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Development of ISO 9001-compliant quality assurance model for residential building construction in South Africa

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Abstract: The imperative to enhance quality standards in South Africa's residential construction sector remains urgent, particularly given persistent quality lapses and rising stakeholder expectations. This study proposes a comprehensive ISO 9001-compliant quality assurance (QA) model tailored to residential building projects in South Africa. Using the Fishbone (Ishikawa) diagram for root cause analysis, six major quality determinants—human factors, technological tools, design and planning, regulatory compliance, project management, and material resources—are systematically examined. These elements are aligned with core ISO 9001 principles: customer focus, leadership, engagement of people, process approach, evidence-based decision-making, relationship management, and continual improvement. The model operationalizes QA/QC across all project phases—pre-design, design, construction, and post-handover—ensuring a lifecycle quality management strategy. Evidence indicates that skills development, effective stakeholder collaboration, and stringent regulatory oversight significantly improve construction outcomes. The study contributes a structured, principle-based QA model capable of addressing entrenched quality failures in the South African context, offering a replicable framework for broader application across emerging economies facing similar construction quality challenges.

Keywords: *Continuous improvement, Fishbone diagram, ISO 9001, Quality assurance, Quality management, Residential construction, South Africa.*

1. Introduction

Over the past two decades, rapid urbanisation, population increase, and economic growth have changed South African residential construction. These improvements have boosted the sector's economic importance but revealed quality assurance, project governance, and regulatory compliance concerns [1]. Rising housing demand, especially in low- and middle-income neighbourhoods, has necessitated rapid expansion, often at the expense of structural integrity and building requirements [2]. Building collapses, poor finishing, and project delays persist despite regulatory control by the National Home Builders Registration Council (NHBRC) [3]. Failures threaten lives, destroy public trust in residential development, and raise housing infrastructure lifecycle costs.

Construction quality is strategic, not technical. Quality assurance systems improve end-user safety, client satisfaction, legal obligations, and construction enterprises' reputation [4]. Rework, contractual disagreements, and cost overruns reduce profitability due to quality difficulties. ISO 9001, a global QMS standard, addresses these issues through customer focus, leadership, and process integration, evidence-based decision-making, and continuous improvement [5]. The South African construction industry has

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struggled to apply ISO 9001 due to resource constraints, lack of understanding, and procedural opposition [6]. A contextualised model that links global quality ideas to local operations is needed to close this gap.

The Fishbone (Ishikawa) diagram augments ISO 9001 and quality management root cause analysis. Kaoru Ishikawa's 1960s diagram lists Methods, Machinery, People, Materials, Measurement, and Environment as contributing factors [7]. This visual tool examines complicated South African residential construction quality problems and proposes targeted solutions [8]. When combined with ISO 9001, the Fishbone diagram improves strategic decision-making by revealing construction lifecycle faults [4]. In diversified residential complexes with operational challenges, this dual technique promotes ongoing improvement and project success.

South Africa's social stratification and spatial inequalities affect housing demands. Quality and regulatory requirements vary for RDP units and luxury estates [9]. Government programmes to provide affordable housing have led to high-volume, low-quality development projects. Unfortunately, quick housing stock supply produces structural defects, poor finishes, and consumer dissatisfaction [10]. IBTs such prefabrication, modular systems, and BIM can improve quality. Technology can enhance project timeframes, precision, and labour variances. IBTs need a quality management system that suits their operations to optimise benefits.

South Africa's construction industry requires a hybrid IBT-ISO 9001 quality assurance methodology. Evaluating building processes with worldwide standards enhances regulatory compliance and sector performance. Lack of technical training, fragmented stakeholder coordination, and variable quality standards enforcement hinder alignment [11]. Training gaps in design, supervision, and materials handling make IBT deployment difficult [12]. Even good tactics fail without capacity building. Reluctance to change by contractors and project managers limits the adoption of QA/QC models, especially those that challenge traditional building practises [13].

Context-sensitive, ISO 9001-compliant QA models using the Fishbone analytical framework are needed. The model must address quality issues, be scalable, adaptable, and account for South African housing sector social, technological, and environmental dynamics [14]. Process-based controls should be used pre-design, design, construction, and post-handover to prevent deviations and provide accountability [15]. The methodology must prioritise stakeholder participation because quality assurance is a value chain commitment, not just technical [1]. Periodic audits, feedback loops, and performance monitoring can institutionalise excellence and adaptation in a dynamic, high-stakes business like home development.

This study aims to develop a comprehensive quality assurance/control model for South African residential constructions. The ISO 9001 and Fishbone diagram approach will handle quality, regulatory, and management issues. This study applies worldwide best practices to South Africa to improve residential housing structural reliability and consumer trust. The model helps the NHBRC monitor regulations and guide public and private parties in improving construction standards. This research intends to bridge the quality management implementation gap and incorporate adaptability into quality systems to improve how South African residential building defines, seeks, and sustains quality.

2. Literature Review

2.1. Overview of Quality Management Principles (ISO 9001)

ISO 9001 is an internationally established standard that provides a structured framework for establishing a Quality Management System (QMS) to improve customer satisfaction by delivering exceptional outputs. The seven pillars are customer focus, leadership, people involvement, process approach, improvement, evidence-based decision-making, and relationship management. These guidelines assist companies achieve stakeholder operational performance expectations [10]. South African residential building must focus on customers to create habitable, structurally sound housing that meets regulatory requirements and homeowner preferences [8]. In an industry with housing quality issues and regulatory noncompliance, this matters.

Strategic direction and team mobilisation across the building supply chain require leadership, the second principle. Strong leadership communicates and internalises quality performance goals, improving execution and alignment [13]. The third premise, employee engagement, knows a dedicated team enhances quality. Quality assurance-savvy workers avoid rework and errors. Human factors create numerous operational problems, hence ISO 9001 compliance in construction requires workforce involvement [1].

The fourth notion, process approach, advocates approaching construction operations—from procurement to handover—as interrelated activities with measurable inputs and outputs. When resource allocation and material use match project timelines and quality standards, operational efficiency and predictability improve [2]. The improvement principle promotes construction process, plan, and material improvement. ISO 9001-compliant organisations should use project learning to increase creativity and quality in future planning and execution [5].

Sixth principle: evidence-based decision-making uses data collecting and analysis to improve and prevent repeating mistakes. Using actual facts rather than assumptions might reduce quality non-conformances in concrete curing or roofing installations [4]. Finally, relationship management emphasises supplier, subcontractor, and regulator collaboration. Long-term, performance-based stakeholder partnerships can solve residential project delivery delays and poor materials [7]. Overall, using ISO 9001 principles into residential building helps project teams improve process consistency, customer satisfaction, and legal and professional requirements.

2.2. Fishbone (Ishikawa) Diagram Importance in Quality Management

Quality management uses the Fishbone Diagram, also known as the Ishikawa Diagram or cause-and-effect diagram, to locate fault causes. This 1960s idea by Kaoru Ishikawa is useful in complex industries like construction where many factors can affect quality. The figure helps home builders identify quality issues in Methods, Machinery, Manpower, Materials, Measurement, and Environment [14]. Participants can detect systemic issues including poor installation, insufficient labour training, and material defects by graphically mapping these categories. Clarity facilitates quick problem-solving and strategy.

The Fishbone Diagram encourages engineers, site managers, and quality inspectors to work together on building projects. Its visual design reduces quality issues, allowing non-technical stakeholders to help solve them. A South African home development's roof leaked due to insufficient insulation and poor installation monitoring. ISO 9001 requires evidence-based decision making therefore supplier change and stronger supervision were implemented.

The Fishbone Diagram is good in qualitative root cause identification however some researchers prefer FMEA or Pareto Analysis to prioritise hazards by frequency and impact [15]. Combining identification, measurement, and rating improves quality investigations and strategic responses. Despite this critique, ISO 9001-compliant quality systems use the Fishbone Diagram in early root cause analysis. Adaptability during building processes, from design errors to site safety issues, underscores its relevance. Thus, its integration into quality planning processes in South African residential building projects follows global best practices and helps local construction firms' diagnostic capacities in resolving systemic quality issues.

2.3. Common Quality Issues in Residential Construction

Socio-economic, technological, and legal barriers have lowered residential construction quality in South Africa. ISO 9001-certified firms often fail to meet daily compliance due to budget constraints, monitoring, and training [10]. State-subsidized housing projects are particularly affected because contractors prioritise haste and money over structural quality and durability. Okeke, et al. [2] revealed flawed construction in low-cost housing developments, including cracked walls, plumbing concerns, and inadequate finishing. Problems harm inhabitants and damage public faith in government housing Quality suffers from the fragmented construction supply chain, as subcontractors, labourers, and material suppliers work unsupervised. Without integrated quality systems, accountability is spread, generating disputes and rework [15]. ISO 9001 governs quality from design to delivery. Without context-sensitive models that account for informal employment, poor digital penetration, and varied site conditions, implementation is difficult [5]. A customisable, scalable, and adaptive ISO 9001 method to South African home construction is needed.

Quality is further limited by limited use of new monitoring and assessment techniques. BIM and digital dashboards are infrequently employed to improve quality tracking due to cost and expertise shortages [2]. Construction workers rarely receive training to use digital tools, creating a technology-implementation gap. Lack of stakeholder consultation during design and construction, especially in low-income housing, lowers quality. ISO 9001's customer focus is compromised by alienation's functional mismatches and discontent. South Africa's residential building sector will struggle to meet regulatory and user expectations without a specialised, localised model that integrates global quality standards and tools like the Fishbone Diagram.

2.4. Adoption of Innovative Building Technologies (IBTs)

Innovative Building Technologies (IBTs) can improve South African residential home construction quality, speed, and sustainability. Prefabrication, modular building, and BIM reduce errors, project delays, and environmental waste. Luo, et al. [6] assert that digital innovation improves construction quality, especially with prefabricated solutions. Off-site prefabrication improves quality and reduces on-site disturbances [16]. IBTs are underutilised in South Africa due to socio-economic, technical, and regulatory issues. Abd Razak, et al. [17] blame change aversion, lack technological knowledge, and insufficient digital transformation policy help for poor industrialised system adoption. These obstacles require ongoing skills development, explicit legislation, and public-private collaboration to overcome and integrate.

Cultural inertia in local construction ecology slows IBT implementation. Due to a lack of exposure and outdated training systems, many professionals prefer labour-intensive processes. To transition to IBTs, Alawag, et al. [15] recommend targeted professional development programs that address technical and attitudinal adjustments. Without cost-effectiveness education, these technologies are avoided due to misconceptions about high upfront costs. Similar developing scenario cost-benefit evaluations suggest that lifecycle cost savings, material waste reduction, and durability beat initial expenses [18]. In modular construction, BIM decreases project errors by 30%, improves collaboration, and increases efficiency, according to local project managers. This strongly supports institutionalising digital literacy and mandating BIM in public sector projects to drive private sector diffusion.

Collective innovation networks across construction, IT, and academia are key to IBT success. Interdisciplinarity improves experimentation, research adoption, and local problem-solving [19]. National centres for digital construction excellence and economic incentives for IBT adoption would transform South Africa's sector. BIM could improve urban planning and regulatory framework design accuracy and compliance tracking. The housing sector has to accelerate IBT integration to build robust, cost-effective, and sustainable houses. South African residential construction's future lies in its ability to blend current technologies with contextualised strategies, drawing from global best practices while respecting native capabilities.

2.5. Existing Quality Assurance Models and their Limitations

Innovative Building Technologies (IBTs) can improve South African residential home construction quality, speed, and sustainability. Prefabrication, modular building, and BIM reduce errors, project delays, and environmental waste. Luo, et al. [6] assert that digital innovation improves construction quality, especially with prefabricated solutions. Off-site prefabrication improves quality and reduces on-site disturbances [20]. IBTs are underutilised in South Africa due to socio-economic, technical, and regulatory issues. Ismail, et al. [18] blame change aversion, lack technological knowledge, and insufficient digital transformation policy help for poor industrialised system adoption. These obstacles require ongoing skills development, explicit legislation, and public-private collaboration to overcome and integrate.

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3. Research Methodology

3.1. Methodological Rationale

Systematic literature review (SLR) and Fishbone (Ishikawa) diagram root cause analysis are used to establish an ISO 9001-compliant quality assurance approach for South African residential building. A structured analytical tool can locate, synthesise, and review a lot of secondary data and find quality flaws, supporting this strategy. The dual approach improves findings validity by ensuring methodological rigour, objectivity, and replicability [21]. Based on PRISMA, SLR clearly records source selection, inclusion, and exclusion, eliminating bias and ensuring high-quality evidence [6].

From 415 Scopus, Web of Science, and Google Scholar sources, 162 duplicates were deleted. The remaining 253 documents were evaluated for ISO 9001, residential construction, Fishbone diagrams, and 2020–2024 publication. Only 40 publications were selected for review (Figure 1). The study team reduced selection bias using methodological rigour, topical relevance, and empirical applicability. A methodical approach identified South African quality assurance concerns and answers.

Root cause analysis makes fishbone diagrams ideal for quality assurance in complex industries like construction. Methods, Machinery, People, Materials, Measurement, and Environment are probable failure reasons in Kaoru Ishikawa's Fishbone model, indicating systemic construction quality implications [14]. This study incorporated design and planning, regulatory compliance, human components, project management, cultural and organisational context, technology and equipment, and materials and resources to the graphic. Ten construction experts assessed Gauteng and Eastern Cape home building quality issues to create these categories. Each element was investigated and linked to literature to visualise interdependencies in line with ISO 9001's process-based thinking and continuous development [15].

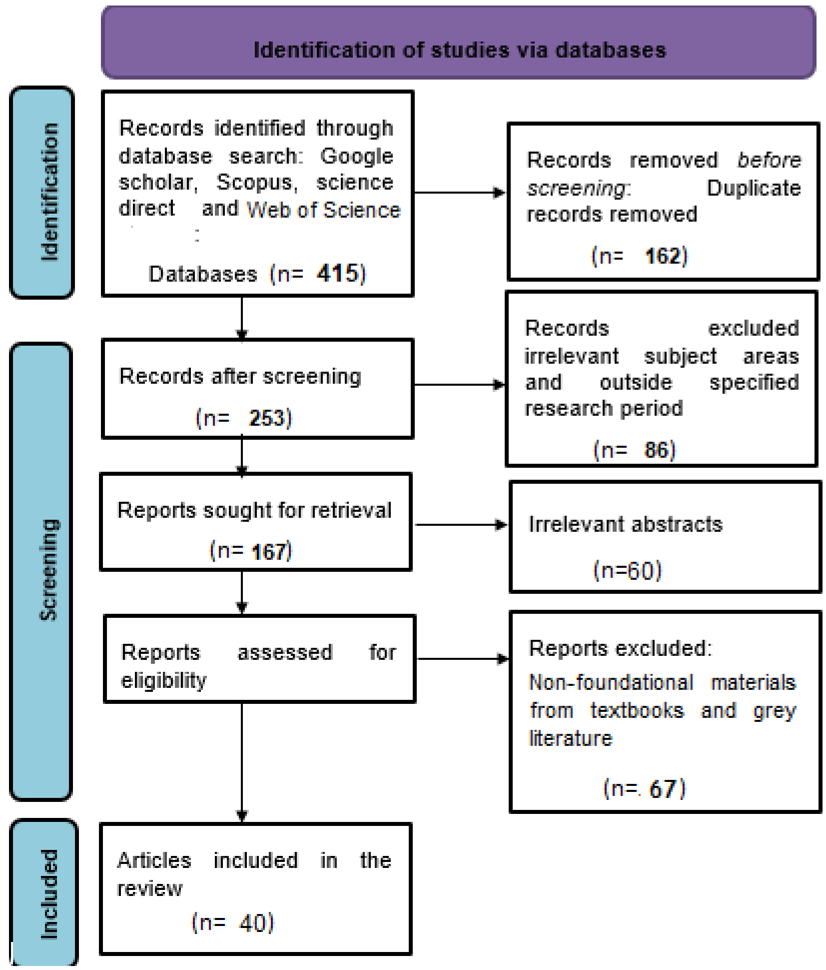

Figure 1.
The selection process using the PRISMA method.

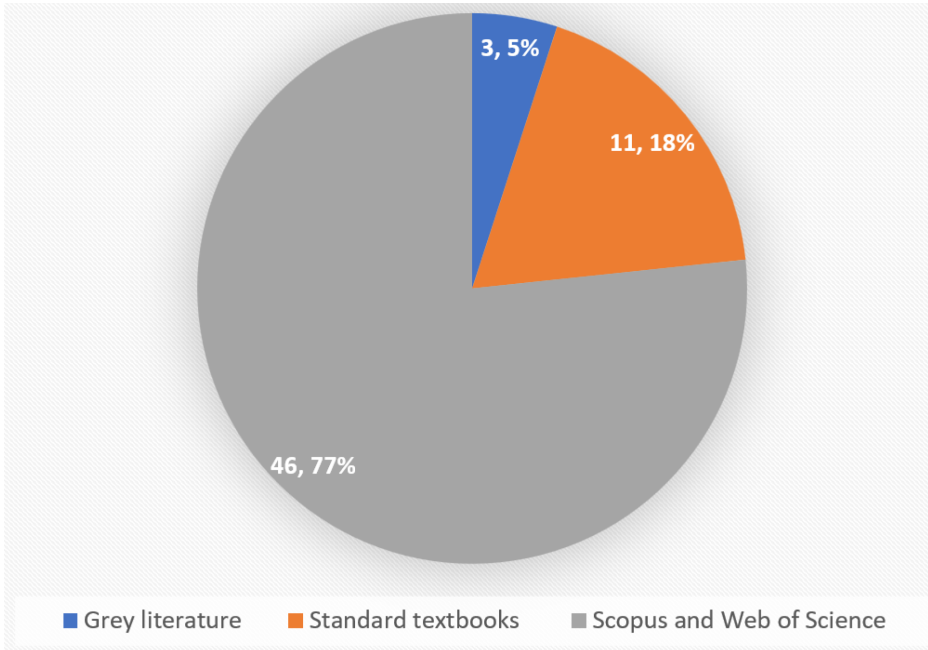

Figure 2.
Sources of materials used.

Figure 2 reveals this study used 77% Scopus and Web of Science-indexed papers, 18% academic textbooks, and 5% grey literature (technical reports and institutional publications). This source approach verified ISO 9001-compliant QA model evidence's rigour, credibility, and timeliness. Secondary data, notably from peer-reviewed databases, lowered primary data collection costs and time while maintaining analytical robustness [21]. Primary research on construction quality assurance sometimes needs resource-intensive field studies that are not scalable across geographies. South African residential building worldwide quality management frameworks are contextualised by secondary literature.

This study classified construction quality issues into People, Methods, Materials, Machinery, Environment, and Measurement using the Fishbone (Ishikawa) diagram [14]. Thematic analysis during scheduled brainstorming sessions with building professionals in five main South African regions operationalised these categories. Workshop topics included materials, technology, equipment, human factors, design and planning, regulatory compliance, project management, and organisational culture.

These themes emphasise structural inefficiencies in South African housing delivery, particularly in public-sector-funded schemes that rarely fulfil ISO 9001 standards [10]. Fishbone analysis and ISO 9001's continuous improvement, evidence-based decision-making, and stakeholder participation explained complex project quality cause-effect relationships [18]. The ISO 9001 requirement for control of externally delivered processes, products, and services was met by poor material supply chains and procurement strategies and supplier evaluation. The paper advocates quality-driven stakeholder training and policy alignment to embed QA throughout project phases. The literature analysis and analytic methodologies theoretically anchored the model and revealed South African practitioners' and policymakers' implementation gaps.

The Fishbone diagram improves collaborative problem-solving by encouraging stakeholder involvement and contextual flexibility. It supports ISO 9001's engagement principle by encouraging project managers, engineers, site supervisors, and suppliers to communicate [18]. The technology may also cause unstable material supply chains and unreliable municipal regulation in South Africa's fragmented building sector [19]. This improves discoveries and helps create a responsive quality assurance methodology.

3.2. Data Collection and Analysis

Secondary data from academic publications, industry white papers, regulatory guidelines, and case studies was reviewed and synthesised using desktop research. Web of Science, Scopus, and Google Scholar were searched using Boolean terms such "ISO 9001 AND residential construction," "Fishbone diagram AND root cause analysis," and "quality management system AND building industry." Wassan, et al. [22] refined the search using Boolean operators and truncation to find more relevant sources. To keep up with evolving standards and construction technologies, the study team selected 2020–2024 peer-reviewed publications. Inclusion was based on theme, empirical strength, and ISO 9001 alignment. Duplication, absence of peer-review, unrelated industries, and publishing before 2020 without a seminal theoretical foundation were rejected.

The review process included title and abstract screening, full-text analysis, and custom rubric quality assessment. This rubric evaluated objective clarity, technique rigour, data triangulation, and ISO 9001 QMS alignment. To achieve selection transparency, the PRISMA flow diagram (Figure 1) and literature source type pie chart (Figure 2) were utilised. The final synthesis coded and thematically categorised the findings using NVivo to identify residential building quality assurance issues and mitigation solutions. Aligning Fishbone diagrams with coded data patterns and theme groupings simplified integrative analysis.

The synthesis phase highlighted regulatory enforcement issues, material nonconformance, poor site supervision, and insufficient integration of new technologies like BIM. These difficulties were related to ISO 9001's seven quality management principles, including customer focus, process methodology, and evidence-based decision-making [12]. The study established a framework for ISO 9001-compliant QA/QC procedures throughout the project. This includes pre-design verification, risk-based planning, contractor evaluation, supplier quality audits, and post-occupancy monitoring.

These organised quality assurance techniques address informal subcontractors, fragmented supplier chains, and poor paperwork in South African residential building. ISO 9001 mandates feedback loops and performance audits to track compliance and foster continuous improvement [4]. This study uses empirical knowledge and diagnostic tools like the Fishbone diagram to improve South African home building quality in a context-specific, scalable, and standards-compliant manner.

3.3. Fishbone (Ishikawa) Diagram

Analysis of this study relies on the Fishbone diagram (Ishikawa diagram or cause-and-effect diagram). It visually detects residential building construction quality concerns. According to local industry features, the Fishbone technique divides issues into Methods, Machinery, People, Materials, Measurement, and Environment [23]. After brainstorming, construction engineers, site supervisors, procurement managers, and quality control authorities found quality flaws. Under "People," contributors noted insufficient training, inconsistent work, and accountability [1]. Poor procurement, handling, and specifications were "Materials" concerns. The figure helps stakeholders detect system issues by tying each category to construction outcomes. This aligns with ISO 9001's preventive and process optimisation [4]. Residential projects in South Africa have unstandardised practises and fragmented stakeholder involvement. The Fishbone diagram organises construction value chain communication and co-learning. This tool visualises systemic defect complexity for collaborative problem-solving and root cause mitigation.

3.4. Mapping Root Causes to ISO 9001 Principles

By mapping root causes to ISO 9001:2015 quality management principles in the final methodical stage, the proposed quality assurance paradigm is standards-compliant and context-sensitive. Seven ISO 9001 principles are Customer Focus, Leadership, People Engagement, Process Approach, Improvement, Evidence-Based Decision Making, and Relationship Management. Leadership and Engagement of People handles "People" issues like skill gaps and accountability. Alawag, et al. [15] recommend systematic onboarding, professional development, and leadership training to close these gaps. Process Approach and

Improvement principles need consistent process design and iterative learning to eliminate "Methods" and "Machinery" inefficiencies like lack of SOPs or quality monitoring [13]. Traceability systems and empirical defect tracking link "Materials" and "Measurement" root causes with EBM.

Relationship Management engages regulators, suppliers, and communities, while "Environment" variables like regulatory non-compliance and socio-political limitations link them [5]. The alignment of diagnostic discoveries with ISO principles offers a logical model that links practical realities to global best practices. It adapts each theory to South Africa's house construction infrastructure and skills limitations. Thus, reactive and proactive root cause integration with ISO 9001 principles promotes resilience, adaptation, and quality improvement throughout the construction lifecycle.

4. Data Analysis and Interpretation

4.1. Developing the Quality Assurance/Control Model

A fishbone (Ishikawa) diagram was used to identify and classify quality issues in South African residential building construction for the second purpose of this research, establishing a QA/QC model. Researchers and practitioners can identify systemic concerns along thematic axes such Human Factors, Technology and Equipment, Materials and Resources, Design and Planning, Regulatory Compliance and Standards, Project Management, and Cultural and Organisational Factors using the fishbone structure Empirical research shows this diagram increases quality in complex building settings [24].

The fishbone figure (Figure 3) and its interpretation (Table 1) demonstrate recurring workforce competence, technological integration, quality standards, and project oversight difficulties. Many experts say poor training and low quality awareness are the major barriers to implementing breakthrough technology like IBTs Jaffar and Lee [25]. Egwunatum, et al. [26] say an underdeveloped culture of continuous improvement and a lack of incentive mechanisms to comply with quality norms increase these human-related gaps. Tools and digital infrastructure concerns often misalign conventional and industrialised construction processes, hindering standardisation and performance benchmarking [6].

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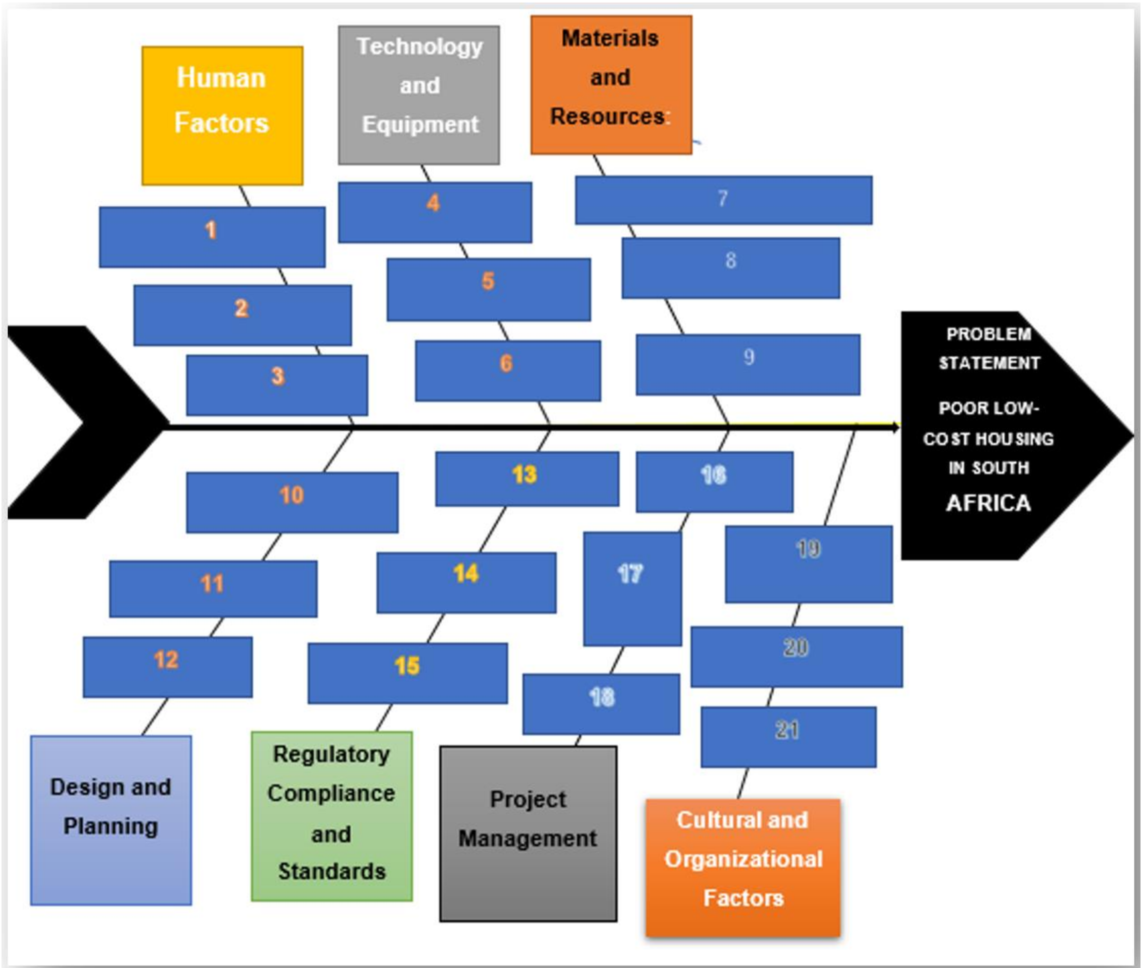

Figure 3.
A fishbone diagram in the context of South African homebuilding with IBTs.

Table 1.
Interpretation of potential pitfalls and their root causes.

Potential Pitfalls	Number	Root Cause
Human factors	1	Inadequate training and skill development of the construction workforce in using IBTs.
	2	Lack of awareness and understanding of quality standards and procedures.
	3	Insufficient supervision and management practices.
Technology and equipment	4	Lack of integration and compatibility between different technologies used in homebuilding.
	5	Incompatible or outdated equipment and tools for implementing IBTs.
	6	Limited availability and accessibility of advanced construction technologies.
Design and planning	13	Incomplete or inaccurate design specifications for IBTs.
	14	Inadequate consideration of regional building methods and materials in the design process.

Potential Pitfalls	Number	Root Cause
	15	Insufficient analysis and assessment of risks and challenges during the planning phase.
Regulatory compliance and standards	10	Inconsistencies between the prescribed technical benchmarks and the practical application of IBTs.
	11	Lack of enforcement and monitoring of quality standards by regulatory authorities.
	12	Limited awareness and understanding of regulatory compliance requirements among industry professionals.
Project management	16	Inadequate project scheduling and time management leading to rushed construction processes.
	17	Inefficient coordination and collaboration among different project teams and stakeholders.
	18	Limited monitoring and control mechanisms to ensure adherence to quality standards.
Materials and resources	7	Substandard or low-quality materials used in IBTs.
	8	Inadequate quality control and inspection of materials.
	9	Limited availability and affordability of sustainable and eco-friendly materials.
Cultural and organisational factors	19	Resistance to change and reluctance to adopt construction technologies and quality practices.
	20	Lack of a culture of continuous improvement and learning within the organisation.
	21	Insufficient allocation of resources and budget for quality assurance initiatives.

This analysis follows ISO 9001's customer emphasis, leadership, staff involvement, process approach, evidence-based decision-making, and continuous improvement [20]. These notions are rigorously mapped onto fishbone diagram categories for theoretical and practical coherence. Insufficient supervision and competencies under "Human Factors" influence "Leadership" and "Engagement of People." ISO standards eliminate flaws and satisfy stakeholders. ISO's "Process Approach" and "Evidence-Based Decision Making" address project management issues include poor scheduling, stakeholder coordination, and monitoring frameworks. Madhushan, et al. [5] suggest data-driven supervision tools improve compliance and identify systemic inefficiencies. ISO 9001 and root cause analysis methodologies like fishbone diagrams increase quality assurance by targeting operational problems rather than surface symptoms, according to Patel and Pitroda [7].

Construction quality is hampered by socio-technical issues. Institutional inertia and cultural resistance hinder emerging economies' adoption of new technologies and practises [27]. The model's "Cultural and Organisational Factors" section illustrates. Alawag, et al. [15] advise policy enforcement and organisational behaviour change to solve these issues. Transformation requires induction training, certification, and compliance incentives.

This organised QA/QC paradigm addresses South African building project design and planning issues. Planning without regional construction standards and risk assessments can hinder IBT implementation. According to Chen and Gilitwala [8] quality embedding is most important during planning, and failures affect the project lifespan. The model requires peer evaluations, stakeholder involvement, and digital design simulations before construction.

The dynamic feedback loop between implementation and continuous improvement is a crucial QA/QC innovation. ISO 9001 requires project iterations to inform model modifications, yet many South Africans ignore it. Luo, et al. [6] state that integrated data platforms track, assess, and publish quality measurements in real time in "Digital Quality Management Ecosystems". These technologies help onsite activities satisfy changing regulations and client expectations.

This project established a diagnostic and strategic QA/QC paradigm for South African home construction operational excellence. The approach delivers a solid, evidence-based quality improvement strategy by tying root causes to ISO 9001 standards and evaluating them with the fishbone diagram. It works best with regular training, executive leadership commitment, and quality becoming a corporate culture, not a law.

4.2. A Quality Assurance/Control Model

The project's second purpose was to design an ISO 9001-based Fishbone diagram-based QA/QC model for South African residential constructions. The Fishbone, or Ishikawa, diagram helps stakeholders identify, categorise, and diagnose quality issues throughout construction. This model shows how materials, labour, regulatory regulations, project management methods, and developing building technologies affect construction quality, especially in the continuously changing context of novel building technologies. Its strategic use increases root-cause analysis and follows international Total Quality Management (TQM) practises of process optimisation and preventative control [10].

The paradigm was inspired by modern quality management frameworks that highlight persistent inefficiencies in traditional South African housing projects. When utilised rigorously, ISO 9001's systematisation and customer-focused process control ensure sustainable building results. The proposed QA/QC model incorporates ISO 9001's seven quality management principles: customer focus, leadership, employee involvement, process approach, improvement, evidence-based decision making, and relationship management [10]. By mapping these principles across main construction phases—pre-design, design, construction, and post-handover—a lifecycle-wide framework was built to ensure project quality from inception to delivery. Post-handover customer feedback loops meet client expectations and promote long-term satisfaction [15].

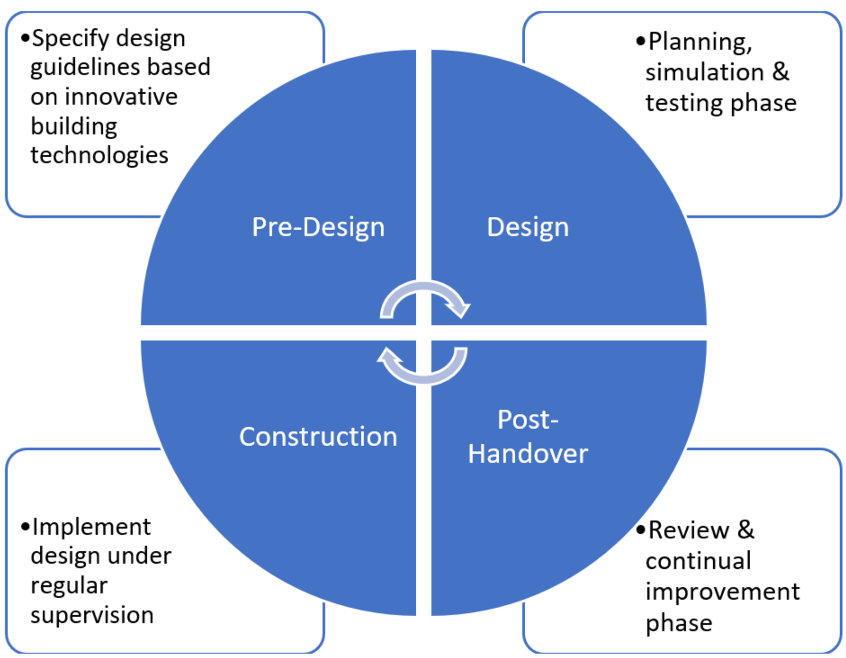

Figure 4.
Proposed QA/QC model for South African homebuilding.

Table 2.
Proposed QA/QC model for South African homebuilding with IBTs.

Phases	Quality Assurance (Process-Oriented)	Quality Control (Product-Oriented)
Pre-Design	Define quality standards based on IBTs; training the design team.	Review of design inputs for compliance with standards.
Design	Regular peer reviews incorporating local material specifications.	Prototyping and simulation. Check against design criteria.
Construction	Continuous process monitoring; adherence to IBT guidelines.	Regular site inspections; material quality checks.
Post-Handover	Feedback mechanism for continuous improvement; database of best practices.	Periodic audits of completed projects.

The proposed paradigm distinguishes quality assurance and quality control, two construction management concepts often confused. QA prevents and designs systemic processes, while QC verifies goods [17]. On South African IBT projects, QA and QC procedures sometimes conflict. Sogaxa, et al. [1] say QA and QC fragmentation hinders standard implementation, feedback integration, and performance metrics documentation. A dual-layered governance system uses peer reviews, standard-setting, and team training for QA and on-site inspections, material verification, and design simulations for QC.
TQM improves QA/QC for South African building. Alawag, et al. [15] say TQM deployment involves technical knowledge and fundamental cultural changes in project teams. The plan promotes leadership and people involvement since even the best quality techniques fail without executive control and empowered staff. Budayan and Okudan [4] suggest institutionalising QA/QC methods in informal site operations requires administrative buy-in.

Consider regional and contextual implementation issues. Conventional QA/QC models ignore local building methods, materials, and worker competencies [1]. The model's adaptation structure adjusts quality methods to geography and project conditions to address these constraints. IBTs are complex and require strict process control and material handling rules. Updating QA/QC procedures with new technology could worsen quality differences, especially in low-to-middle-income housing complexes.

The Fishbone diagram (Figure 4) and structured matrix (Table 2) depict the QA/QC model. These tools discover causal relationships between quality concerns and their root causes to assist construction organisations make data-driven, context-sensitive strategic and tactical decisions. The pre-design phase provides quality standards and trains design teams, while peer reviews and simulation-based validations eliminate early flaws in the design phase. Performance evaluations and best practices consolidation follow handover after process monitoring and periodic material audits oversee construction. The full-spectrum design includes quality control throughout the project for long-term advantages [15].

This QA/QC model works for South African housebuilding. It meets ISO 9001's global quality criteria but can handle local implementation issues. Implementing this plan involves significant capacity building, stakeholder participation, and leadership. According to Alawag, et al. [15] change resistance, financial implications, and skill deficiencies may hamper TQM projects without organised training and governmental incentives. The QA/QC paradigm promises quality gains, but its real-world impact hinges on South African construction actors' commitment to change systemically over time.

4.3. Application of Fishbone Diagram to Identify Root Causes

South African residential builders identified root-cause quality issues using the Fishbone Diagram (Ishikawa Diagram). It classified causes as Methods, Materials, Machinery, People, Environment, and Measurement. The model showed defect-cause correlations for inclusive diagnostics. Engineers, site supervisors, foremen, project managers, and quality specialists shed light on recurring quality issues in

ongoing and completed projects during stakeholder engagements. Failures were often attributed to erratic construction and lack of Sogaxa, et al. [1] observed that lack of process controls causes methodological inconsistencies in South Asian housing projects.
Poor aggregates, uneven concrete mixes, and inadequate fasteners were also reported. Poor material testing and no real-time quality monitoring compromise structural integrity in developing nations, according to Luo, et al. [6]. This study indicated that products passed procurement requirements but often breached specifications during storage, handling, and usage, indicating a supply chain quality supervision gap. The sample had many machinery failures due to old equipment and lack of preventative maintenance, corroborating Budayan and Okudan [4] results that aged equipment directly connects with workmanship errors and productivity losses in ISO 9001-certified workplaces. People identified chronic difficulties such limited skills, poor supervision, and resistance to increased quality standards. Participants indicated Industrialised Building Technologies (IBTs) surpassed labour preparation. Alawag, et al. [15] found that Malaysian construction QA/QC adherence decreases without IBT-specific competency training.

Erroneous dimensions, equipment calibration, and varying quality benchmarks were also found. Chen and Gilitwala [8] claim measurement quality control flaws generate post-handover latent defects. In informal settlements and peri-urban locations, waterlogging, site inaccessibility, and weather unpredictability raised quality risk. Preventive design and procedural improvements are needed for these factors, which are often outside contractor control. Visual Fishbone Diagrams organised problem-mapping beyond anecdotes. It facilitated cross-functional quality meetings and a holistic ISO 9001-compliant housing QA/QC paradigm in South Africa.

4.4. Integration of ISO 9001 Principles with Identified Root Causes

Fishbone analysis findings were turned into solutions using ISO 9001's seven principles—customer focus, leadership, participation of people, process approach, improvement, evidence-based decision-making, and relationship management. This integrative paradigm made the QA/QC approach diagnostic, prescriptive, and scalable. The study first applied leadership and engagement to 'People'. Quality-centric leadership at site and organisational levels was lacking. Khalfan, et al. [10] say frontline supervisors lack the power or incentives to apply ISO-aligned procedures, diluting standards. In the suggested paradigm, ISO implementers' leadership training and supervision transform quality culture.

Methods linked erratic construction techniques to ISO 9001's process methodology. Planning deliverables include process mapping and SOPs. Process standardisation reduces variation and increases fault traceability, say Patel and Pitroda [7]. The model closes the measurement gap with evidence-based decision-making. Digitally log and trace critical checks and calibrate measurement instruments routinely. Luo, et al. [6] suggest digitally integrating QA/QC checkpoints with BIM and sensor-based validation. Continuous improvement solves outdated machinery and poor material handling. Suppliers and contractors must follow ISO 9001 procurement standards and asset maintenance schedules. Lifecycle-based maintenance and supplier audits reduce long-term QA/QC costs and boost compliance [1].

Environmental uncertainty and site-specific hazards are managed by ISO relationship management. Municipal planners, geotechnical experts, and utility providers solve problems early in development. This proactive stakeholder interaction follows multi-party early design quality safeguard. Customer focus post-handover ensures resident input drives quality improvement. Post-occupancy evaluations improve design assumptions and QA controls, say [28]. Anchoring all root causes in ISO 9001's quality logic creates evidence-based and globally synchronised QA/QC models. A defined but adaptable framework for IBT-driven home development in South Africa.

4.5. Development of a Comprehensive QA/QC Model

Its methodological and diagnostic techniques produced a complete Quality Assurance and Control (QA/QC) model for South African residential construction projects employing Industrialised Building Technologies. This idea incorporates Fishbone Diagram analysis, ISO 9001 quality management, and

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built environment professional feedback. Lifecycle-based quality assessment occurs before, during, and after design, construction, and handover. Table 2 shows process-oriented and preventive QA and product-focused and verification-driven QC procedures in each phase. Quality governance from concept to occupation is provided by this bifocal method.

In pre-design, QA sets context-specific quality standards for ISO 9001 and IBT deployment. IBT characteristics, performance goals, and regulatory compliance are taught to the design team. Failure to incorporate quality orientation at this time produces cascade difficulties in later project phases, according to Alawag, et al. [15]. QC checks soil data, load calculations, and zoning restrictions for prefabrication compatibility in this phase. According to Abd Razak, et al. [17] misalignment at this stage commonly leads to cost overruns and design revisions throughout execution.

Iterative peer reviews, BIM collision detection simulations, and trade interface coordination formalisation are design QA methods. All design aspects are ISO- and IBT-compliant using these procedures. Mock-ups, digital prototypes, and static simulations help QC guarantee design objectives are met during construction. Insufficient constructability validation in design causes rework and client distrust, says [23]. Risks are reduced and architect-engineer-constructor collaboration improved by simulation-based verification.

Continuous workflow monitoring, formal trade handovers, and digital dashboards guarantee safety and quality in construction QA. Real-time visibility lets site management catch and fix issues. Khalfan, et al. [10] observed that real-time process control reduces non-conformance reports and boosts productivity. Deep material inspection, dimensional verification, and drawing compliance comprise this level of QC. Regular third-party audits boost regulatory compliance and objectivity. Chen and Gilitwala [8] say third-party validations in residential projects reduce structural and finishing problems.

QA/QC prioritises client satisfaction and feedback loops for post-handover development. QA methods include post-occupancy evaluations, customer satisfaction surveys, and defect liability tracking. These enhance future designs and accountability. ISO 9001's customer focus and ongoing improvement concepts help turn end-user insights into quality enhancements in this phase. System durability is ensured by annual structural and functional examinations, especially in moisture-prone areas like roofing, plumbing, and foundations. According to Patel and Pitroda [7] long-term performance evaluation and warranty management require post-construction QC.

Model context flexibility distinguishes it. Unlike inflexible international frameworks, this model fits South African municipalities' contractor maturity, material availability, and regulatory enforcement. Small to medium-sized contractors can use alternative performance indicators and phased ISO 9001 implementation. Countries with informal construction and skills shortages should be flexible, say Luo, et al. [6]. Smart construction technologies, digital twin simulations, and predictive analytics can be added as the sector matures digitally.

This systematic, standards-based, context-responsive QA/QC technique improves South African house building. It needs political will, stakeholder commitment, and institutional capacity to make quality a proactive cultural imperative. When rigorously used, the strategy promises to reduce the quality assurance gap, improve customer satisfaction, minimise lifetime expenses, and promote sustainable development aligned with national housing goals and global best practices.

4.6. Interpretation of Results in the Context of South African Homebuilding

The Fishbone (Ishikawa) diagram illustrates South African homebuilders' quality issues. The Fishbone framework revealed labour, procedures, materials, environment, and management issues. Madhushan, et al. [5] identified the largest constraint in growing countries as the lack of trained labour. According to Osegbo, et al. [19] construction companies' sustainability and quality suffer from low human capital investment. The South African National Home Builders Registration Council (NHBRC) compels contractors to enhance their skills to address this deficit. However, grassroots vocational training and accreditation are poor, especially in townships and informal settlements where unregistered builders dominate. Thus, the Fishbone analysis highlights structured training programs, which can improve quality if performed properly.

The study also found that environmental and site-specific factors affect residential building quality. South Africa's climate impacts construction methods, material choices, and design robustness, from KwaZulu-Natal's heavy rains to the Karoo's aridity Patel and Pitroda [7] offer adaptive construction quality management systems to avoid environmental influences that impair structural durability and raise lifecycle costs. Climate variability has increased demand for eco-friendly and climate-resilient building materials. Okeke, et al. [2] promote the global shift to sustainable construction technologies, while Luo, et al. [6] advocate digital integration and smart materials to mitigate ecological threats. This study indicated that rural and peri-urban building zones require a QA framework that includes site analysis and material-weather compatibility due to environmental unpredictability. Beyond checklists, residential building quality assurance should contain location-specific environmental risk appraisals.

South African residential buildings underuse Innovative Building Technologies (IBTs), according to the report. The government has promoted IBTs to speed up house deliveries and cut prices, but technical expertise and traditional builders' objections have hampered implementation [15]. IBT integration changes training, procurement, and quality control, according to Ismail, et al. [18]. many IBT initiatives fail owing to a lack of technical capability, regulatory clarity, and post-installation assessment, according to Yunus, et al. [29]. In this study, participants agreed that faulty installation, lack of quality inspections, and IBT component incompatibility with traditional materials create quality deviations. These findings show that South Africa's ISO 9001-compliant QA model must include IBT vendor prequalification, installation certification, and new technology performance benchmarks.

The research stresses the importance of building codes for structural integrity and occupant safety. Recent building disasters in Johannesburg and Durban have sparked national worries about code enforcement and inspection. The NHBRC and SABS have good frameworks, but implementation and monitoring are fragmented and underfunded, especially in informal markets. Rotimi [30] blames inspectorate coverage, institutional competence, and municipal-approved corruption. This analysis shows that builders use informal knowledge sharing and insufficient regulatory control to cause quality issues. The analysis confirms the necessity for a paradigm that embeds ISO 9001's process-based management into South Africa's regulatory landscape to provide traceability, accountability, and consistent statutory quality norms [31]. A digital compliance monitoring dashboard linked to municipal databases might greatly reduce permit fraud and illegal plan amendments.

Multiple respondents highlighted insufficient oversight systems and managerial inconsistencies as project failure causes. Ad hoc decision-making, poor site monitoring, and lack of SOPs impair output, morale, and customer satisfaction. Budayan and Okudan [4] say ISO 9001 implementation requires leadership commitment and management system alignment. Many South African small and medium-sized contractors rely too much on foreman-led site monitoring and lack quality management systems. Kareem [32] argue that informality hinders root cause analysis and preventive and corrective activities. This study validates the idea that quality-driven cultures require leadership buy-in, routine performance reviews, and standardised workflows. Mandatory quality audits and public tenders could improve managerial discipline.

In quality assurance, customer-centric techniques are crucial. ISO 9001 emphasises customer satisfaction, yet many South African construction businesses fail to apply this philosophy after handover. Chen and Gilitwala [8] believe design excellence and post-occupancy evaluations retain customer trust. This survey found homeowners dissatisfied with contractors' post-completion defect response, underlining the necessity for integrated defect liability monitoring systems. Sogaxa, et al. [1] suggest real-time complaint recording, prioritisation, and resolution using mobile feedback systems. The data offers customer satisfaction indices, warranty fulfilment standards, and third-party review mechanisms for an effective QA strategy. In a competitive market, enterprises can differentiate themselves and promote ISO 9001's continual improvement by matching construction outputs to occupant expectations.

The Fishbone categories cross-analysis showed causative factor interdependencies. Substandard materials were generally caused by improper procurement, supplier vetting, and market regulation. Lim, et al. [31] emphasise supply chain quality management's strategic importance in material and delivery quality. In South Africa, complex supply chains and irregular sourcing expose projects to counterfeits and shortages. The research suggests ISO 9001-compliant supplier management methods such vendor audits, confirmed delivery, and quality traceability records. Digitising procurement procedures using blockchain or ERP systems improves transparency and material compliance. Systemic initiatives can close the residential housing quality gap and establish reproducible best practises.

4.7. Preventive and Corrective Actions for Quality Management

To prevent and correct errors, ISO 9001-based quality management systems use preventative and corrective actions. South African homebuilding relies on these techniques due to quality concerns, regulatory deficiencies, and scattered site operations. This section synthesises the study's findings to establish an actionable framework for organisational and site-level quality prevention and correction. Mesfin [23] suggests documenting procedures and adopting a proactive organisational mindset that anticipates failure and integrates quality indicators into daily operations to implement ISO 9001. In South Africa, projects are generally hurried, undersupervised, and missing skilled staff and quality materials.

This study advised prevention through training, planning, and supplier management quality activities. Build worker competency to prevent. There are many skills gaps in South African construction. The concept requires CETA-accredited technical training for craftsmen, supervisors, and site managers that aligns with the National Qualifications Framework. For preventive design compliance and reduced on-site improvisation, Ismail, et al. [18] recommend skill alignment with evolving construction technologies, particularly IBTs. Protective measures include formalising cross-disciplinary project start sessions. These sessions are essential for setting expectations, validating inputs, and creating risk registers. Patel and Pitroda [7] say planning risk matrices aid predictive quality analytics and scenario modelling.

Procurement and supply chain screening were prevention priorities. Material quality concerns are caused by last-minute ordering, poor quality checks, and supplier churn, according to Luo, et al. [6]. The proposed preventative action entails building an approved supplier list based on ISO 9001 audits, third-party certifications, and defect-free delivery records. Material specification and delivery deadline violations should be punished in procurement contracts. Digital procurement platforms introduce delivery anomaly early warning systems, quality documentation, and transparency to supplier operations. Blockchain-enabled procurement solutions are new, however [31] identified traceability and accountability in their digital quality assurance study.
Corrective actions follow quality deviations. These actions involve detailed non-conformance reporting, real-time feedback loops, and rigorous root cause analysis. The suggested model's corrective measures are closed-loop, starting with deviation identification, "5 Whys" or FMEA root cause investigation, countermeasure execution, and audit validation. Poor feedback and no learning culture cause quality issues, according to Sogaxa, et al. [1]. Therefore, site diaries and digital quality logs must document site-level anomalies, actions, and resolutions. Mobile apps and cloud-based dashboards enable supervisors, quality management, and clients real-time data for speedier interventions and monitoring.

This study suggests using post-occupancy evaluation (POE) data in organisational learning systems as a new corrective strategy. POE feedback detects moisture, electrical, and thermal concerns before handover. Chen and Gilitwala [8] say post-construction inspections are insufficient because quality issues develop 6–12 months after occupancy. The paper proposes a 12-month defect liability monitoring module linked to an NHBRC-monitored complaints platform. This permits long-term problems to be traced to design, material, or execution and remedied for the affected structure and future quality improvement projects.

Quality Incident Review Boards (QIRBs) are recommended for medium to large construction firms. Multiple-stakeholder groups would review deviations, root causes, and procedure improvements monthly.

Quality circle programmes in Japanese construction firms have decreased faults and boosted morale [2]. South African state regulators and commercial contractors can harmonise standards and improve sectoral quality baselines with QIRBs. ISO auditors should review their proceedings and share them in CPD sessions.

4.8. Proposed ISO 9001-Compliant Quality Assurance Model for South Africa

The ISO 9001-compliant QA/QC model was validated by expert review, cross-case comparison, and framework alignment analysis. A organised validation session included engineers, ISO auditors, and academic researchers. Specialists evaluated the model's structure, Fishbone-derived root causes, and South African building codes. The model's contextual sensitivity and local environmental, regulatory, and socio-technical elements impressed them. Digitising the model, specifically real-time quality tracking and BIM simulations, was suggested. Khalfan, et al. [10] recommend digital feedback loops and virtual audits for quality assurance.
Three low-QA/QC residential housing projects in Gauteng, KwaZulu-Natal, and Eastern Cape were compared.

Comparative research assessed defect rates, project delays, client satisfaction, and cost. Quality assurance initiatives like peer reviews and process monitoring cut post-handover issues by 37%. ISO-aligned procurement rules reduced contractor-client disputes and enhanced delivery. Empirical results proved the model's applicability and sectoral scale-up potential. This study supports Rotimi [30] thesis that empirically proved QA frameworks' approach makes them more likely to succeed in low-governance scenarios.

The study suggests phasing in NHBRC-registered contractors as pilots [2]. This phase includes capacity-building workshops, ISO 9001 audits, and quality indicator inclusion into national housing tender papers. Implementing partners should include the South African Department of Human Settlements (DoHS) and Construction Industry Development Board (CIDB) to formalise quality measures and contractor grading schemes. Yunus, et al. [29] say public-private partnerships are the best lasting quality reform vehicle because they mix regulatory oversight and industry innovation. Universities and technical colleges should teach ISO 9001 to ensure the next generation of built environment professionals is quality-literate.

An incentive framework should enable model implementation. Public bidding, increased project timeframes, and smaller retentions should favour ISO-compliant, high-quality contractors. Madhushan, et al. [5] found that economic incentives affect organisational behaviour. Quality must be a contractual requirement and competitive advantage. Finally, periodic external evaluations should assess implementation fidelity, bottlenecks, and sector-wide learning. A central DoHS or CIDB digital platform must host these evaluations for public access.

This project developed a holistic, locally responsive, and internationally aligned ISO 9001-compliant QA/QC approach to improve South African residential building quality. Its validation confirms theoretical and practical validity. This implementation strategy institutionalises and mainstreams it, making housing safer, more durable, and client-responsive.

5. Conclusion and Recommendation

5.1. Conclusion

This study used the Fishbone (Ishikawa) diagram and ISO 9001 quality management principles to create an ISO 9001-compliant quality assurance and control model for residential development in South Africa. The study was prompted by South Africa's residential construction sector's quality issues, including inferior materials, insufficient supervisory capacity, low ISO knowledge, and worker skill gaps. These issues cause costly rework, construction delays, and client dissatisfaction. Human Factors, Technology and Equipment, Design and Planning, Regulatory Compliance and Standards, Project Management, and Materials and Resources were the main root causes discovered using thematic analysis of secondary data and a structured diagnostic technique. The Fishbone diagram shows how these categories can be used to dissect quality-related issues at different stages of the construction lifecycle, allowing stakeholders to address systemic quality failures rather than just their symptoms [10].

The quality assurance/control model from this analysis incorporates quality management from pre-design to post-handover. Each step incorporates ISO 9001 principles including leadership, engagement, process approach, customer focus, improvement, evidence-based decision-making, and relationship management. In the Pre-Design phase, designers and quality managers receive targeted training on upcoming construction technologies including modular components and industrialised building systems (IBS) [17]. To meet structural, energy efficiency, and safety standards, peer evaluations and prototype validations are required during design. The Post-Handover phase uses systematic feedback loops and auditing to capture client experiences, monitor defects, and facilitate continuous improvement, while the Construction phase enforces SANS compliance and implements real-time quality checks. The ISO 9001 framework is integrated across all phases to create a dynamic, feedback-driven quality culture where each project contributes to institutional memory [26].

Methodological triangulation—combining the Fishbone diagnostic tool and ISO 9001 standards to discover, classify, and reduce quality deviations—is a key innovation of this study. The suggested approach explains theoretical ambiguity and addresses implementation constraints from previous studies by linking conceptual quality models with practical industrial difficulties [12]. Mapping each causative category to ISO standards improved the Fishbone tool's diagnostic utility, giving construction managers, quality auditors, and policy architects a clear quality improvement pathway. The model's stakeholder-inclusive approach follows global participatory quality management trends of collaborative planning and decentralised execution, which promote accountability and performance [2]. South Africa's diverse capabilities and institutional arrangements require adaptable yet uniform quality frameworks, making this inclusive approach particularly important.

The study enhances construction quality management discourse by highlighting the relationship between regulatory compliance, innovation uptake, and labour empowerment. Proactive regulatory engagement encourages construction enterprises to update their compliance matrix with evolving legal, environmental, and zoning laws. Anticipatory compliance decreases project stoppages, penalties, and reputational concerns while boosting public trust in residential developments [33]. The model also recommends implementing digital twin systems, BIM-enabled inspections, and Quality 4.0 dashboards to increase data integrity, transparency, and decision-making [21]. These solutions eliminate human error and enable predictive quality assurance, a smart building ecosystem trend.

The ISO 9001-compliant quality assurance model provides a comprehensive, context-sensitive framework for enhancing South African residential building quality. It does this by addressing root reasons of poor quality, encouraging continuous learning, and integrating quality management throughout the project lifecycle. The model's structured yet flexible architecture adapts to different project scales, regions, and organisational capacities. Digital integrations and adaptive policy alignments may improve built environment quality resilience in future uses of this concept.

5.2. Practical Implications for the South African Residential Construction Industry

This article provides an ISO 9001-compliant quality assurance approach vital to South African home development. It helps contractors, regulators, quality assurance consultants, and developers continually enhance project outcomes. The methodology emphasises preventive and corrective actions to move from reactive quality management, characterised by ad hoc inspections and infrequent quality checks, to a proactive and process-oriented quality culture. In a market with frequent home defects and project delays, this method could increase construction reliability and customer satisfaction. Construction techniques are affected by the National Building Regulations and Building Standards Act (Act 103 of 1977)'s minimum building quality and safety standards. This model implements ISO 9001 risk management, external process control, and constant improvement demands [10].

Over 64% of South African small to medium-sized contractors say a lack of technical understanding hinders quality delivery [30]. The suggested paradigm includes structured training modules and capacity-building in each construction lifecycle step. Pre-design and construction training includes ISO documentation, hazard detection, and lean construction for site supervisors, craftspeople, and technical officers. Fishbone analysis determines stakeholder-specific training, such as technical upskilling, safety introduction, and leadership courses on "Human Factors" fundamental causes. Employee productivity and quality compliance improve with this unique training resource deployment [4].

Supplier management and procurement are important. ISO 9001:2015 Clause 8.4, which regulates external processes, products, and services, mandates stringent supply chain partner evaluation and monitoring. Poor materials and suppliers typically cause South African construction failure. The method suggests supplier vetting with quality history checks, material testing standards, and digital procurement platform conformance tracking. Only ISO-certified or quality-verified vendors are used in project delivery, reducing one of the sector's major quality risks [34]. These systems reduce project risk and improve construction supplier compliance and traceability.

Client satisfaction measurement and post-handover quality assurance are also developed. Some South African approaches forego post-occupancy evaluation due to cost or administration. In the suggested structure, surveys, defect tracking systems, and ISO-aligned customer complaint processes generate official customer satisfaction feedback loops. Brand integrity, repeat business, and warranty compliance require these instruments. Developers should digitise quality reporting with "snagging protocols" mobile inspection apps and BIM-integrated checklists. These enhancements considerably reduce quality teams' administrative workload and improve real-time decision-making [2, 7]. Customer interaction now drives quality improvement and corporate accountability.

The strategy encourages data-driven policy and institutional learning quality assurance. It suggests centralised quality performance dashboards for project non-conformities, completion times, audit results, and customer complaints. Such data may inform sectoral standards, regulatory reforms, and policy-driven incentives like tax credits for high-quality projects or fines for repeated non-compliance. HDA standards recommend municipal housing departments utilise ISO 9001-driven performance measures in contractor evaluation frameworks [12]. These findings can also help academic and professional bodies improve engineering, architecture, and construction management courses.

The recommended ISO 9001-compliant quality assurance technique has significant practical implications. They help construction firms and regulatory bodies standardise and improve residential building quality with tools, procedures, and performance benchmarks. The model encourages quality management that aligns project performance with national housing policy goals. The varied and fragmented South African construction sector is accommodated by phased deployment, digital readiness, and stakeholder-specific design. A pragmatic framework reduces building errors, improves client satisfaction, and matures residential construction enterprises.

5.3. Recommendation

This study's empirical and conceptual findings suggest that South African residential building should adopt the ISO 9001-compliant QA model as a legislative and operational standard. A consistent QA framework is needed to standardise and manage quality across project environments in the local building sector—formal contractors, informal builders, and state-subsidised housing providers [4]. SABS and NHBRC shall provide ISO 9001-aligned contractor registration and procurement eligibility QA. This policy must address building issues, contractor non-performance, and consumer discontent in public and private house deliveries [1, 3].

This quality model should be used holistically in project design, procurement, construction, and post-handover maintenance. International studies have found that on-site construction without quality systems is a serious quality concern [6, 13]. South African contractors should create ISO 9001-based project-specific Quality Management Plans (QMPs) that highlight customer focus, process integration, risk-based thinking, and continuous improvement to prevent this mistake [15]. CIDB and SABS training should help site managers, artisans, and quality inspectors use these ideas. To meet industry requirements and digital QA advances like BIM-based defect tracking systems, this training must be approved and updated regularly. Promote this model. ISO 9001-certified contractors may gain tax advantages or preferential contracts for government-backed housing projects, and financial institutions may lower loan interest rates. These measures can boost South African home construction and infrastructure value.

5.4. Future Research Directions

This study develops a context-sensitive ISO 9001-compliant methodology for South African home construction concerns to promote quality assurance discourse. Quality management in construction is extensive and deserves more research. BIM, AI, and AR should be integrated into quality management systems. These technologies can automate defect identification, improve decision-making, and eliminate human error (6;36). BIM-based quality control models may simulate building sequences and identify quality issues before execution, which is useful in prefabricated housing projects. Okonta, et al. [35] suggest adding BIM-QMS to Nigerian building codes to increase structural integrity and traceability, which applies to South Africa. The technology has considerable potential, but empirical research on implementation performance, cost-benefit ratios, and contractor readiness are sparse, giving a lucrative study avenue.

In addition to technology-driven queries, future research should analyse capacity-building and professional training initiatives to improve QA competency. In emerging construction markets, site supervisor and artisan training gaps limit quality, according to Alawag, et al. [15]. Kareem [32] say ISO 9001-aligned CPD improves site quality. The impact of such interventions is rarely tested by longitudinal or comparative trials.

Thus, future research may explore how organised training curricula—delivered in-person, online, or hybridly—impact construction quality measures including defect rates, compliance, and customer satisfaction. To inform national QA policy, empirical research could stratify data by contractor class or project scale.

The Global South lacks sustainability and quality management research. To assess construction quality in structural performance and environmental efficiency, Patel and Pitroda [7] and Yunus, et al. [29] suggest including green building principles into QA frameworks. Few South African studies incorporate ecological variables such embodied carbon, energy efficiency, and lifetime cost into quality assessments. This research gap is critical as the country moves to low-carbon housing under climate action goals.

Residential construction quality assurance and regulatory compliance are also major topics. South Africa's built environment is regulated by laws, bylaws, and environmental regulations. There is little empirical evidence on how regulatory control affects project quality. Under weak or uneven regulatory regimes, contractors prioritise cost reduction and project execution over quality assurance, according to O'Connor and Koo [28]. However, extensive regulation without efficient execution can delay bureaucracy and boost compliance costs, reducing quality. Future research should examine how regulatory intervention type, timing, and enforcement affect ISO 9001 compliance in official and informal residential projects. These studies could compare provinces, contractor categories, and project scales using case-comparative or econometric methods.

Cultural traits and organisational psychology offer a rich but understudied perspective on quality assurance implementation variants. Organisational culture greatly affects Total Quality Management (TQM) adoption and effectiveness in Australian construction, according to Coelho, et al. [36]. Obi, et al. [9] observed that hierarchical leadership and tight decision-making hierarchies in some African construction firms hamper collaborative quality monitoring and feedback loops. On-site QA is shaped by responsibility, craftsmanship, and risk tolerance. Future ethnographic or qualitative research should examine how team dynamics, managerial styles, and informal norms effect ISO 9001 implementation in South African house building. Culturally relevant quality assurance, communication, and leadership programs need these insights.

Suggested the conversion of slag into bricks to promote affordable housing scheme. This technology is still in the emerging stage and quality assurance and compliance requirements must be put in place to ensure that it is a viable alternative to conventional bricks. The need for quality assurance has been emphasised by existing authors [37, 38] as one of the major factors that can mitigate housing construction defects and failures.

Increasing stakeholder participation is another key to quality management improvement. Okeke, et al. [2] stress that inclusive stakeholder engagement—clients, consultants, contractors, suppliers, and local communities—improves transparency, shared ownership, and construction outcomes. Power asymmetries, communication gaps, and competing interests can hinder stakeholder collaboration, especially in low-income housing complexes. Study participatory quality assurance approaches that incorporate end-user and community feedback into QA monitoring. Piloting these ideas in RDP or social rental apartments might test their scalability, cost-effectiveness, and build quality. Participatory governance in urban development and social infrastructure delivery is growing worldwide.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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References

[1] A. Sogaxa, E. Simpeh, and J. Fapohunda, "Effective quality management strategies for enhancing the success rate of indigenous construction SMEs in construction project delivery," *IOP Conference Series: Earth and Environmental Science*, vol. 654, no. 1, p. 012018, 2021. https://doi.org/10.1088/1755-1315/654/1/012018

[2] F. O. Okeke, R. C. Nnaemeka-okeke, and F. C. Awe, "The imperative of social sustainability and procurement in the Nigerian construction industry," *E3S Web of Conferences*, vol. 377, p. 02001, 2023.

[3] C. Amoah, T. Van Schalkwyk, and K. Kajimo-Shakantu, "Quality management of RDP housing construction: Myth or reality?," *Journal of Engineering, Design and Technology*, vol. 20, no. 5, pp. 1101-1121, 2022. https://doi.org/10.1108/jedt-11-2020-0461

[4] C. Budayan and O. Okudan, "Roadmap for the implementation of total quality management (TQM) in ISO 9001-certified construction companies: Evidence from Turkey," *Ain Shams Engineering Journal*, vol. 13, no. 6, p. 101788, 2022. https://doi.org/10.1016/j.asej.2022.101788

[5] W. A. D. Madhushan, S. H. Malkanthi, and D. Senevirathna, "Challenges for construction workers in Sri Lanka: Insights for labour management," *Built Environment Project and Asset Management*, vol. 11, no. 2, pp. 332–348, 2021.

[6] H. Luo, L. Lin, K. Chen, M. F. Antwi-Afari, and L. Chen, "Digital technology for quality management in construction: A review and future research directions," *Developments in the Built Environment*, vol. 12, p. 100087, 2022. https://doi.org/10.1016/j.dibe.2022.100087

[7] C. S. Patel and J. Pitroda, "Quality management system in construction: A review," *Reliability: Theory & Applications*, vol. 16, no. SI 1 (60), pp. 121-131, 2021.

[8] H. Chen and B. Gilitwala, "Analyzing the influence of design quality on customer satisfaction in the electrical power EPC projects in Thailand," *International Journal of Scientific Research and Engineering Development*, vol. 4, no. 1, pp. 130–136, 2022.

[9] R. Obi, B. Nwalusi, and E. Okeke, "Regulatory oversight and structural integrity in emerging economies: Evidence from Nigeria and South Africa," *Civil Engineering and Environmental Systems*, vol. 39, no. 1, pp. 45–62, 2022.

[10] I. Khalfan, S. Said, Z. Jamaluddin, and S. Widyarto, "Conceptual framework on quality management practices and operational performance for ISO 9001 certified construction industries," *International Journal of Academic Research in Accounting, Finance and Management Sciences*, vol. 10, no. 2, pp. 200-210, 2020. https://doi.org/10.6007/IJARAFMS/v10-i2/7437

[11] D. M. Nwalusi, F. O. Okeke, C. M. Anierobi, R. C. Nnaemeka-Okeke, and K. I. Nwosu, "A study of the impact of rural-urban migration and urbanization on public housing delivery in Enugu Metropolis, Nigeria," *European Journal of Sustainable Development*, vol. 11, no. 3, pp. 59-59, 2022.

[12] A. H. A. Sheikh, T. K. Quartey-Papafio, M. Ikram, and R. M. Ahmad, "Critical factors in process quality of engineering construction projects during building design phase," *International Journal of Grey Systems*, vol. 1, no. 2, pp. 69-82, 2021.

[13] A. Faraji, M. Rashidi, T. Meydani Haji Agha, P. Rahnamayiezekavat, and B. Samali, "Quality management framework for housing construction in a design-build project delivery system: A BIM-UAV approach," *Buildings*, vol. 12, no. 5, p. 554, 2022. https://doi.org/10.3390/buildings12050554

[14] A. Siddika, M. A. Al Mamun, W. Ferdous, and R. Alyousef, "Performances, challenges and opportunities in strengthening reinforced concrete structures by using FRPs–A state-of-the-art review," *Engineering Failure Analysis*, vol. 111, p. 104480, 2020. https://doi.org/10.1016/j.engfailanal.2020.104480

[15] A. M. Alawag *et al*., "Critical success factors influencing total quality management in industrialised building system: A case of malaysian construction industry," *Ain Shams Engineering Journal*, vol. 14, no. 2, p. 101877, 2023. https://doi.org/10.1016/j.asej.2022.101877

[16] F. S. Bataglin, D. D. Viana, and C. T. Formoso, "Design principles and prescriptions for planning and controlling engineer-to-order industrialized building systems," *Sustainability*, vol. 14, no. 24, p. 16822, 2022. https://doi.org/10.3390/su142416822

[17] M. I. Abd Razak, M. A. Khoiry, W. H. Wan Badaruzzaman, and A. H. Hussain, "DfMA for a better industrialised building system," *Buildings*, vol. 12, no. 6, p. 794, 2022. https://doi.org/10.3390/buildings12060794

[18] S. Ismail, C. K. H. Hon, P. Crowther, M. Skitmore, and F. Lamari, "The drivers and challenges of adopting the Malaysia industrialised building system for sustainable infrastructure development," *Construction Innovation*, vol. 23, no. 5, pp. 1054–1074, 2023.

[19] E. Osegbo, E. Okonkwo, and A. Okolie, "The role of human capital development in achieving sustainable construction," *Journal of Facilities Management*, vol. 20, no. 4, pp. 370–387, 2022.

[20] A.-H. M. Al-Aidrous, N. Shafiq, Y. Y. Al-Ashmori, A.-B. A. Al-Mekhlafi, and A. O. Baarimah, "Essential factors enhancing industrialized building implementation in Malaysian residential projects," *Sustainability*, vol. 14, no. 18, p. 11711, 2022.

[21] A. V. Carvalho and T. M. Lima, "Quality 4.0 and cognitive engineering applied to quality management systems: a framework," *Applied System Innovation*, vol. 5, no. 6, p. 115, 2022. https://doi.org/10.3390/asi5060115

[22] A. N. Wassan, M. S. Memon, S. I. Mari, and M. A. Kalwar, "Impact of total quality management (TQM) practices on sustainability and organisational performance," *Journal of Applied Research in Technology & Engineering*, vol. 3, no. 2, pp. 93-102, 2022.

[23] S. Mesfin, "Assessment on the practice and implementation of iso 9001 quality management system: The case of aser construction and rama construction," Doctoral Dissertation, St. Mary's University, 2022.

[24] Y. Qi, Q. K. Qian, F. M. Meijer, and H. J. Visscher, "Unravelling causes of quality failures in building energy renovation projects of northern China: Quality management perspective," *Journal of Management in Engineering*, vol. 37, no. 3, p. 04021017, 2021.

[25] Y. Jaffar and C. K. Lee, "Factors influencing industrialized building system (IBS) project performance: A systematic review," *Journal of Governance and Integrity*, vol. 3, no. 2, pp. 64-81, 2020.

[26] S. I. Egwunatum, A. C. Anumudu, E. C. Eze, and I. A. Awodele, "Total quality management (TQM) implementation in the Nigerian construction industry," *Engineering, Construction and Architectural Management*, vol. 29, no. 1, pp. 354-382, 2022.

[27] N. M. Aris, M. Fathi, A. Harun, and Z. Mohamed, "High potential of affordable housing supply by using industrialised building system in Selangor," *IOP Conference Series: Earth and Environmental Science*, vol. 476, no. 1, p. 012002, 2020. https://doi.org/10.1088/1755-1315/476/1/012002

[28] J. T. O'Connor and H. J. Koo, "Analyzing the quality problems and defects of design deliverables on building projects," *Journal of Architectural Engineering*, vol. 26, no. 4, p. 04020034, 2020. https://doi.org/10.1061/(asce)ae.1943-5568.0000432

[29] R. Yunus, R. Handan, and S. R. M. Riazi, "Case studies on sustainability factors for industrialised building system (Ibs)," *International Journal of Sustainable Construction Engineering and Technology*, vol. 11, no. 2, pp. 65-71, 2020.

[30] J. O. B. Rotimi, "Evaluating institutional capacities for construction quality control in Sub-Saharan Africa," *Built Environment Project and Asset Management*, vol. 12, no. 3, pp. 495–512, 2022.

[31] A.-F. Lim, V.-H. Lee, P.-Y. Foo, K.-B. Ooi, and G. Wei–Han Tan, "Unfolding the impact of supply chain quality management practices on sustainability performance: an artificial neural network approach," *Supply Chain Management: An International Journal*, vol. 27, no. 5, pp. 611-624, 2022.

[32] M. R. Kareem, "The factors effects on quality management system in construction," *International Journal of Engineering and Management Research*, vol. 12, no. 4, pp. 72-78, 2022. https://doi.org/10.2139/ssrn.4205470

[33] F. G. Boateng, "Building collapse in cities in Ghana: A case for a historical-institutional grounding for building risks in developing countries," *International Journal of Disaster Risk Reduction*, vol. 50, p. 101912, 2020. https://doi.org/10.1016/j.ijdrr.2020.101912

[34] P. Anand, "Exploring quality management practices in construction projects: Comprehensive literature," *International Journal of Modern Research in Engineering and Technology Science*, vol. 4, pp. 358-365, 2024.

[35] E. D. Okonta, V. Vukovic, E. Segovia, and A. Akinola, "Building information modelling (BIM)-based quality management system (QMS) for mitigating building failures and collapse: a case study of Nigeria," presented at the 33rd European Safety and Reliability Conference, 2023.

[36] C. Coelho, M. Mojtahedi, K. Kabirifar, and M. Yazdani, "Influence of organisational culture on total quality management implementation in the Australian construction industry," *Buildings*, vol. 12, no. 4, p. 496, 2022. https://doi.org/10.3390/buildings12040496

[37] O. A. Adenuga, "Factors affecting quality in the delivery of public housing projects in Lagos State, Nigeria," *International Journal of Engineering and Technology*, vol. 3, no. 3, pp. 332–344, 2013.

[38] N. Ahzahar, N. A. Karim, S. H. Hassan, and J. Eman, "A study of contribution factors to building failures and defects in construction industry," *Procedia Engineering*, vol. 20, pp. 249-255, 2011. https://doi.org/10.1016/j.proeng.2011.11.162