution, while increasing emphasis has been placed on sustainability and energy security (Borowski, 2022; Arshad et al., 2023). However, despite these technological developments, quality-related challenges remain prevalent, particularly within power transmission, distribution, and end-user installations.

Quality management deficiencies in electrical systems have been linked to power quality disturbances, energy losses, equipment failures, and electrical fire disasters (Hassero et al., 2020; Odhiambo et al., 2022). Power quality problems—such as voltage fluctuations, harmonics, and overloads—have significant economic and safety implications, resulting in equipment damage, reduced system efficiency, and substantial financial losses globally (Chindris et al., 2017; Jacob & Kaiser, 2019). These challenges highlight the importance of effective quality management systems in ensuring reliable and safe electricity supply.

Residential electrical installations constitute a substantial portion of overall electricity consumption and represent a critical area for quality and safety improvement. Studies have identified frequent non-compliance with installation standards, improper load estimation, poor workmanship, and inadequate protection systems as major contributors to electrical faults and fire hazards in residential buildings (Basri et al., 2022; Listrik et al., 2022). Fire statistics from both developed and developing regions indicate that electrical failures remain a leading cause of residential fires, resulting in significant loss of life and property.

Although various quality management frameworks and regulatory standards exist for electrical installations, gaps remain in their application to residential buildings, particularly in relation to load optimization, conformity assessment, energy efficiency, and systematic quality control during design and installation stages (Barbato et al., 2014; Soluyanov et al., 2022). These gaps underscore the need for a structured and context-specific quality management framework for residential electrical installations to enhance safety, reduce energy losses, and improve overall system performance.

## 2. Methodology

This study adopted an applied research design aimed at developing and evaluating a quality management framework for residential electrical installations. A mixed-method approach was employed to capture both quantitative and qualitative aspects of installation quality, safety, and compliance with electrical standards.

### 2.1 Target Population

For this study, the study population comprised key stakeholders involved in the quality management of residential electrical installations, including electrical contractors (80), electrical consultants (8), energy and regulatory institution representatives (4), and 150 residential dwellers occupying low-voltage residential electrical systems. Professional stakeholders were selected due to their direct involvement in electrical design, installation, inspection, and regulatory enforcement, while residential dwellers were included to capture end-user safety experiences and perceived installation quality.

The professional stakeholder population totaled 242 respondents. Residential dwellers were included primarily for triangulation and framework validation rather than for statistical population inference.

Table 1 Population Distribution

| Participants | Population |
|---|---|
| Energy Institutions | 4 |
| Electrical Contractors | 80 |
| Consultants | 8 |
| Residential Dwellers | 150 |
| **Total** | **242** |

### 2.2 Sample Size Calculation

The sample size for this study was determined using a standard statistical approach suitable for a finite population, adopting a 95% confidence level and a 5% margin of error. Taro Yamane's formula was applied to determine an adequate sample size from the known population of professional stakeholders:

$$n = \frac{N}{1 + N\,(e^2)}$$

$$\frac{242}{1+242(0.05*0.05)}$$

where N=242 represents the population size and e=0.05 is the margin of error. Substituting these values yielded a final sample size of 150 respondents, which was considered sufficient to ensure representativeness and statistical reliability for analyzing quality management practices in residential electrical installations

### 2.3 Data Collection Methods

Data were collected using a mixed-methods approach. Primary data were obtained through structured questionnaires with a 5-point Likert scale administered to electrical professionals, regulatory stakeholders, and residential dwellers to assess installation quality, safety, and compliance practices. Qualitative data were gathered through semi-structured interviews with selected electrical and regulatory experts to capture deeper insights into quality enforcement and installation

challenges. Secondary data were sourced from relevant electrical standards, regulatory documents, and peer-reviewed literature to support benchmarking and framework development.

### 2.4 Ethical Considerations

Ethical approval was obtained prior to data collection, and all participants provided informed consent. Participation was voluntary, and respondents were informed of the study objectives and their right to withdraw at any stage without penalty. Confidentiality and anonymity were maintained by ensuring that no personally identifiable information was collected or disclosed. All data were securely stored and used solely for academic research purposes in accordance with institutional ethical guidelines.

## 3 Findings

### 3.1 Quantitative Respondent's General Information

The study achieved a complete quantitative response rate (100%) and a high qualitative response rate (85%), demonstrating strong engagement and data reliability. The quantitative sample comprised electrical contractors (n = 24) and residential dwellers (n = 120).

Table 2: Summary of Respondent Characteristics

| Variable | Electrical Contractors (n=24) | Residential Dwellers (n=120) |
|---|---|---|
| Predominant Gender | Male (91.7%) | Male (54.2%), Female (45.8%) |
| Dominant Age Group | Below 35 years (83.3%) | 25–44 years (59.2%) |
| Highest Education | Diploma/Undergraduate (83.3%) | Postgraduate (44.2%) |
| Residence Status | Rent (70.8%) | Own (80.8%) |

Source: Author 2024

The contractor sample reflects a young, male-dominated workforce, while residential dwellers demonstrate broader demographic diversity.

### 3.2 Quality Enforcement Challenges in Residential Electrical Installations

Electrical contractors identified several factors contributing to quality enforcement challenges. Insufficient project planning emerged as the most prominent issue, followed by inadequate supervision and poor-quality materials. Regulatory compliance issues elicited mixed responses, indicating variability across projects.

Table 3: Perceived Quality Enforcement Challenges

| Challenge Factor | Agree / Strongly Agree (%) |
|---|---|
| Insufficient project planning | 62.5 |
| Inadequate supervision | 50 |
| Poor-quality materials | 41.7 |
| Regulatory compliance issues | 45.8 |

Source: Author (2024).

These findings highlight operational and managerial weaknesses as primary contributors to quality challenges.

### 3.3 Significance of Factors Affecting Installation Quality

Respondents rated multiple factors as critical determinants of installation quality, with most being classified as "very" or "extremely significant."

Table 4: Significance of Factors Influencing Electrical Installation Quality

| Factor | Very / Extremely Significant (%) |
|---|---|
| Skilled labour availability | 62.5 |
| Quality of materials | 79.2 |
| Adherence to installation standards | 70.8 |
| Adequacy of project planning | 66.7 |
| Supervision effectiveness | 70.8 |
| Regulatory compliance | 79.2 |
| Client expectations & budget constraints | 70.8 |

Source: Author (2024).

Material quality, regulatory compliance, and skilled labour emerged as the most influential factors.

### 3.4 Extent to Which Factors Affect Installation Quality

Respondents further evaluated how strongly each factor affects installation outcomes.

Table 5: Extent of Impact on Installation Quality

| Factor | Very / Extremely (%) |
|---|---|
| Skilled labour availability | 91.7 |
| Quality of materials | 87.5 |
| Project planning | 100 |
| Supervision | 87.5 |
| Client expectations & budget | 70.8 |

Source: Author (2024).

Project planning demonstrated unanimous agreement as a critical determinant of quality.

### 3.5 Essential Elements for Quality Electrical Installations

There was strong consensus on essential quality management elements required for residential electrical installations.

Table 6: Essential Elements for Quality Electrical Installations

| Element | Agree / Strongly Agree (%) |
|---|---|
| Comprehensive training programs | 95.8 |
| Use of high-quality materials | 91.7 |
| Adherence to standards & regulations | 91.7 |
| Detailed project planning | 87.5 |
| Regular inspections & supervision | 91.7 |
| Feedback mechanisms | 95.8 |

Source: Author (2024).

These elements reflect core quality management principles applicable to residential construction contexts.

### 3.6 Effectiveness of a Quality Management Framework (QMF)

Most contractors viewed a Quality Management Framework as highly effective in improving safety, reliability, and compliance.

Table 7: Perceived Effectiveness of a Quality Management Framework

| Effectiveness Level | Percentage (%) |
|---|---|
| Extremely effective | 70.8 |
| Very effective | 8.3 |
| Moderately effective | 8.3 |
| Slightly effective | 12.5 |

Source: Author (2024).

This indicates strong professional support for structured quality management systems.

### 3.7 Residential Dwellers' Satisfaction with Electrical Installations

Residential dwellers reported high satisfaction across most installation attributes, though communication and planning involvement were comparatively lower.

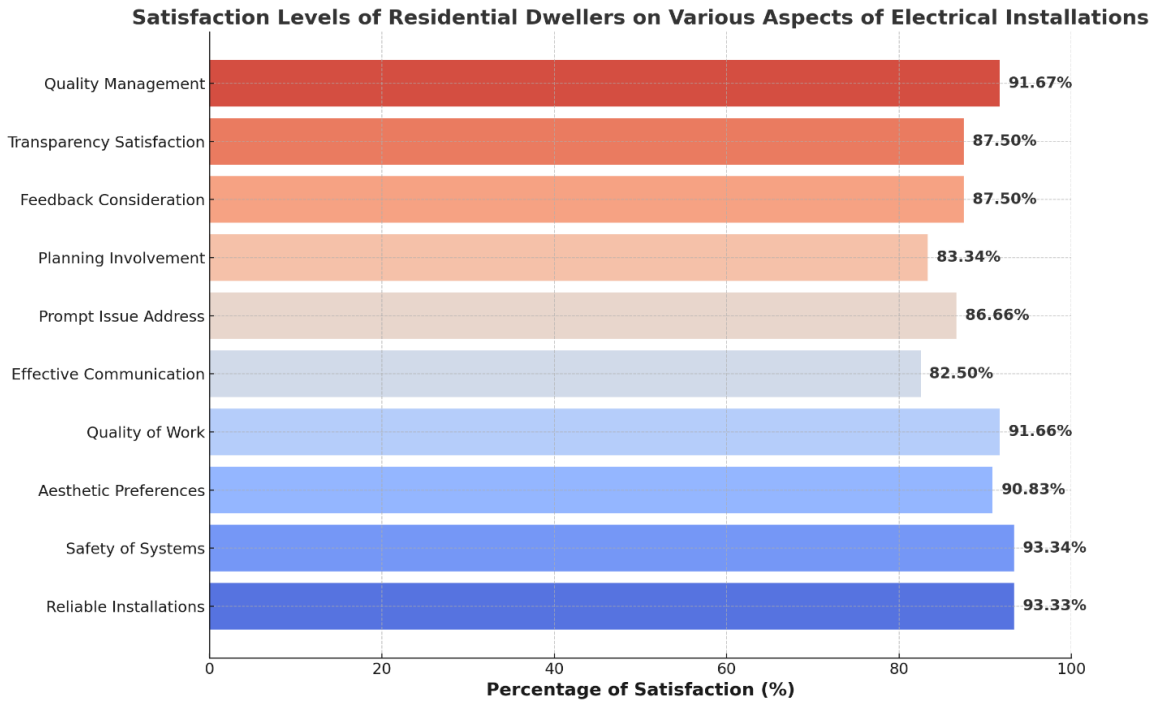


Figure 1: Residential settlements dwellers involvement Quality Electrical Installations

The findings underscore the commercial importance of communication and client engagement.

### 3.8 Inferential Analysis: Chi-Square Results

Statistically significant relationships were observed between skilled labour availability and both project planning adequacy and supervision effectiveness.

Table 8: Summary of Chi-Square Test Results

| Variable Pair | $\chi^2$ | p-value | Significance |
|---|---|---|---|
| Skilled labour × Project planning | 34.65 | 0.004 | Significant |
| Skilled labour × Supervision | 24.4 | 0.018 | Significant |
| Skilled labour × Material quality | 22.52 | 0.127 | Not significant |
| Skilled labour × Regulatory compliance | 17.71 | 0.125 | Not significant |

Source: Author (2024).

These results suggest that labour availability directly influences managerial effectiveness.

### 3.9 Qualitative Data Presentations

The qualitative component comprised six key informants (QMF01–QMF06), all professionally engaged in electrical installation and quality management within residential construction projects. Participants possessed substantial field experience and formal technical qualifications, enabling informed perspectives on quality enforcement, regulatory compliance, and commercial challenges in electrical installations

#### Electrical Wiring Deficiencies

Respondents consistently identified wiring deficiencies as a major contributor to compromised quality and safety. Issues included improper cable sizing, incorrect colour coding, inadequate earthing, and generally poor house wiring practices. These deficiencies were perceived to increase the risk of electrical faults, equipment damage, and fire hazards.

For instance, QMF02 reported "improper wire sizes and colour codes," while QMF06 highlighted "poor house wiring" as a recurring problem. Similarly, QMF01 emphasized "inadequate cable and breaker sizing," noting that such practices can lead to overloaded circuits and frequent tripping. Collectively, these views indicate persistent non-compliance with basic wiring standards in residential installations.

#### Contractor Competence and Workmanship

Contractor competence and workmanship quality emerged as critical determinants of installation outcomes. Several respondents attributed poor quality to unqualified or unlicensed contractors, lack of standardization, and inappropriate material selection.

**QMF03** explicitly cited "contractor incompetence" as a cause of substandard work and safety non-compliance. **QMF04**

further noted "poor workmanship, lack of standardization, poor material selection, and unjustifiable costings," linking these issues to inconsistent quality and increased rework. These findings suggest that contractor capability and professional standards directly influence compliance and overall installation quality.

### Project Management and Supervision Challenges

Weak project management and inadequate supervision were widely reported as significant contributors to quality enforcement challenges. Respondents linked these shortcomings primarily to budget constraints and insufficient investment in professional oversight.

**QMF05** reported a "significant lack of supervision and project management during construction stages," attributing this to client budget limitations. The respondent further indicated that "insufficient investment in project management" exacerbates coordination problems and quality lapses. These perspectives underscore the role of effective supervision in ensuring adherence to designs and standards.

### Regulatory Enforcement and Compliance Gaps

Respondents expressed concern over inconsistent regulatory enforcement and limited inspection effectiveness. While some reported minimal compliance issues, others highlighted notable enforcement gaps, particularly in certain residential contexts.

**QMF04** stated that the "absence of compulsory standards regulating electrical installations leads to inconsistent quality," while **QMF05** described existing regulatory measures as "not effective." **QMF06** went further, indicating that regulatory measures were "nonexistent" in some instances. In contrast, **QMF02** observed that compliance issues had reduced following requirements for certification by registered professionals. These mixed experiences point to variability in enforcement rather than uniform regulatory failure.

### Budget Constraints and Client Expectations

Budgetary pressures and client expectations were identified as significant factors influencing quality enforcement. Respondents noted that cost-cutting often leads to the use of inferior materials, reduced supervision, and compromised safety outcomes.

**QMF03** emphasized that "client expectations and budget constraints are the most significant factors impacting quality enforcement," while **QMF02** observed that "tight budgets frequently result in the use of substandard materials." **QMF05** added that clients often seek savings on less visible components such as conduits and wiring, increasing safety risks. These findings reflect the commercial realities shaping quality decisions in residential projects.

### Need for Structured Quality Management Frameworks

There was strong consensus on the need for structured quality management frameworks to improve consistency, compliance, and accountability in electrical installations. Respondents advocated standardized procedures, training, independent supervision, and continuous improvement mechanisms.

**QMF01** emphasized the importance of quality control and continuous improvement frameworks, while **QMF02** recommended independent supervision by qualified engineers. **QMF04** highlighted standardization as a means to reduce errors, and **QMF05** noted that quality frameworks can "mitigate poor execution issues and save time and costs." These perspectives reinforce the perceived value of formal quality systems in addressing recurring installation challenges.

## 4 Discussion of Findings

### 4.1 Quality Enforcement Challenges in Residential Electrical Installations

The study demonstrates that quality enforcement challenges in residential electrical installations are predominantly driven by operational and managerial deficiencies rather than isolated technical failures. Inadequate project planning emerged as the most critical challenge, followed by insufficient supervision and the use of poor-quality materials. Regulatory compliance issues, while present, exhibited mixed perceptions, suggesting inconsistent enforcement across projects.

These findings align with construction management literature that identifies planning, supervision, and human resource capacity as fundamental determinants of project quality. Previous studies have similarly emphasized that deficiencies in planning and scheduling often lead to cost overruns, rework, and compromised quality (Doloi, 2013; Ogwueleka, 2013). The prominence of skilled labour and supervision in this study reinforces the argument that human factors remain central to quality outcomes in construction-related activities.

Qualitative insights further substantiate these findings, revealing recurring issues such as improper wiring practices, contractor incompetence, lack of standardization, and weak project oversight. These challenges collectively contribute to safety risks, increased maintenance costs, and inconsistent installation quality, underscoring the need for integrated quality control mechanisms.

### 4.2 Impact of Critical Factors on Electrical Installation Quality

The study confirms that skilled labour availability has a profound influence on the quality of electrical installations.

Contractors consistently perceived skilled labour as essential to ensuring compliance with installation standards, effective supervision, and overall workmanship quality. This finding supports prior research that links workforce competence and training to improved project performance and reduced defects (Gurmu & Mahmood, 2024; Wawak et al., 2020).

Material quality and project planning were also unanimously recognized as critical determinants of installation quality. High-quality materials reduce system failures and enhance safety, while comprehensive project planning facilitates coordination, resource allocation, and timely execution. Effective supervision further reinforces quality outcomes by enabling early identification and correction of defects.

Although client expectations and budget constraints were perceived as influential, their impact appeared more context-dependent. This variability suggests that while commercial pressures shape quality decisions, their effects can be mitigated through strong planning, supervision, and communication strategies.

### 4.3 Implications for Quality Management Frameworks

The strong endorsement of a Quality Management Framework (QMF) among contractors indicates broad recognition of the need for structured, standardized quality systems in residential electrical installations. The perceived effectiveness of the framework reflects its potential to address recurring challenges such as inconsistent practices, inadequate supervision, and weak compliance monitoring.

The findings are consistent with literature on Total Quality Management and ISO-based quality systems, which emphasize standardization, continuous improvement, and stakeholder involvement as key drivers of quality performance. By integrating training, supervision, regulatory compliance, and feedback mechanisms, the proposed QMF provides a systematic approach to improving installation quality, reducing safety risks, and enhancing operational efficiency.

### 4.4 Residential Dweller Satisfaction and Commercial Implications

High satisfaction levels reported by residential dwellers indicate that contractors are largely successful in delivering safe and reliable electrical installations. Satisfaction with system safety, reliability, and workmanship suggests that technical performance meets user expectations in most cases.

However, comparatively lower satisfaction levels related to communication, transparency, and planning involvement highlight areas requiring improvement. These findings emphasize that quality in residential electrical installations extends beyond technical execution to include client engagement and information flow. Improved communication practices and greater client involvement during planning stages may enhance trust, satisfaction, and perceived service quality.

From a commercial perspective, these insights underscore the importance of integrating customer relationship management into quality frameworks to sustain competitive advantage and client loyalty.

## 5 Conclusion and Recommendations

### 5.1 Conclusion of Research Findings

This study concludes that quality challenges in residential electrical installations are largely driven by inadequate project planning, insufficient supervision, poor material quality, limited skilled labour, and inconsistent regulatory enforcement. These factors collectively undermine installation safety, reliability, and overall project performance.

The findings further demonstrate that skilled labour availability is a critical determinant of quality, influencing compliance with standards, effectiveness of supervision, and workmanship outcomes. Material quality, detailed project planning, and effective supervision were also identified as essential for achieving high-quality installations, while client expectations and budget constraints exert a variable but notable influence.

A key contribution of the study is the development of a bespoke Quality Management Framework (QMF) for residential electrical works. Strong practitioner support for the framework confirms its practical relevance in standardising practices, improving compliance, and enhancing project efficiency. Overall, the study establishes that improving residential electrical installation quality requires an integrated quality management approach that addresses technical, managerial, and regulatory dimensions simultaneously.

### 5.2 Quality Management Framework (QMF) for Residential Electrical Installations

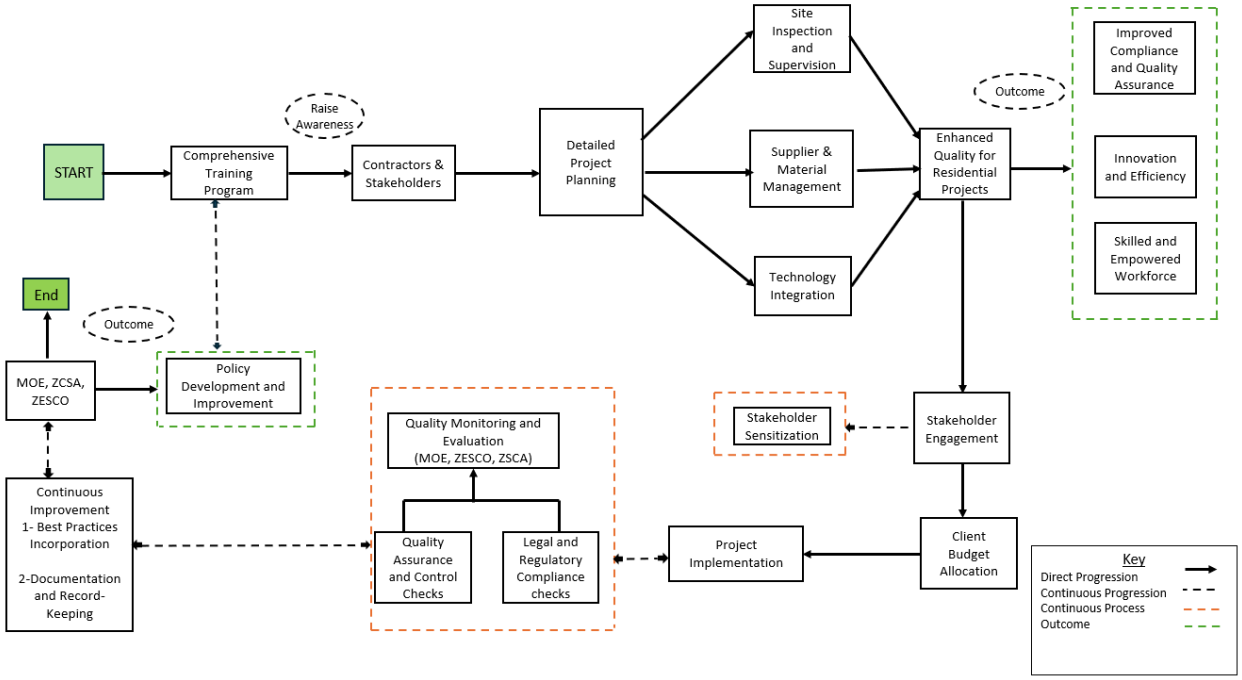


Figure 2: Proposed Quality Management Framework for Electrical Installations for Residential Settlements. Source: Author (2024).

Figure 2 presents the proposed Quality Management Framework (QMF) for residential electrical installations. The framework is structured as a closed-loop quality system integrating planning, execution, inspection, and continuous improvement to ensure safety, compliance, and performance across residential electrical projects.

At the core of the framework are nine interlinked components: comprehensive training programmes, detailed project planning and management, contractor capacity building, site inspection and supervision, standard compliance monitoring, quality assurance and quality control, technology integration, leadership and communication, and stakeholder and policy engagement. These components collectively regulate how electrical works are designed, executed, verified, and improved. Training and contractor development ensure technical competence, while planning, supervision, and quality control govern how installations are carried out in practice. Regulatory and stakeholder involvement ensures conformity with statutory requirements and professional standards.

The framework operates through a continuous feedback mechanism, whereby inspection results, regulatory reports, and client feedback are systematically reviewed and used to improve future planning, training, and operational procedures. This ensures that quality is not treated as a one-time activity but as an ongoing management process. Through this integrated and cyclical approach, the QMF enhances installation safety, reduces defects and rework, improves customer satisfaction, and promotes long-term sustainability of residential electrical systems.

## 5.3 Recommendations

Based on the study findings, the following recommendations are proposed:

**Enhance Skills Development:** Continuous training for electricians, including emerging areas such as home automation, should be prioritized to improve technical competence and compliance.

**Strengthen Regulatory Enforcement:** Regulatory authorities and local councils should enhance inspection and enforcement mechanisms to ensure strict adherence to electrical standards before utility connections.

**Adopt the Quality Management Framework:** Contractors and organizations are encouraged to implement the proposed QMF to support standardization, risk management, continuous improvement, and customer satisfaction.

**Improve Planning and Supervision:** Greater emphasis should be placed on detailed project planning and effective supervision to reduce defects, delays, and safety risks.

## 5.4 Future Areas of Research

Future research should consider:

- Comparative studies across different regions to evaluate the adaptability of the QMF under varying regulatory and market conditions.
- Longitudinal studies to assess the long-term impact of QMF implementation on quality, cost, and customer satisfaction.
- Human and organisational factors, including safety culture, motivation, and leadership, and their influence on quality management effectiveness.

### Declaration of Competing Interests

The authors declare that they are not aware of any competing financial interests or personal relationships that may have influenced the work described in this document.

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### Ethical considerations

The article followed all ethical standards appropriate for this kind of research.

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