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IMPROVING CONSTRUCTION PROJECT DOCUMENT MANAGEMENT IN THE ETHIOPIAN CONSTRUCTION INDUSTRY USING QR CODE TECHNOLOGY: A CASE STUDY ANALYSIS ACROSS THREE SECTORS IN ADDIS ABABA

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Abstract

This research aimed to determine the applicability of QR code technology in improving document management efficiency within the construction industry. Globally, construction project management increasingly relies on modern information and communication technologies to facilitate data exchange, decision-making, and project control. In Ethiopia, however, the construction sector continues to depend heavily on paper-based documentation, and QR-integrated digital document management remains largely unexamined. Given the novelty of this approach in the country, scientific investigation is necessary to document evidence on its implementation and effectiveness. The study therefore sought to investigate document management practices throughout the document lifecycle among key construction stakeholders and to propose a QR code-based solution. Specifically, it aimed to identify the challenges of traditional document management, and to design and develop a mobile-based QR code documentation system, and evaluate the system's technical functionality and usability in terms of system usefulness, information quality, interface quality, and overall usability. A developmental and qualitative research design was employed, six organizaions representing the principal stakeholder groups in the construction industry in Addis Ababa wree purpesively selected for semi structured interview, In addition, four implementaion case studies in which the QR code system was deployed were purposively selected to evaluate its technical funcionality and usability within a mixed-methods framework. Findings from current document management practices revealed that frequent loss of file records is a critical issue, primarily due to document distortion and fragmentation. These challenges often result in legal consequences from mismanagement, as well as delays in sharing updated files between field and office. Consequently, access to the latest documentation on site remains inefficient and unreliable. In contrast, the proposed QR-based system passed all technical tests and demonstrated strong usability, enabling file access within two to three minutes. The system thus offers a practical tool to bridge the digital divide and promote a more efficient, transparent construction sector in Ethiopia.

Keywords: Construction Documentation, Digital Transformation, Document Management system, Information Management, Mobile Application, Paper-Based Systems, QR Code.

1. Introduction

Effective project document management is critical for construction project success, It serves as the backbone for communication, quality control, and informed decision-making throughout a project's lifecycle, yet Ethiopia's construction industry continues to suffer from persistent shortcomings. Common issues include a lack of disciplined record keeping and haphazard document storage, leading to inefficiencies, errors, and managerial breakdowns (Bewuketu & Mequanint, 2023). Although digital technologies are transforming construction globally, Ethiopia's sector still relies on fragmented, largely paper-based systems that perpetuate lost, duplicated, or outdated records. Furthermore, the application of digital tools to quality management remains underexplored (Bitew et al., 2023).

Construction companies encounter operational inefficiencies as a direct result of their continued dependence on manual document management. Bitew et al. (2023) highlight how these inefficiencies manifest across multiple dimensions of project execution, undermining both productivity and project control. Key problems include considerable difficulties in timely document retrieval, excessive time spent searching for and managing physical records, and heightened risks of document loss due to the inherent vulnerabilities of manual handling.

Moreover, communication gaps also emerge from the geographical distance between project sites and administrative offices, making coordination challenging. To tackle these interconnected issues, adopting a technology-driven management system is not merely beneficial but crucial. Such a system must simplify documentation workflows, ensure data precision and integrity, and effectively manage information generated by geographically dispersed teams (Builder, 2022).

Despite the proliferation of digital solutions that offer proven pathways to enhance information management, adoption within Ethiopia's construction industry remains critically limited, thereby impeding overall project efficiency. Recent scholarship confirms that practitioners still rely heavily on paper-based systems or fragmented digital storage methods that offer little improvement over manual processes (Bewuketu & Mequanint, 2023). The global shift toward digitization has spurred interest in accessible, low-cost technologies (SharePoint, Google Workspace, Con Ditital, etc.) and other EDMS tools that deliver immediate improvements in documentation practices. QR codes are increasingly cited in construction literature as a practical alternative to paper-based documentation. Janapala (2021) identifies operational benefits including speed, low error rates, security, and traceability, while Hein (2021) and Rellon et al. (2021) highlight smartphone compatibility and seamless integration with cloud-based systems. Collectively, these studies present QR codes as a low-barrier solution to documentation inefficiencies.

Although QR codes represent a promising element within modern document management systems, limited research has explored their application in Ethiopia's construction sector. Their potential to streamline documentation practices remains largely unexamined in academic literature. Hence, this study addresses that gap by: assessing current construction document management practices, identifying existing challenges and limitations, and designing a QR code–based system to improve efficiency within the Ethiopian construction sector. This study is situated within the broader context of rapid technological advancement in construction, focusing on the application of QR codes. However, it is subject to several limitations. The reliance on interviews and case studies, combined with the absence of organized

secondary data, introduces elements of subjectivity and recall bias. Additionally, the lack of a comparative component (e.g., contrasting organizations without digital systems) impedes the precise attribution of observed challenges to the absence of QR-code-based tools.

The research addresses a gap concerning the use of QR codes to improve construction documentation, particularly for document management. The proposed value lies in simplifying document access across the industry value chain, enabling convenient and readily updatable distribution to relevant departments. This study is specifically designed to examine the application of QR code technology to improve document management practices within Ethiopian construction companies. It proposes a QR code–based document management system as a targeted intervention to address pervasive inefficiencies, where traditional manual processes for tracking engineering deliverables remain time-consuming, error-prone, and heavily reliant on physical documentation. Through this approach, the study seeks to demonstrate a practical, low-cost pathway for digital transformation that can enhance overall project efficiency and reliability.

Hence, the objective of this study is to improve construction project document management in the Ethiopian construction industry through the application of QR code technology, with a focus on three stakeholder groups that influence system implementation. The study is divided into three main sections: the first identifies the potential challenges associated with document management practice in the Ethiopia construction industry, and the second examine the use of QR code technology in the construction document management system, and finaly analyze the prefromance of the recommended solution in the document management of three cotegories of business in Addis Ababa.

2. Literature Review

2.1 Document Management System

Document Management Systems (DMS) are specifically designed to facilitate and streamline the myriad activities associated with document management throughout their lifecycle (Jane, 2020). An Electronic Document Management System (EDMS) serves as a centralized digital repository that streamlines the creation, organization, retrieval, tracking, and archiving of documents across multiple formats including text, audio, video, and images. EDMS reduces reliance on ad hoc storage methods such as shared drives or sync-and share tools, thereby enhancing accessibility, minimizing the risk of lost or misplaced files, and enabling employees to locate and manage information efficiently (Hayland, 2025). The transition from traditional paper-based methods to a Digital Document Management System represents a fundamental shift in how organizations approach information management. Adopting a digital DMS streamlines workflows by automating routine tasks such as filing, retrieval, and distribution (Biels Document Management, 2021). Furthermore, by incorporating digital document storage, businesses can simplify overall document management processes and significantly enhance the efficiency and accuracy of information retrieval (Pratt, 2021).

2.2. The Importance of Document Management in Construction

In the construction industry, document and record management plays a pivotal role in project management and in facilitating effective communication among stakeholders and the organization. Implementing a construction document management system offers numerous advantages:

Improve communication & collaboration: Centralized, real-time document storage enables teams to work from a single authoritative source, aligning software with organizational needs and ensuring strong information security are key success factors for such systems (Ziemba et al., 2022).

Reducing Project Delays: Strong document control streamlines workflows and ensures faster access to accurate information, preventing delays caused by missing documents or slow approvals (Stack, 2020).

Enhanced Document Control & Organization: A centralized DMS organizes documents systematically, enables controlled access, reinforces version control, and provides features like version tracking and advanced search for efficient retrieval (Li et al., 2020).

Reduce Errors & Mistakes: Controlled access to only approved, current versions prevents field errors and rework. Digitalized document management drastically reduces errors while increasing generation, sharing, viewing speed, and precision (Chen et al., 2022).

Enhanced Accessibility & Information Retrieval: Keyword and filter-based searches enable rapid access to relevant documents, eliminating inefficiencies of manual or disorganized systems (Lim et al., 2021).

Cost Savings & Efficiency: A DMS reduces physical resource costs (storage, printing), lowers labor hours, minimizes rework, supports compliance, and prevents budget overruns (Building Design Construction, 2021).

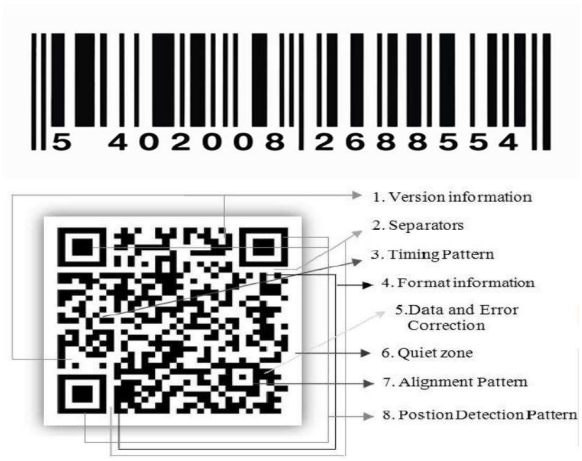
Compliance & Risk Management: Integrated audit trails, permission controls, and standardized processes ensure regulatory compliance and legal dispute mitigation, promoting accountability and transparency (Wang & Plume, 2012).

Improved Version Control: Automated version control ensures all stakeholders use current documents, streamlining review and approval workflows to enhance efficiency and productivity.

Improve Project Execution & Delivery: Reducing administrative tasks allows focus on core work. Accurate documentation minimizes clashes, supports cost control, and optimizes resources, ensuring successful project delivery (Love et al., 2017; Bubshait et al., 2019).

2.3. A Review on QR Code

QR codes which stand for "*Quick Response codes*" is a machine-readable two-dimensional bar code (Price, 2013:1-2). The black and white squats can represent numbers from 0 to 9, letters from A to Z, or characters in non-Latin scripts such as Japanese Kanji. QR codes were created in 1994 by Denso Wave, a Toyota subsidiary, to overcome traditional bar-code limitations in the automotive industry (Yang-Wai et al., 2020). QR codes function as data carriers; when you scan one with a smartphone, tablet, or a dedicated QR code reader, you open a digital door to access the information within (Figure 1).



Error! Reference source not found. Structure of The Evolution of QR Code (D.B. Dandekar et al., 2024)

2.4. Research Gap

The review of related literature indicates that QR code technology has been successfully applied in various domains to improve document access, tracking, and information sharing. Previous studies have demonstrated the technical feasibility of QR code based systems and their potential to enhance efficiency, reduce human error, and support digital transformation. However, existing research has not adequately addressed the development of a secure, cost-effective, and user-friendly QR code based document management system specifically tailored for construction projects, where efficient document retrieval, version control, and stakeholder collaboration are critical. The following gaps were identified from the reviewed studies:

1. **Limited research on QR code implementation in construction environments.** Lee and Bharat (2015) demonstrated the feasibility of QR codes for document control in construction projects but identified challenges related to unreliable internet connectivity, workforce resistance, and rigid workflows. This indicates a need for practical and adaptable QR code solutions for construction settings.
2. **Insufficient focus on organizational document management applications.** Likitha et al. (2023) developed a QR code

generator for real-time website access, demonstrating the versatility of QR technology. However, the study did not address document retrieval, document security, or organizational adoption of QR-based document management systems.

3. **Lack of integrated and affordable document retrieval systems.** Raorane et al. (2023) proposed a QR code–based document retrieval system but highlighted the absence of simple, cost-effective, and integrated solutions that can be readily implemented in organizations.
4. **Limited evaluation of QR code effectiveness in document management.** Abdrabou (2023) examined the role of digitalization in reducing paper-based documentation but identified a lack of empirical studies evaluating the effectiveness of QR code systems for managing and retrieving documents.
5. **Limited application to construction document management.** Antonio et al. (2023) demonstrated that QR code–enabled record tracking systems improve efficiency and reduce human error. However, their study focused on general records management and did not address the specific requirements of construction document control and collaboration.

3. Research Design and Methods

This chapter presents the research methodology, including the research design, data collection methods, sampling design, and data analysis approach for improving document management using QR code technology.

3.1. Research Philosophy Underpinnings

Interpretivism (Constructivist): Adopted to understand stakeholder experiences, institutional practices, and contextual challenges in construction document management. It aligns with qualitative inquiry when existing knowledge is limited and deeper meaning is needed (Pabel et al., 2021).

Pragmatism: Adopted as a practical, action-oriented approach. Methods are chosen based on the research question, aiming to produce actionable knowledge through iterative intervention specifically for applying QR code technology to construction document management (Allemang et al., 2022).

3.2 Research Design

The study employed a joint design method combining descriptive Case research and prototyping. A descriptive qualitative approach was used to address objectives one and three, analyzing existing document management practices and the need for a QR-capable system. Prototyping was adopted for objective two to design and develop a QR-code-based document management system application.

3.3 Research Approach

3.3.1 Qualitative Research

A qualitative case study approach was adopted to explore stakeholder experiences, institutional practices, and contextual challenges in construction document management. It examined how construction workers describe existing documentation practices, workflows, and opportunities for

3.3.2 Action Research

Applied action research was adopted, combining research and development through iterative cycles to bring about tangible improvements (Kananen, 2013). Originating from Kurt Lewin (1946), this approach emphasizes active researcher involvement in the change process. The study applied action research to address the lack of an integrated project document management system in Ethiopia's construction industry by implementing a QR-code-based solution in Addis Ababa.

3.4 Research Methods

A case study design within a mixed-methods framework was adopted, incorporating pre-test and post-test evaluations to measure existing practices, system performance, and user satisfaction. Qualitative data were gathered via open-ended questionnaires, with detailed documentation maintained for replicability.

3.4.1 Case Studies

A multiple-case study approach addressed the first and third research objectives. It evaluated current document management practices, identified key challenges, and established integration requirements for a QR-based system. Three stakeholder categories (clients, contractors, consultants) across four projects and six institutions were compared, allowing combination of multiple data sources.

3.4.2 System Development Method

An object-oriented approach using Rapid Application Development (RAD) was employed, characterized by iterative prototyping and minimal advance planning.

User requirements were assessed iteratively, with design revisions until needs were satisfied. RAD guided development, testing, maintenance, and integration phases, supported by gap analysis. Pre-test and post-test evaluations measured practice, performance, and user satisfaction over time.

3.5 Sampling Design

Target Population: All employees from six construction stakeholder organizations in Addis Ababa. Sample of 20 participants (ICT officers, document controllers, project engineers, project managers) who regularly handle records.

Sampling Technique: Purposive sampling – selected individuals with ≥5 years of decision-making experience (project managers, senior engineers, site supervisors, QA officers) plus six key organizations.

Sample Size: Not statistically determined; based on information richness. Focus groups of 4–6 participants each; total 20 participants plus 10 senior key informants.

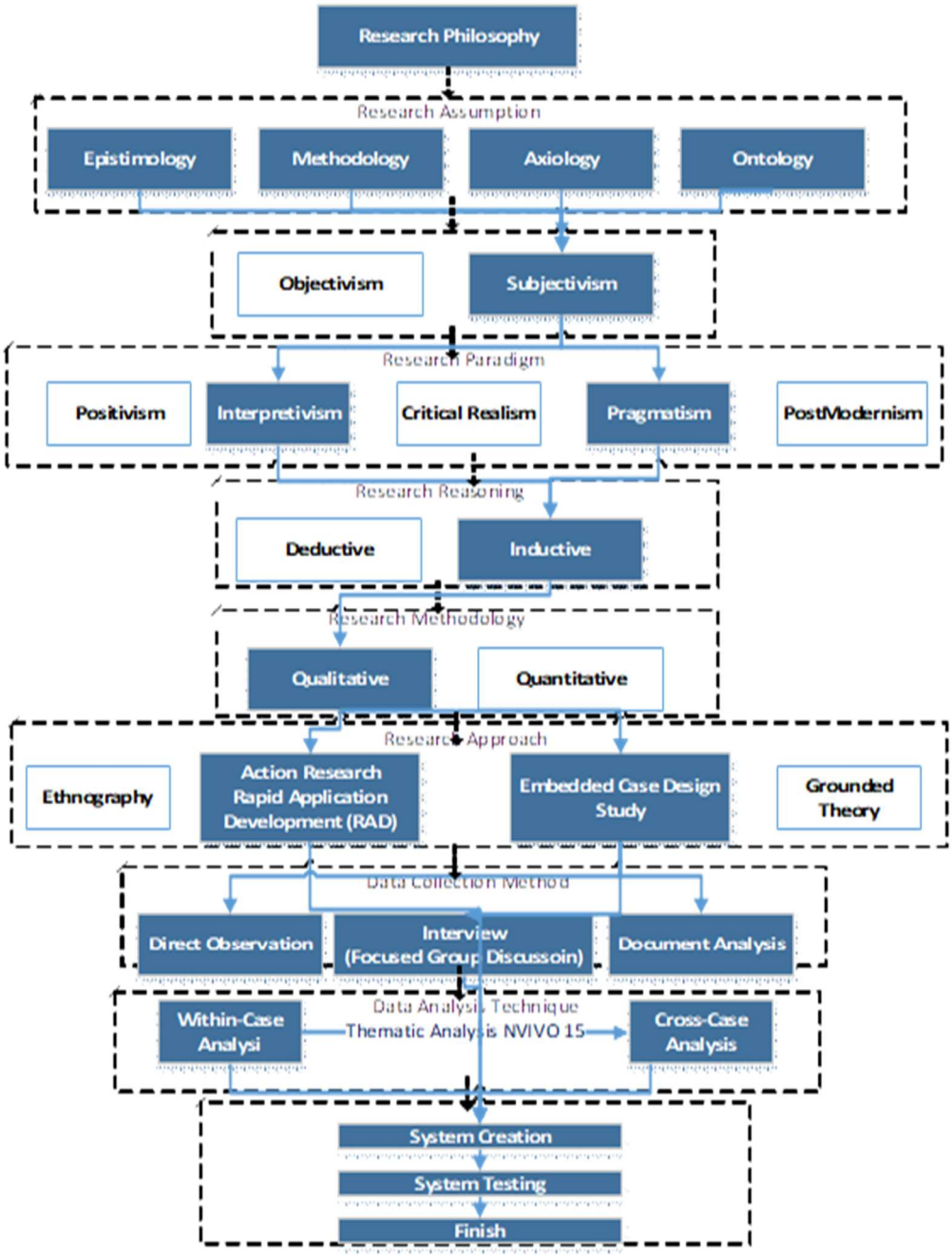


Figure 3.1: The Overall Research Process adapted from Turnbull et al. (2021)

3.6 Method of Data Collection (Primary data only)

Focus Group Discussion (FGD): Facilitated interactive sessions (6–12 participants) to explore collective experiences, challenges, and expectations regarding QR-based document management.

Semi-structured Interview: Flexible, open-ended interviews to gain deeper individual insights on document handling, approval workflows, version control, and accessibility.

Document Review: Systematic examination of project records (contracts, drawings, correspondence, approval sheets, revision logs, filing formats) for triangulation.

Observation: Direct observation of filing, approval, retrieval, version control, and communication to identify inefficiencies and informal practices not reported elsewhere.

3.7 Data Analysis

Qualitative data analysis involved systematically organizing and interpreting collected data to identify patterns, themes, and insights relevant to the research objectives (Flick, 2024; Willis, 2025). This enabled discovery of recurring behaviors, stakeholder perceptions, systemic challenges, and opportunities for system improvement grounded in real-world practice. Reflexive Thematic Analysis (RTA): RTA was used to identify, analyze, and interpret patterns of meaning across qualitative datasets from focus group discussions and semi-structured interviews. Themes are viewed as actively constructed by researchers through reflexive engagement with the data, emphasizing interpretive judgment, contextual sensitivity, and analytic transparency (Braun & Clarke, 2025; Kaur & Smith, 2025). RTA enabled the development of meaningful themes regarding construction document management practices and stakeholder views on the final system design.



Figure 3.2: Phases of Reflexive Thematic Analysis (Virginia Braun & Victoria Clarke, 2020)

To answer the research questions, each theme was systematically defined and validated against representative data extracts form Nvivo 15. Figures 3 & 4 illustarte the procedures used.

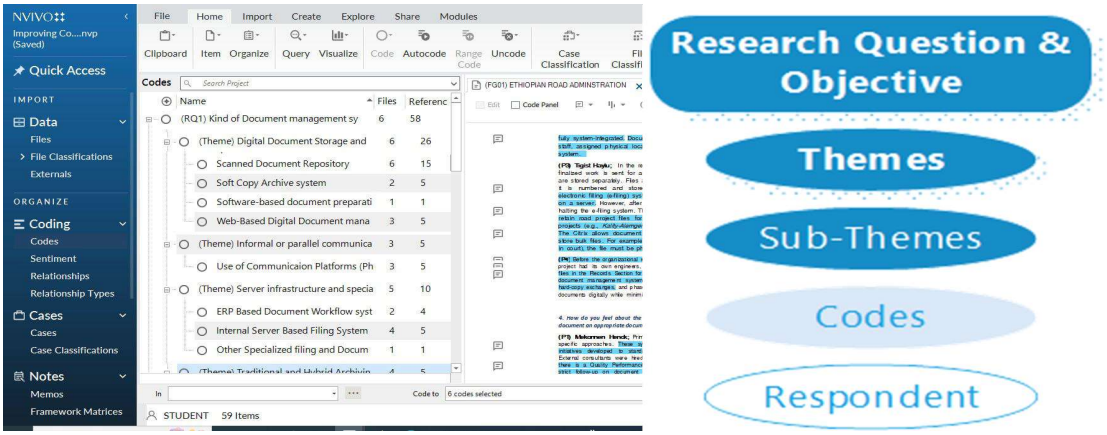


Figure 3.3: The Process of Systematic Coding (Nvivo, 2024)

3.10 Quality of the Research

Qualitative quality was ensured through contextual sensitivity, commitment, rigor, transparency, and coherence (Timonen et al., 2024; Ahmed, 2024).

Sensitivity to context: Literature review, construction management insights, and technology adoption literature shaped data collection and analysis while remaining open to emergent themes.

Commitment and rigor: Researcher immersion in observing workflows, conducting interviews, and system testing; systematic documentation of each stage ensured real-world grounding.

Transparency and coherence: All research phases were clearly documented and logically aligned (research question, design, methods, thematic analysis) without internal contradiction

3.11 Ethical Considerations

Informed consent: Participants were fully informed of objectives, risks, and benefits; voluntary participation with written consent; right to withdraw without penalty.

Confidentiality and privacy: Data anonymized, secure storage, strict access controls for QR tracking data to protect organizational and participant identities.

Respect and dignity: Cultural and professional sensitivity maintained; hierarchical and local norms respected; no disruption to work.

Responsible reporting: Findings reported honestly and accurately; recommendations based on aggregated data, avoiding unfair portrayal or exposure of individuals/organization.

4. Data Analysis & Proposed Solution

This chapter presents the findings obtained from focus group discussions (FGDs), as well as the design, development, and field testing of the prototype system.

4.1 Demographic Information

To identify current practices, challenges, and research gaps, the researcher conducted a literature review, focus group discussions, and informal interviews with 20 participants from three stakeholder groups: government client offices, design/consulting firms, and construction companies. The findings presented are based on interview data and the literature reviewed. Purposive sampling of 19 participants (47% female, 53% male; ages 23–46) from three sectors—government clients (25.2%), design/consulting firms (33.6%), and construction companies (41.1%)—provided diverse professional perspectives on document challenges. Data were collected via focus groups and semi-structured interviews.

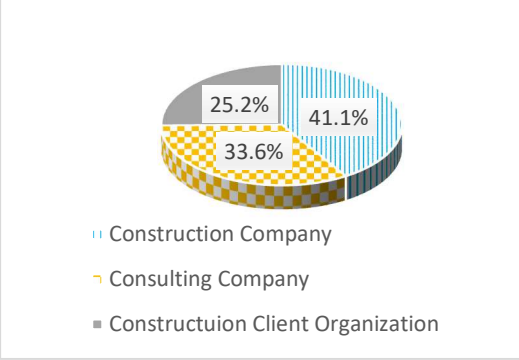


Figure 4.1: Distribution of Reference Code in Stakeholder Group

4.2 Examination of Existing Documentation Practices Traditional Manual Practices: Qualitative findings reveal distinct sector-specific variations in paper-based manual documentation practices across Ethiopia's construction industry. Consulting companies demonstrated a balanced use of color coding and reference binders (52.60%) alongside hard copy file systems (50.32%), reflecting structured yet flexible organization for managing design documents and revisions (Autodesk, 2024; Traxxeo, 2023). Client organizations showed a stronger preference for hard copy systems (44.68%) with lower reliance on color coding (28.33%), indicating institutional priorities centered on long-term archival, audit compliance, and contractual evidence consistent with weak digital governance (Getachew & Ayalew, 2023; RIB Software, 2024).

Construction companies exhibited a polarized approach: minimal pure hard copy use (5%) combined with substantial discipline-specific categorization (37.7%), driven by operational

needs such as trade, work package, and technical category requirements, where poor organization leads to delays and rework (PlanGrid, 2020; Pericent, 2023).

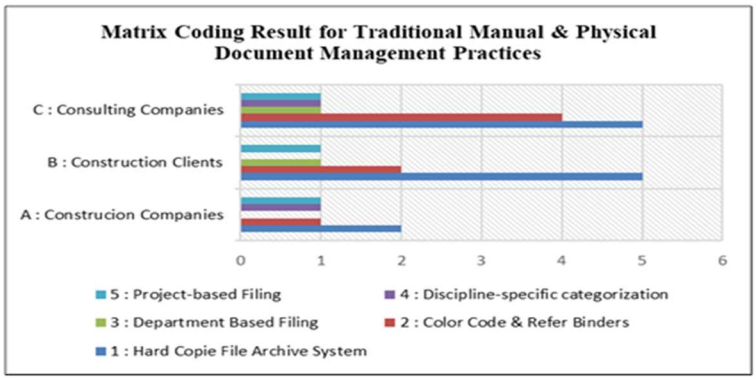


Figure 4.2: Matric Coding Result for Traditional Manual Practice

Digital Document Management: Qualitative findings reveal distinct sector-specific variations in digital document management adoption across Ethiopia's construction industry. Consulting firms demonstrated leadership in software-based document preparation (e.g., AutoCAD, Revit) but lagged in comprehensive digital adoption, potentially due to resource limitations or organizational resistance to change (Vararean-Cochisa & Crisan, 2024). Client organizations showed a stronger reliance on scanning (54.16%) and soft-copy archiving (87.93%), with web-based systems (e-Fieling, ERP, OutLook, SharePoint) used by 64.0% of government clients indicating institutional priorities centered on record retention and audit compliance, consistent with a fragmented digital transition where governance systems remain weak (Wang, 2012). Construction companies exhibited a lower adoption of web-based systems (36.0%), reflecting an uneven shift toward digital documentation, where barriers such as resource constraints, resistance to change, and organizational fragmentation slow comprehensive digital transformation (Omics online, 2025).

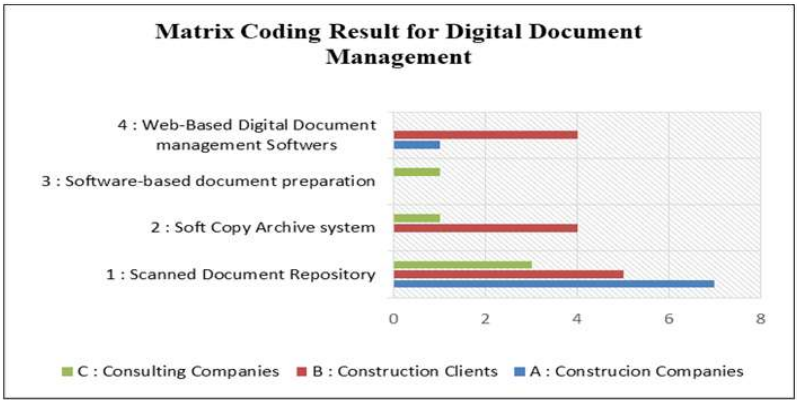


Figure 4.3: Matrix Coding Result for Digital Document Management

4.3 Challenges in The Current Document Management system

Information Governance and Quality Control inefficiencies: Qualitative findings reveal distinct sector-specific variations in information governance and quality control practices across Ethiopia's construction industry. Government (client) organizations showed higher implementation rates of ISO standards (64.58%) and Kaizen methodologies (64.08%), yet these figures may reflect institutional compliance rather than proven operational improvement consistent with research indicating that weak supervision,

coordination issues, and implementation complexity limit measurable gains in quality assurance and efficiency (Shokr & Chileshe, 2014; Soetjipto et al., 2025). Consulting firms demonstrated leadership in restricted access controls (80.36%) and secretary document custodian roles (80.36%), driven by client confidentiality needs and flexible structures; however, overly restrictive access can reduce efficiency by delaying information sharing and coordination (Marrone & Kolbe, 2011). These disparities suggest that governance tools may exist formally but remain ineffective unless evaluated through measurable operational outcomes—such as reduced document loss, improved traceability, and faster retrieval highlighting a research gap in measuring actual practice effectiveness beyond surface-level metrics.

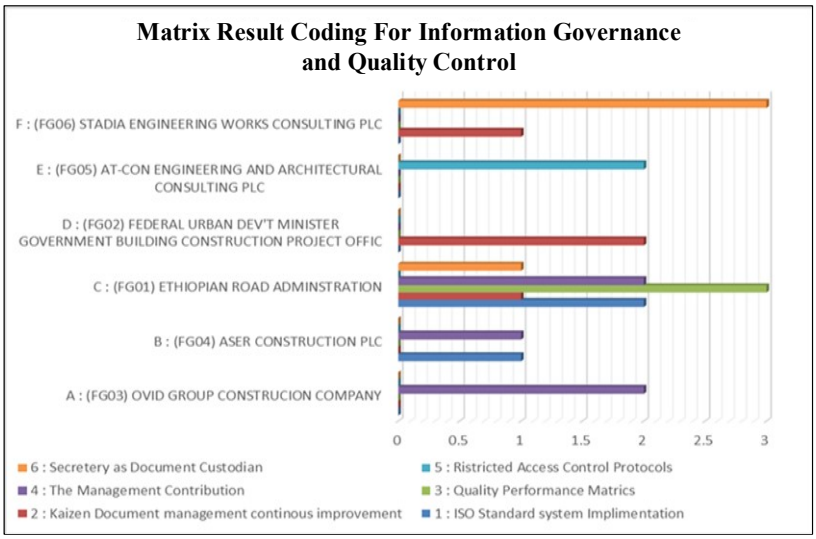


Figure 4.4: Matrix Coding Result for Information Governance and Quality Control

Inefficiencies in Manual document handling: Qualitative findings reveal distinct sector-specific variations in manual document processing inefficiencies across Ethiopia's construction industry. Government offices reported the most acute problems: poor storage conditions (96.0%), space constraints (83.9%), frequent file loss (70.39%), and disorganized record-keeping (61.57%)—directly impairing retrieval and project decision-making (Ayalew & Birhan, 2023; Neupane & Jaisi, 2024).

Consulting companies experienced lower physical space constraints (16.1%) but still reported high document overload (52.45%) and disorganized record maintenance (38.46%), indicating that paper volume overload is a cross-sectoral challenge contributing to duplication, delayed approvals, and inconsistent storage across departments and stakeholders (CollabWorx, 2025). These findings underscore the need for interventions that reduce reliance on paper workflows through structured digital systems, improved indexing, and enhanced traceability solutions.

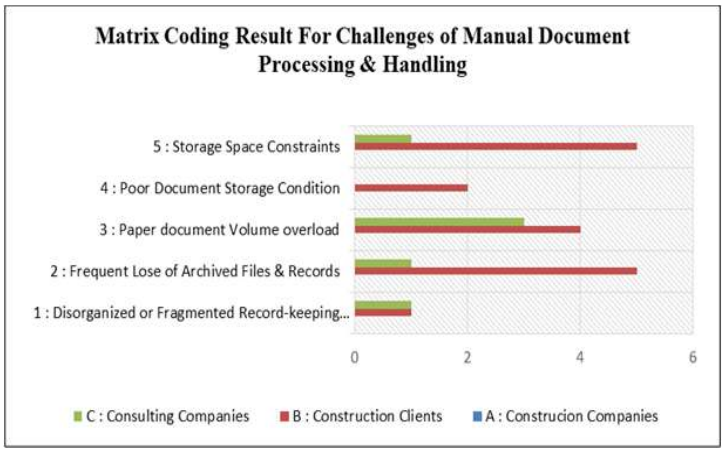


Figure 4.5: Matrix Coding Result for Challenges of Manual Document Handling

Inefficiencies in Digital Documentation systems: Qualitative findings reveal distinct sector specific variations in digital documentation system inefficiencies across Ethiopia's construction industry. Government construction agencies reported the most significant shortcomings: 56.77% lacking notification tools and 37.79% operating without tracking systems aligning with research indicating that fragmented digital adoption and incomplete system integration yield limited operational benefits, creating information silos and coordination breakdowns (Gebrehiwot & Singh, 2023). Construction Company's demonstrated partial digitization excluding departments (30.23%), while consulting firms showed 43.23% lacking tracking tools and 31.98% operating without a unified system. Literature confirms that partial digitalization increases complexity through inconsistent versions, multiple storage locations, and mixed manual digital processes, undermining transparency and real time access (Zewdie & Molloy, 2024). Furthermore, insufficient integration between digital systems and organizational processes diminishes the value of digital tools (Hassan et al., 2024). These findings reinforce that government organizations are burdened by bureaucratic inertia, while consulting and construction companies struggle to deploy cohesive digital document systems.

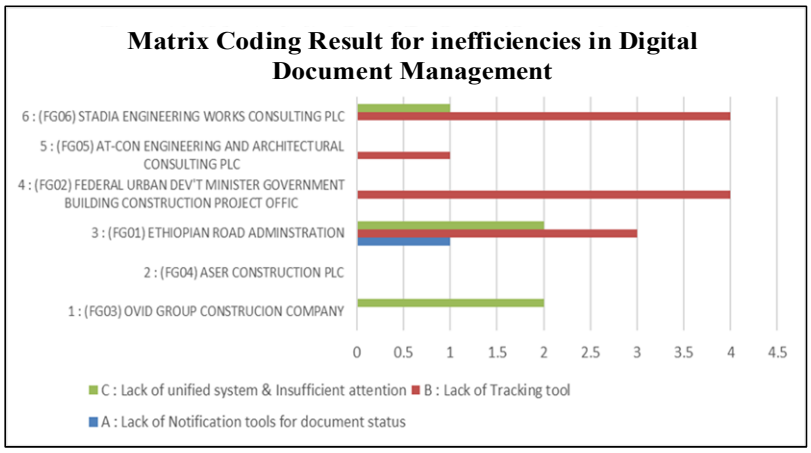


Figure 4.6: Matrix Coding Result for inefficiencies in Digital Document Management

Implementation challenges and operational barriers: Construction companies face the highest implementation challenges, aligning with literature on limited technological readiness and resistance to change (Gebrehiwot & Singh, 2023). Government offices experience significant interdepartmental coordination

breakdowns (61.54%) and limited large scale data management capacity echoing research on public sector technology challenges, Where poor internal communication, siloes departments, and lack of cross functional integration impede effective digital document system utilization (Zewdie & Molloy, 2024). Additionally, resistance to technological change within public sector entities (18.21%) persists due to staff fear of disrupting established routines or lack of confidence in technical skills. Consulting companies reported severe version control issues (99.94%) and significant communication gaps (38.48%), consistent with research showing that technical documentation challenges are especially acute in firms responsible for design, specification, and coordination tasks, which require sophisticated version management tools and rigorous protocols to maintain accuracy and traceability (Hassan et al., 2024).

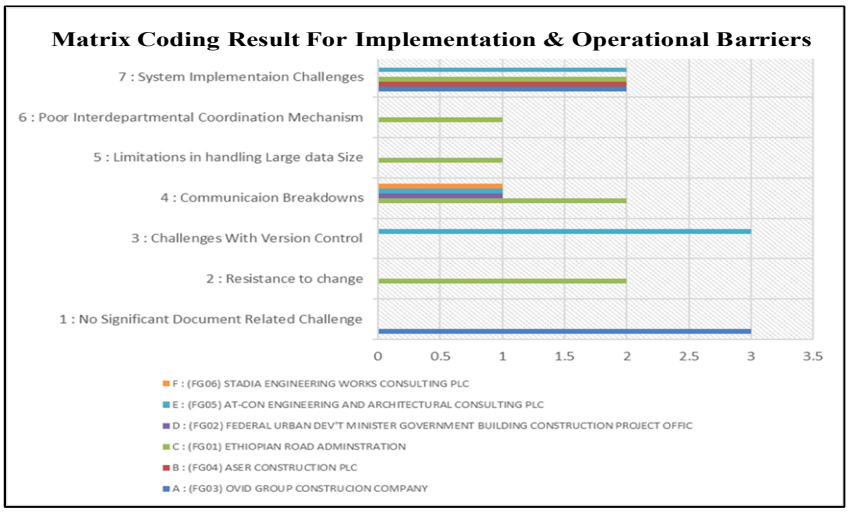


Figure 4.6: Matrix Coding Result for Implementation & Operational Barrier

4.4. Impacts of Inefficient Document Management System: Sector-specific impacts of inefficient document management across Ethiopia's construction industry. Construction companies reported significant timeline delays (52.24%) and document delivery delays (49.45%), reflecting how manual, fragmented workflows disrupt project schedules and coordination (Nawari & Ravija, 2024; CollabWorx, 2025).

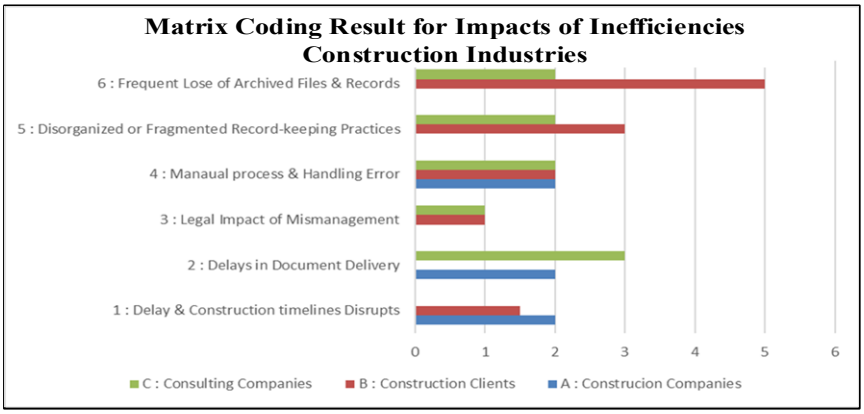


Figure 4.7: Matrix Coding Result for Impacts of Inefficiencies DMS in Construction Industries

4.5 Summary of FGD Key Findings:

Uneven digital transition: General shift toward digital, but adoption is inconsistent across sectors.

Sector-Specific documentation variation: Consulting firms (structured/flexible), public offices (weak digital governance), construction companies (polarized approach). firms (structured/flexible), public offices (weak digital governance), construction companies (polarized approach).

Formal standards with limited gains: Government offices adopt ISO/Kaizen, yet weak supervision and coordination limit measurable improvements. Consultancies emphasize security but may lack operational effectiveness.

Poor storage impairs decision-making: Across all sectors poor storage, space constraints, file loss, disorganization, document overload, delayed approvals.

Coordination and capacity hinder implementation: Construction companies face highest challenges (low technological readiness); coordination breakdowns, limited data management capacity, resistance to change, poor integration impede digital system use.

Poor documentation disrupts project outcomes: Results in timeline delays, document delivery delays, legal impacts (liability, litigation), and fragmented records that hinder project history tracking and accountability.

4.6 Proposed Application: Design, Implementation and Testing: The Rapid Application Development (RAD) methodology was selected for its iterative nature and adaptive flexibility, enabling accelerated system creation through iterative cycles and continuous user feedback. Each development phase was applied according to the study's specific needs. In this RAD methodology method, it was divided into 4 main phases as shown in figure 4.7. Stages that must be passed in the designing process of document management system:

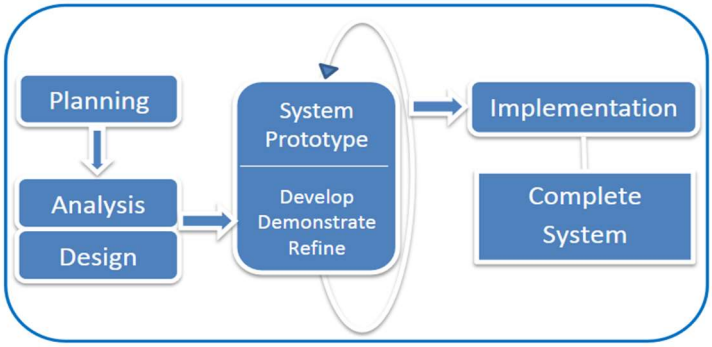


Figure 4.7: Four Main Phases in Rapid Application Development (RAD) Methodology(Retrieved July 18, 2026 from: DQMS Dissertation PDF (Tay Zhi Wei, 2013)

Problem and Requirement Identification: The RAD process begins by prioritizing key requirements and defining broad system objectives. This initial phase involved semi-structured interviews and direct observations with selected departments within construction industry organizations to trace document transmission pathways and understand existing tracking procedures. Problems identified from focus group discussions were used as a starting point to inform the subsequent proposed solution.

Objectives of the proposed system: For this research, the following core objectives were established to guide the development of the Construction Projects Document Management System:

- Establish a centralized platform enhanced by QR code integration to link physical documents to digital records for instant access.
- Enable mobile accessibility to support on-site operations.
- Facilitate real-time collaboration to reduce discrepancies among stakeholders.

- Develop the entire system iteratively using the Agile RAD methodology, incorporating continuous feedback to meet practical industry requirements.

Prototype System Development

This research developed a QR-based web and mobile documentation system using an iterative prototyping process (development → demonstration → refinement) applied to database design, user interface, document management, QR code modeling, and integration.

Database Design: NoSQL schema with collections for Users (credentials, roles), Documents (metadata, file paths, versioning), QR codes (mapping to document IDs), and Access logs (tracking interactions). Normalization and indexing enhanced performance and scalability. The database was designed using a NoSQL schema on GitHab to accommodate flexible document structures. Key collections include:

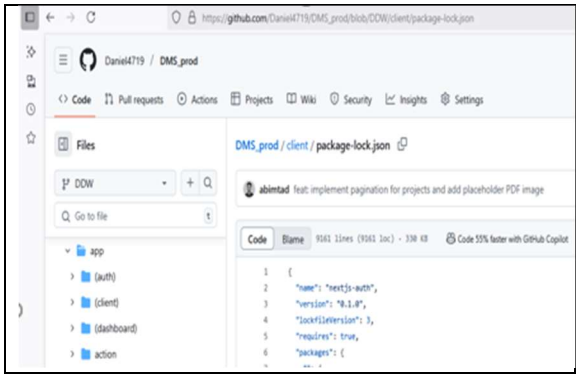


Figure 4.8: Document Database Interface Using GitHab

User Interface Design: Wireframes created in Figma, featuring a dashboard with document summary and QR scanner, upload/tagging interface, QR code generator (printer-friendly), and access control panel. Design prioritized usability, accessibility, and minimal training.

Document Management Model: Supports uploading, tagging, categorizing, and versioning. Each document stores metadata (project ID, location, date, and uploader).

QR Code Model: Codes are dynamically generated and linked to specific documents or sets. Scanning fetches documents based on user role and project phase.

QR Code Integration: Each document or physical asset has a unique QR code (embedded with Document ID, Project ID, access URL). The mobile app scans codes via device camera, authenticates the user, decodes the QR, and retrieves the document. Offline caching supports limited connectivity.

System Planning and Design: After specifying technical requirements, the system development plan and architectural design were outlined. The System employs a modular architecture to ensure centralized document control, seamless accessibility, and real-time synchronization.

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4.7 System Implementation

4.7.1 Website Interfaces: The implementation phase transforms pre-established design specifications into operational components compatible with both web and mobile platforms.

User Interface Design: Wireframes/Web interface and prototypes were developed in Figma. Key UI screens include: Users: Stores user credentials, role. metadata, file path, version info.

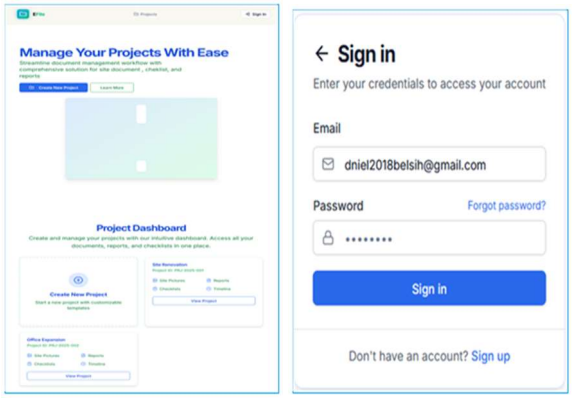


Figure 4.9: User interface

Document Management Module: This module allows for uploading, tagging, categorizing, and versioning of project documents. Each document is associated with metadata such as project ID, location, date, and uploader.

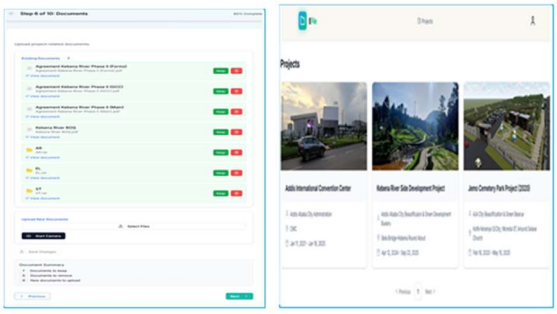


Figure 4.10: Document Control Tool interface

QR Code Integration:

QR Code Generation: Each document or physical asset (e.g., blueprints, safety manuals) is associated with a unique QR code. The code is generated upon document creation or upload. The information embedded includes: Document ID, Project ID, Access URL (tokenized) and Timestamp.

QR Code Scanning: The mobile app allows scanning QR codes using the device camera. Upon scanning, the app authenticates the user, decodes the QR, and fetches the document from the server. Offline caching is used for areas with limited connectivity.

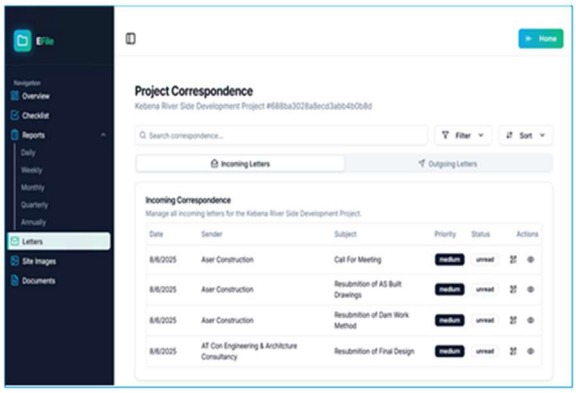


Figure 4.11: Automatic QR code generator & Scanner

4.7.2 Design Translation and Performance Evaluation

Role-Based Access Control – The system implements a secure, role-based access control that centralizes project documentation with strict authentication. An administrator registers users via a sign-in form and manages all registered users from a single screen. Integration of project team members into a web application with database checks improves document integrity and security. The framework generates and verifies document status linked to responsible staff, reducing misplacement or tampering.

Document Workflow and Activity Tracking: Activities are prioritized using color-coded completion status (pending, in-progress, completed) and urgency levels (critical, high, medium, low), with temporal tracking displaying milestone due dates and required documents per activity. QR code implementation improves document verification for both digital and hardcopy formats, ensuring better data availability, minimal scanning errors, and faster information access.

Project Reporting Page: The report page displays all required reports with automated generation and indexed retrieval. Users can search reports by metadata categories including written date, reference number, functional classification, departmental ownership, and content descriptors. QR code-linked reports reduce misplaced files and streamline retrieval to 1-5 minutes. Mobile-based QR tracking provides centralized access to document status,

supporting reporting, data collection, traceability, and workflow monitoring, while also facilitating document distribution and updates.

Project Communication Page: The module manages institutional correspondence using a dual-axis classification system (project association and data attributes). Each document is cataloged with four indexing parameters: unique reference number, compliant date/time stamp, verified sender/receiver credentials (organizational roles), and subject line keywords. The system provides real-time, easily accessible information, reducing delays and miscommunication common in manual environments. Integrating QR codes into outgoing/incoming letters enables instant mobile access to digital documents, significantly enhancing data accessibility for field operators and office data managers. This allows quick retrieval and interpretation of information, reduces reliance on slow, intermediary-based manual retrieval, and lowers communication barriers across teams.

4.7.3 Functional System Testing

Unit testing: The system uses a QR code-mediated workflow for secure upload of digital softcopy communication letters to the central document management system. Test 1: Uploading outgoing letters: Scanning the project-specific QR code attached to an outgoing correspondence triggers an upload sequence to the centralized document database.

Integration testing: The system implements a QR code-mediated workflow for controlled distribution of drawings and plans, along with progress monitoring via site images and photos of site conditions.

Test 2: Mobile-optimized image capture and upload of construction project drawings and plans: Scanning project-specific QR codes attached to design drawings triggers an upload sequence.

System testing: The system was evaluated under simulated real-world conditions, including varying internet speeds and user loads, to validate the effectiveness of QR code–based secure document sharing for mobile construction collaboration.

5. Conclusion & Recommendation

This chapter summarizes the study findings, presents conclusions, and offers practical recommendations as well as directions for future research, consistent with the objectives stated in Chapter One.

5.1 Summary of Findings: This study used reflexive thematic analysis and focus group discussions with 20 participants (ICT officers, document controllers, project managers, engineers) from six construction organizations in Addis Ababa, plus ten senior key informants. It aimed to identify document management challenges, examine QR code use, and evaluate the proposed solution's performance—answering three questions: current practices, how QR improves handling, and its extent of improvement in Ethiopia's construction sector. The study argues findings from focus group discussions:

Uneven digital transition: Adoption varies across sectors, driven more by organizational/external factors than readiness alone.

Formal standards with limited gains: ISO/Kaizen adopted in government offices but implementation gaps (weak supervision, coordination issues) limit improvements.

Poor storage impairs decisions: Acute infrastructural deficiencies (file loss, disorganization, space constraints, and delays) hamper decision-making; physical barriers need workflow redesign.

Partial digitalization creates silos: Fragmented adoption and hybrid workflows cause duplication, breakdowns, and information silos, worsening inefficiencies.

Coordination & capacity gaps: Construction companies face greatest challenges (low tech readiness, coordination breakdowns, limited data management, and resistance to change).

The study also examines the proposed QR-based web solution performance:

Role-based access control: Integrates real-time tracking and mobile scanning; improves document integrity, retrieval speed (1–3 minutes), and transparency; reduces misplacement and tampering; centralizes document status.

Document workflow & activity tracking: Provides centrally accessible, real-time information for efficient status reporting; faster lookup and retrieval; improved accuracy; addresses slow, error-prone manual tracking.

Project reporting: QR-linked reports reduce misplaced files and streamline retrieval (1–5 minutes); mobile tracking supports reporting, traceability, and workflow monitoring; facilitates distribution and updates.

Project communication: Real-time, easily accessible information reduces delays and miscommunication; enhances data accessibility for field operators and office managers; reduces reliance on slow intermediaries.

5.2. Conclusions

Current document management in Ethiopia's construction sector is fragmented and inefficient, with no uniform system across consulting firms, public offices, and construction companies.

- Partial digitalization and poor physical infrastructure (storage deficits, file loss, disorganization) create major barriers, causing duplication, silos, and decision-impairing delays.
- The proposed QR-based web solution effectively improves retrieval speed (1–3 minutes), document integrity, traceability, and real-time communication while reducing misplacement and intermediary reliance.
- QR technology tangibly enhances reporting, tracking, and communication, directly targeting slow, error-prone manual processes.
- Performance is promising but conditional; success depends on resolving uneven digital readiness, physical storage deficits, weak governance, coordination gaps, and resistance to change.
- Final answer: QR technology significantly improves handling practices but cannot overcome systemic fragmentation alone without parallel workflow redesign, capacity building, and mandatory integration.

5.3 Recommendations

- **Assess current document management efficiency using standardized tools**: Construction firms, public offices, and consulting firms should evaluate existing document handling practices (retrieval time, misplacement rate, storage conditions) using validated assessment scales to identify specific gaps and prioritize QR code implementation.
- **Redesign physical document workflows before or alongside QR deployment**: Since poor storage and fragmented manual practices are the most critical barriers, organizations should improve filing systems, reduce space constraints, establish clear task identity for document controllers, and implement feedback loops on document status.
- **Adopt auser-centered implementation approach**: Leaders must address field operators' and office staff's technological readiness, device availability, connectivity, and resistance concerns through appropriate training and support. This will improve work quality, operational efficiency, client satisfaction, and competitive advantage.
- **Ensure consistent enforcement across organization types**: Standardized procedures for QR scanning responsibilities, document status updates, and compliance auditing should be applied uniformly across consulting firms, public offices, and contractors to avoid the fragmentation and policy-implementation gaps identified in the study.

5.4 Future Research Directions

- **Expand variables:** Incorporate organizational culture, leadership support, infrastructure readiness, training quality, and inter-organizational coordination into the theoretical framework.
- **Use multiple methods:** Employ in-depth interviews, direct observation, diary

studies, and quantitative surveys to validate QR effectiveness.

- **Widen scope:** Include other Ethiopian regions (Bahir Dar, Hawassa, Dire Dawa) and diverse organization types (small contractors, international firms, regulators).
- **Focus on specific functions:** Assess QR performance for contracts, drawings, safety reports, payment certificates; examine version control, audit trails, and compliance tracking.
- **Conduct comparative studies:** Compare QR with other low-cost digital solutions (barcodes, RFID, cloud systems) in low-resource environments.
- **Perform6-month post-implementation evaluation:** Measure retrieval time, error reduction, user satisfaction, document loss rates; conduct cost-benefit analysis (costs vs. time saved, rework reduction, decision speed); and investigate resistance factors to redesign incentives.

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