

ARTICLE

Design documentation deficit in public infrastructure: A mixed-methods analysis of compliance, coordination, and lifecycle management in Nepal's irrigation projects

Sadikshya Dhakal^{1,2}  and **Subash Kumar Bhattarai**^{1,3*} ¹Construction Management, Center for Postgraduate Studies, Nepal Engineering College, Pokhara University, Bhaktapur, Bagmati, Nepal²Department of Water Resources and Irrigation, Kathmandu, Bagmati, Nepal³Construction Engineering and Management, Institute of Engineering, Pulchowk Campus, Tribhuvan University, Kathmandu, Bagmati, Nepal

Abstract

This study was conducted as part of the first author's Master's research in Construction Management at Nepal Engineering College, with the corresponding author serving as supervisor. This study provides a comprehensive, evidence-based diagnosis of design documentation management practices in public lift irrigation projects in Nepal. Employing a sequential mixed-methods approach, the research integrates a systematic document review of 50 projects, surveys of 96 stakeholders, comprising 50 contractor representatives and 46 Department of Water Resources and Irrigation engineers, and key informant interviews. Analytical techniques include descriptive statistics, Kendall's Tau correlation, mean response analysis, artificial neural networks (ANNs) for predictive modeling, relative importance index (RII), and thematic analysis using NVivo software. A significant "compliance paradox" was identified: while most stakeholders perceived the design documentation as adequate, no project achieved 100% compliance, with critical design artifacts such as operation and maintenance manuals and quality assurance plans consistently missing. External regulatory factors emerged as the most powerful determinant of design documentation quality (100% normalized importance from ANN), followed by human resource capacity (72%). Inadequate design documentation was directly linked to project delays (54.2% of respondents) and cost overruns (43.8%), while adequate documentation most significantly improved stakeholder coordination (RII = 0.817). The study proposes an actionable five-point blueprint for design process reform: standardized protocols, mandatory training, dedicated documentation officers, Electronic Document Management Systems, and enhanced stakeholder coordination. This paper is the first to provide a comprehensive mixed-methods investigation of design documentation management in Nepal's public irrigation sector, contributing to design innovation for sustainable infrastructure development in resource-constrained settings.

Keywords: Design documentation; Compliance management; Design coordination; Mixed-methods research; Infrastructure lifecycle management; Sustainable infrastructure design

***Corresponding author:**
Subash Kumar Bhattarai
(subashkbhattarai@gmail.com)

Citation: Dhakal S, Bhattarai SK. Design documentation deficit in public infrastructure: A mixed-methods analysis of compliance, coordination, and lifecycle management in Nepal's irrigation projects. *Design+*. doi: 10.36922/DP026260028

Received: June 27, 2026

Revised: August 1, 2026

Accepted: August 18, 2026

Published online: September 10, 2026

Copyright: © 2026 Author(s). This is an Open-Access article distributed under the terms of the Creative Commons Attribution Noncommercial License, permitting all non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Publisher's Note: AccScience Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

1.1. Background

In the world of construction, design extends far beyond initial sketches and conceptual drawings. It is a continuous, collaborative process made tangible through construction documentation. Paperwork is often seen as a bureaucratic hurdle to be cleared on the way to the “real work” of building. Yet, this perception belies a critical truth: design documentation forms the very backbone of a project. It is the tangible record of design decisions, the blueprint for execution, and the first line of defense in disputes. From contracts and design drawings to meeting minutes and inspection reports, these documents bind the diverse stakeholders—clients, contractors, engineers, and government bodies—into a cohesive design team with a shared understanding of the project’s intent.^{1,2}

In public infrastructure projects, where accountability for public funds is paramount, the role of meticulous design documentation is magnified.³ This is especially true in the water sector, where projects such as lift irrigation systems are vital for food security and rural livelihoods. The design process for such infrastructure requires systematic documentation to ensure that design intent is preserved through construction and into operational life. While global best practices have evolved to include digital tools such as building information modeling (BIM), the reality in many developing countries, including Nepal, is a persistent reliance on paper-based systems, leading to inefficiencies, errors, and a lack of design transparency.

1.2. Problem statement

Within Nepal’s Department of Water Resources and Irrigation (DWRI), this challenge is not just theoretical; it is a recurring operational headache. Audit reports consistently flag deficiencies in design documentation for lift irrigation projects, often citing the term “Saidantik Beruju” to indicate theoretical inconsistencies or conceptual irregularities.⁴ A familiar, frustrating cycle ensues: an audit identifies missing design documents, the project team scrambles to compile them, and the issue is temporarily resolved until the next audit repeats the finding.

This reactive approach treats the symptom, not the disease. The root causes—lack of standardized design documentation practices, fragmented record-keeping, and insufficient training on design documentation requirements—remain unaddressed. Different stakeholders use different methods, leading to inconsistencies and making it nearly impossible to retrieve crucial design information when needed.⁵ The consequence is a system where design history is often lost, design accountability

is blurred, and the long-term sustainability of vital infrastructure is compromised.⁶

While the importance of design documentation is well recognized, most studies in contexts such as Nepal remain largely descriptive. Although the problem exists, there remains a lack of rigorous, evidence-based diagnosis of its scale, underlying causes, and specific effects on design coordination and project outcomes. This study addresses this gap by moving beyond anecdotal evidence to provide a data-driven, holistic analysis of design documentation practices, aimed at informing practical and sustainable solutions for improving their effectiveness.

1.3. Research objective

The general objective of this research was to assess the management of design documentation in DWRI-implemented lift irrigation projects. The specific objectives were:

- (i) To assess the existing design documentation management practices and their compliance status in these projects.
- (ii) To identify and analyze the key factors influencing the effectiveness of design documentation management.
- (iii) To evaluate the impacts of both adequate and inadequate design documentation on project performance and design coordination, and to propose practical measures for design process improvement.

1.4. Significance of the study

This research offers value on multiple fronts. For policymakers and DWRI management, it provides a clear, evidence-based picture of the current state of design documentation, pinpointing systemic weaknesses rather than isolated failures. For project managers, design engineers, and contractors, it quantifies the very real costs of poor design documentation delays, budget overruns, and rework, empowering them to advocate for better design practices.

Methodologically, the study demonstrates the power of a mixed-methods approach for diagnosing deficiencies in the design process. By combining advanced statistical techniques, such as artificial neural networks (ANN), with in-depth qualitative analysis, we move from simply ranking problems to understanding the complex human and institutional dynamics behind design compliance failures. It is our hope that this research will not only lead to improved design documentation within DWRI but will also serve as a model for diagnosing and addressing similar challenges in other sectors of Nepal’s public infrastructure system, contributing to the broader discourse on design innovation for sustainable development.

2. Literature review

2.1. The anatomy of a project: Types of construction documents as design artifacts

A construction project generates a vast paper trail, each document serving a distinct purpose in the design process. These can be broadly categorized to understand their collective role as design artifacts^{7,8}:

- (i) Contract and financial documents: These are the project's legal and financial backbone, including the contract agreement, bill of quantities, and payment certificates. They define the rules of the game, outlining scope, cost, and responsibilities, all of which are critical design parameters.⁹
- (ii) Design and planning documents: These constitute the project's DNA: the drawings, specifications, and site investigation reports that translate an idea into a buildable plan. They guide every excavation, concrete pour, and installation, representing the core output of the design process.¹⁰
- (iii) Execution and compliance records: These are the project's pulse, captured through daily progress reports, quality inspection checks, safety audits, and environmental compliance records. They provide a real-time narrative of the project's health and adherence to design standards.¹¹
- (iv) Project closeout documents: Often neglected, these are the project's handover package, including as-built drawings and operation and maintenance (O & M) manuals. They are essential for the long-term viability and usability of the asset, representing the culmination of the design process and its transition to operational use.¹²

In Nepal, the standard bidding documents (SBDs) from the Public Procurement Monitoring Office (PPMO) provide the official checklist, legally mandating which documents form part of the contract.⁹ Despite this clear framework, our study confirms that compliance with design documentation requirements remains elusive.

2.2. The web of influence: Factors shaping design documentation quality

Managing design documents effectively is not a simple task. It is influenced by a complex web of factors that interact dynamically. Scholarly work has identified several key categories^{13,14}:

- (i) External factors: Government policies, regulatory pressure, and stakeholder scrutiny often act as the primary drivers, forcing organizations to prioritize design documentation.¹⁵
- (ii) Human resource factors: The skills, experience,

and stability of the workforce are fundamental. High staff turnover can erode institutional memory, while a lack of training on design documentation requirements leads to inconsistent and error-prone documentation.¹⁶ In the Nepalese context, previous research has specifically identified a lack of qualifications, knowledge, skills, and experience among the contract management team, as well as a lack of cooperation and proper communication between project stakeholders, as critical factors limiting effective project management. Research on retrofitting projects in Nepal has further identified "limited manpower" and "limited resources" as key challenges, alongside a lack of coordination among project stakeholders.¹⁷

- (iii) Organizational and technological factors: The organization's internal culture, leadership commitment, and its willingness to invest in digital tools (such as cloud-based systems or BIM) create the environment in which design documentation either thrives or withers.^{18,19} Research on supply chain management in construction projects has found that poor communication and lack of coordination among project stakeholders are major challenges that lead to project inefficiencies.
- (iv) Project-specific and financial factors: The size, complexity, and budget of a project also play a role, with larger, more complex projects demanding more rigorous design documentation systems.

Recent empirical research from other developing countries confirms these patterns. A study of Tanzanian construction projects identified human capacity, procurement systems, and organizational culture as key factors affecting the quality of design documentation.²⁰ In South Africa, project managers identified competence, procurement systems, time management, accuracy of design information, and communication as the five most critical factors influencing document quality.²¹ These findings underscore the cross-contextual relevance of the factors identified in our study and highlight the importance of context-specific analysis.

2.3. Design documentation as a foundation for design practice

Design documentation serves as the foundation upon which effective design practice is built. It enables the following critical design functions:

- (i) Design communication: Documentation provides the primary medium through which design intent is communicated across the project lifecycle, from conception through construction to operation.

Without systematic documentation, design knowledge becomes tacit and inaccessible.

- (ii) Design coordination: Effective design requires coordination among multiple disciplines: structural, civil, mechanical, electrical, and environmental. Documentation serves as the common reference point that enables this coordination.
- (iii) Design verification and validation: Documentation provides the evidence base for verifying that designs meet requirements and validating that constructed assets perform as intended.
- (iv) Design evolution and adaptation: Documentation records design decisions and their rationale, enabling future designers to understand and build upon previous work, supporting design innovation over time.

The absence of systematic design documentation, particularly at critical handover points such as the completion of O & M manuals, represents a fundamental failure of the design process itself. This failure compromises not only project performance but also the long-term sustainability of infrastructure assets.

2.4. The methodological frontier in design compliance research

The question of how to study these issues is as important as the questions themselves. Traditionally, research has relied on surveys, case studies, and descriptive statistics. While valuable, these methods can struggle to unravel the complex, non-linear relationships between factors influencing design documentation quality.

This is where the methodological frontier is expanding. Internationally, researchers are beginning to apply more sophisticated predictive analytics. For instance, studies in Portuguese procurement have used machine learning to forecast compliance risks, while others have automated safety checks using artificial intelligence.^{22,23} Advanced optimization techniques, such as fuzzy logic combined with multi-objective genetic algorithms, have been applied to address complex trade-offs in construction scheduling, including time, cost, and environmental impact considerations. Similarly, metaheuristic algorithms have been developed to address time–cost trade-off optimization problems in construction project management.

In the Nepalese context, hybrid metaheuristic frameworks integrating non-dominated sorting genetic algorithm III and multi-objective particle swarm optimization have been developed to address time–cost–environmental sustainability trade-off problems, demonstrating that even in resource-constrained settings such as Nepal, sophisticated computational approaches

can be effectively applied to optimize construction project scheduling.²⁴ These approaches are powerful but are often designed for data-rich, technologically advanced environments.

This presents a clear gap: the need for robust, context-sensitive methodologies that can deliver deep insights even in resource-constrained settings such as Nepal. This study responds to that need by proposing an integrated analytical framework. We employed ANNs to objectively model and rank the complex factors influencing design documentation, moving beyond simple correlations. Simultaneously, we used NVivo-driven thematic analysis to mine qualitative data from experts, providing narrative depth and contextual understanding that numbers alone cannot. By marrying computational power with human insight, this mixed-methods approach aims to deliver a diagnosis that is both statistically rigorous and deeply grounded in the realities of the field. Similar methodological approaches have been employed in construction research, where multivariate statistical techniques have been used to categorize causes of project delays into distinct components, demonstrating the value of such analytical approaches in understanding project performance issues.

A recent systematic review confirms that design deficiencies, including documentation problems, are a primary cause of cost and schedule deviations in construction projects globally.²⁵ The methodological approach of combining quantitative ranking with qualitative explanation, as employed in this study, has been validated in other developing-country contexts for diagnosing systemic documentation challenges.^{20,21}

3. Methodology

This research adopted a pragmatic, sequential mixed-methods approach to capture both the breadth and depth of design documentation management practices. The design involved quantitative data collection followed by qualitative inquiries to explain and enrich the initial findings.

3.1. Study population and sampling

The study population comprised all 50 lift and groundwater irrigation projects implemented through Nepal's e-GP portal from the fiscal year 2075/76 onwards. A full census was undertaken for the document review. For the survey, we selected 50 contractor representatives (one from each project) and, using Cochran's formula for a 90% confidence level, a simple random sample of 46 DWRI engineers. To gain nuanced insights, we conducted key informant interviews (KIIs) with a senior divisional engineer, a project engineer, and an experienced contractor.

3.2. Data collection

Data were collected from both primary and secondary sources to provide a comprehensive assessment of design documentation practices, the factors influencing them, and their impacts on project outcomes.

- (i) Primary data collection: A structured questionnaire, employing a five-point Likert scale, was deployed to gauge stakeholder perceptions on design documentation adequacy, influencing factors, and impacts. The KIIs were semi-structured, allowing for probing questions to explore emergent themes related to design process challenges.
- (ii) Secondary data collection: We performed a comprehensive audit of project archives against a 33-item checklist derived directly from the PPMO's SBDs. Each document was assigned a binary compliance score (1 for present, 0 for missing).

While the qualitative component relies on a small number of key informants ($n = 3$), this is consistent with the methodological tradition of key informant interviewing, where depth of insight from strategically selected individuals with unique, comprehensive knowledge of the system under investigation is prioritized over statistical representativeness. These three individuals were purposively selected for their direct, multi-project oversight roles spanning employer, contractor, and regulatory perspectives. The qualitative data serve to explain, contextualize, and enrich the quantitative findings, a classic triangulation function in mixed-methods research rather than to represent the full diversity of stakeholder opinions. Future research should expand qualitative engagement to include a broader cross-section of project stakeholders.

3.3. Analytical framework

The data analysis was structured to address each research objective directly.

- For Objective 1 (assess status): We used descriptive statistics to summarize perceptions and compliance rates. Kendall's Tau correlation helped uncover relationships between the causes of design documentation failures.
- For Objective 2 (identify influencing factors): Mean response analysis (MRA) provided an initial ranking of influencing factors. To model the complex, non-linear interactions between these factors, we employed ANN in IBM SPSS 27. The detailed architecture of the optimal ANN models is provided in Section A1. A multilayer perceptron model was used with a 70%/30% training-testing split. The model's reliability was rigorously validated by calculating the root mean

square error (RMSE) and a 95% confidence interval for the mean absolute error (MAE). Thematic analysis of KII transcripts provided qualitative context to the quantitative rankings.

- For Objective 3 (evaluate impacts and propose measures): This objective was analyzed in two parts:
 - (i) Impact analysis: The relative importance index (RII) was calculated to rank the consequences of design documentation quality based on survey responses. This was supplemented with descriptive analysis of closed-ended survey questions on dispute experiences and common consequences.
 - (ii) Solution development: A systematic qualitative analysis of the KIIs was conducted using NVivo 15 software. This process involved:
 - Importing and coding: Transcripts were imported into NVivo and coded to identify key concepts related to design process challenges and solutions.
 - Thematic analysis: Codes were grouped into parent and child nodes to generate key themes related to design challenges, impacts, and solutions.
 - Data visualization: NVivo's visualization tools were used to generate a word cloud to highlight frequently mentioned terms and a word cluster analysis to map the strength of relationships between these concepts. This structured, software-assisted analysis ensured that the proposed measures were derived directly and rigorously from the qualitative data.

It is important to clarify that the ANN model employed here serves an exploratory rather than a predictive purpose. Given the modest sample size (50 projects, 96 survey responses), the objective was to identify and rank the relative importance of influencing factors rather than to develop a generalizable prediction engine. To mitigate the risk of overfitting, a well-documented concern in small-sample neural network applications, we adopted a deliberately simple architecture (a single hidden layer with rectified linear unit [ReLU] activation) and employed early stopping as a regularization technique. Recent advances in civil engineering demonstrate that even with limited data, appropriately regularized neural networks can yield robust rankings of feature importance. Nevertheless, we acknowledge that the normalized importance values should be interpreted as relative indicators rather than absolute measures, and future research with larger datasets could employ meta-learning or few-shot approaches to enhance predictive generalizability.

3.4. Reliability and validity

The internal consistency of the survey instrument was confirmed, with Cronbach's alpha scores exceeding 0.87 for all constructs, indicating high reliability. For qualitative data, credibility was ensured through data triangulation (using multiple KII sources) and by maintaining a clear audit trail of the NVivo analysis process.

3.5. Ethical considerations

This research, which involved human participants, was conducted in accordance with the core ethical principles for social science research. Formal clearance from a national ethics review board was not required as the study was a low-risk evaluation of professional practices, overseen and approved by the DWRI. The following procedures were implemented to ensure ethical integrity:

- Informed consent: Verbal informed consent was obtained from all participants after the study's purpose and their rights were explained.
- Anonymity and confidentiality: All survey responses were collected anonymously. The identities of key informants are kept confidential.
- Voluntary participation: Participation was voluntary, and respondents were free to withdraw at any time.
- Data use: Ethical standards for secondary data were maintained through proper attribution and respect for data source regulations.

4. Results and discussion

The integration of quantitative and qualitative data reveals a complex picture of design documentation management, characterized by a significant gap between perception and practice, driven by a handful of systemic factors.

4.1. The compliance paradox: Perception versus reality

A clear dissonance was evident in the data. On one hand, survey results suggested a general level of satisfaction, with 59.6% of contractors and 53.2% of employers rating design documentation as "adequate." This perception, however, was starkly contradicted by the physical document review. Our audit found that not a single project had achieved 100% compliance with the mandatory design documentation checklist. The highest compliance level recorded was 87.88% (in eight projects), while the majority (42 projects) had 84.88%, with at least five critical design documents missing. The distribution of compliance levels is presented in [Table 1](#) and [Figure 1](#).

The KIIs helped unravel this paradox. The contractor interviewee shed light on this, noting, "On the ground, work moves forward. We solve problems as they come. The

documents might not all be in the file, but the project gets built." This suggests that a focus on physical progress leads to design documentation being treated as a secondary, administrative task rather than an integral part of the design process. A senior divisional engineer added that the practice of compiling documents only after an audit flag creates a "cycle of reactivity," where the absence of a major dispute fosters a false sense of security, masking the underlying systemic vulnerability in design practice.

4.2. Systemic gaps and their root causes

The missing documents were not random. A consistent pattern emerged: O & M manuals, quality assurance plans (QAPs), mitigation actions, compensation event approvals, and site investigation reports were the most frequently absent, all of which are critical design artifacts for infrastructure lifecycle management. The trend of these missing documents is visualized in [Figure 2](#).

To dig deeper into the reasons, we turned to qualitative data from the KIIs and analyzed it using NVivo. A word cloud visualization of the interview transcripts prominently featured terms such as "no system," "not enforced," and "who is responsible?" A subsequent cluster analysis grouped these concepts into central themes that explain the design documentation gaps:

- Theme: Procedural ambiguity in design processes: This theme, strongly linked to the absence of QAPs, was captured in the engineer's statement: "The guidelines are vague on who must prepare the QAP and when. Without a clear directive, it is easily postponed and eventually forgotten." This indicates that design documents requiring proactive planning fall through the cracks when design procedures are not explicit and mandatory.
- Theme: The handover void in the design lifecycle: The consistent lack of O & M manuals was explained by the senior divisional engineer, who highlighted a systemic break in design responsibility: "Our focus is on construction completion. The O & M manuals are for the end-user, the Water Users' Associations. There is no formal, monitored handover process to ensure these documents are prepared and delivered." This points to a critical failure in lifecycle design planning for the infrastructure.
- Theme: Informal resolution culture undermining design documentation: The missing site investigation and compensation event reports were contextualized by the contractor, who explained that on-site issues are often resolved through verbal agreements to avoid delays. "We fix the problem then and there. Writing up a formal variation or compensation claim is seen

Table 1. Construction-document compliance among lift irrigation projects

Serial number	Details	Number	Remarks
1	Projects with 100% documentation compliance	0	At least one type of document is missing
2	Projects with 87.88% documentation compliance	8	At least four types of documents are missing
3	Projects with 84.88% documentation compliance	42	At least five types of documents are missing
	Total	50	

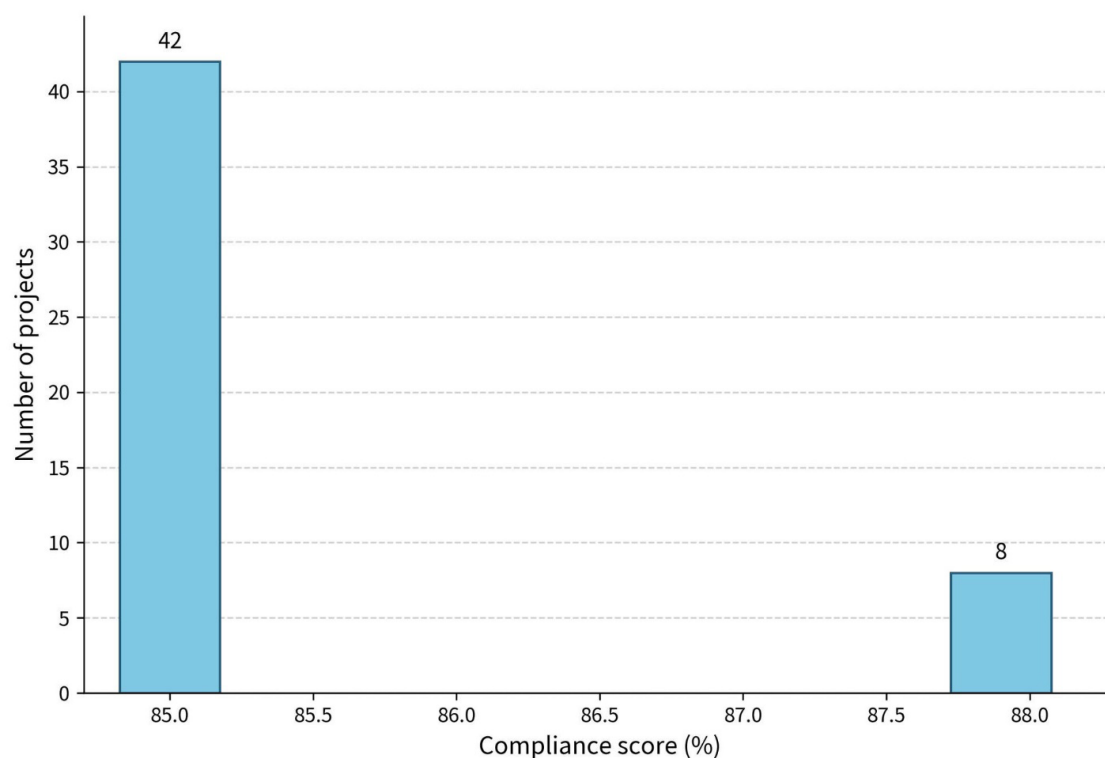


Figure 1. Distribution of documentation compliance levels across projects

as creating paperwork and conflict,” he stated. This reveals a cultural preference for informal problem-solving that actively undermines the formal design documentation process.

4.3. What drives design documentation quality? An integrated view

The MRA ranked external factors (MRA = 4.021), such as government audits, as the most influential, followed by operational and financial factors (MRA = 3.917). A graphical representation of the MRA results is shown in Figure 3. This ranking approach is consistent with

established construction management research, where the RII method has been effectively used to prioritize factors contributing to project delays and extensions of time.

The ANN model (Section A1) provided a more refined, non-linear ranking of normalized importance, with the results detailed in Table 2. Multivariate statistical techniques, such as principal component analysis, have also been employed in construction research to categorize causes of project delays into distinct components, demonstrating the value of these analytical approaches in understanding project performance issues.

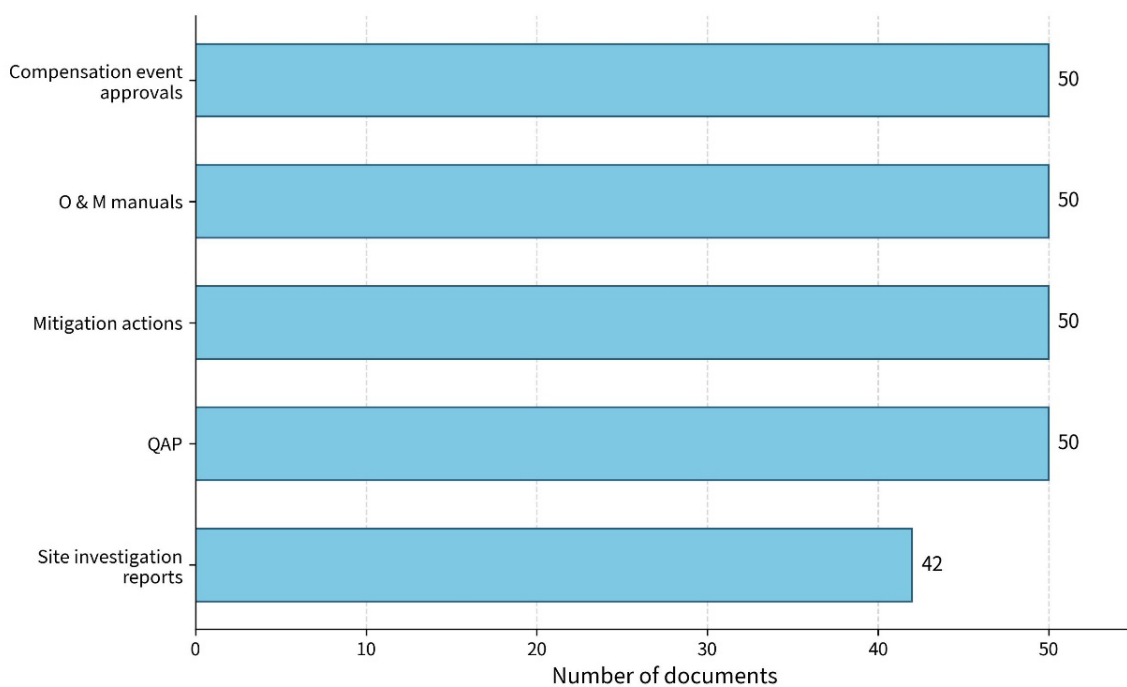


Figure 2. Most frequently missing construction documents
Abbreviations: O & M: Operation and maintenance; QAP: Quality assurance plan.

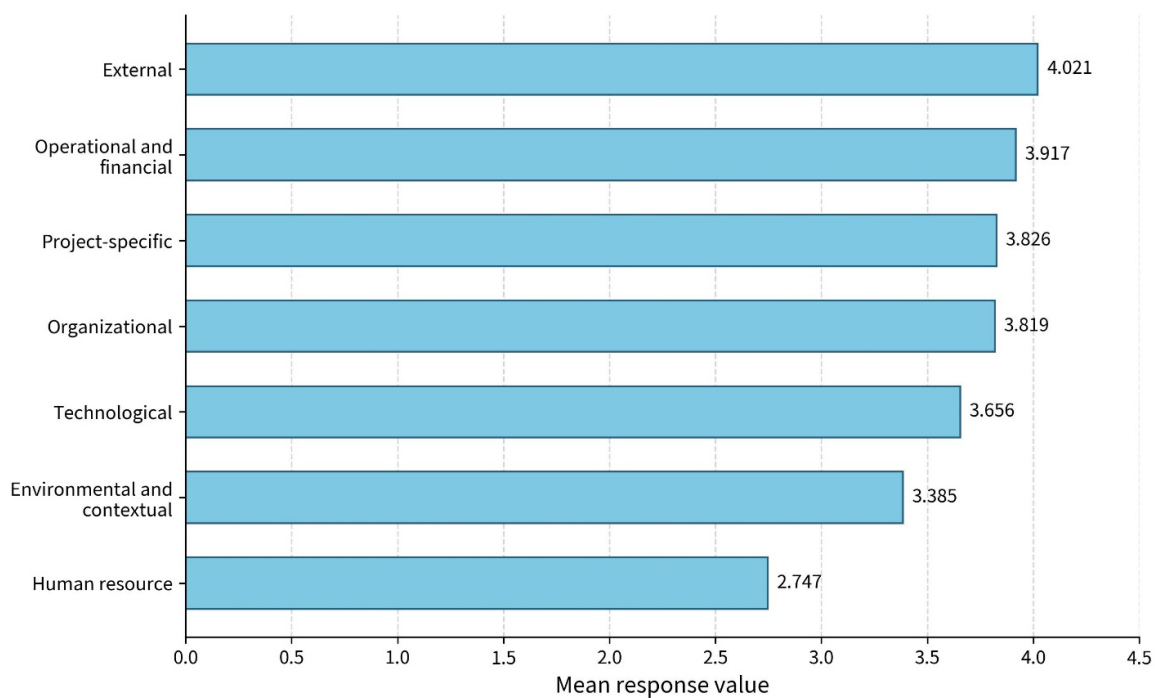


Figure 3. Mean response analysis of factors influencing construction documentation

Table 2. Sensitivity analysis and ranking of factors influencing construction documentation from an artificial neural network

Neural network (NN)	Organizational	Technological	Project-specific	Human resource	External	Operational and financial	Environmental and contextual
NN (i)	0.646	0.717	0.531	0.912	1.000	0.654	0.367
NN (ii)	0.285	0.325	0.269	0.735	1.000	0.456	0.335
NN (iii)	0.459	0.371	0.410	0.797	1.000	0.534	0.458
NN (iv)	0.364	0.267	0.066	0.791	1.000	0.393	0.493
NN (v)	0.711	0.718	0.461	1.000	0.884	0.425	0.775
NN (vi)	0.108	0.574	0.116	0.703	1.000	0.210	0.103
NN (vii)	0.456	0.323	0.282	0.733	1.000	0.332	0.300
NN (viii)	0.189	1.000	0.370	0.474	0.975	0.273	0.205
NN (ix)	0.386	0.336	0.172	0.450	1.000	0.163	0.280
NN (x)	0.240	0.369	0.196	0.548	1.000	0.252	0.348
Average importance	0.384	0.500	0.287	0.714	0.986	0.369	0.366
Normalized importance	39%	51%	29%	72%	100%	37%	37%
Rank	4	3	7	2	1	5	6

Notes: The ranking of human resource factors as the second most important determinant (72% normalized importance) is consistent with recent research from South Africa, where “competence,” defined as the appointment of qualified professionals with appropriate skill sets, emerged as the most influential factor affecting construction document quality.²¹ Similarly, research from Tanzania has identified human capacity as a critical determinant of design documentation quality in developing-country contexts.²⁰

The KIIs put flesh on these statistical bones. The senior engineer directly attributed the dominance of external factors to the “immense pressure” of audit observations. The high ranking of human resource factors was echoed by the project engineer, who lamented that “frequent transfers of key staff break the chain of memory,” making consistent design documentation nearly impossible. The contractor contextualized the lower technological ranking, explaining that “profit margins are too slim to invest in fancy document management software,” linking it directly to financial constraints.

4.3.1. Validation of the artificial neural network model

The reliability of the ANN model was rigorously assessed using the RMSE and a 95% confidence interval (CI) for the MAE. The model demonstrated strong predictive accuracy and generalization, with a mean RMSE of 0.382 on the training dataset and 0.408 on the testing dataset across 10 runs. The small difference between these values (mean difference = 0.026) indicates minimal overfitting. Furthermore, the 95% CI for the MAE was calculated to be 0.02044–0.05034. This narrow range, which does not cross

zero, confirms that the model’s error is both low and stable, providing high statistical confidence in the reliability of the factor rankings presented in Table 2.

This integrated analysis confirms that while the strong arm of external regulation is the primary driver, its effectiveness is heavily mediated by internal capacity, the skills, and the stability of the human resources tasked with executing design documentation.

4.4. The impact of design documentation on project performance and pathways to improvement

To move from diagnosis to solution, we conducted a systematic analysis of the key informant interviews using NVivo 15. This software enabled a rigorous thematic analysis, moving beyond anecdotal evidence to identify the most frequent and interconnected concepts discussed by experts. The process involved coding interview transcripts and generating visualizations to uncover the underlying structure of the challenges and solutions. The importance of proper record-keeping, timely issue management, and reporting during the construction period has been similarly emphasized in studies of other Nepalese infrastructure

sectors, where these practices were found to significantly improve the efficiency of contract management.

4.4.1. The double-edged sword: Consequences of adequate versus inadequate design documentation

It should be noted that the RII analysis measures stakeholder-perceived importance of various impacts rather than establishing direct causal relationships. However, the study employs methodological triangulation combining RII rankings with document audit findings (revealing actual compliance gaps), survey responses (quantifying consequences), and qualitative interviews (explaining underlying mechanisms) to build a comprehensive evidence chain. This multi-method approach strengthens the validity of the conclusions regarding the relationship between documentation quality and project outcomes.

The RII analysis provides a clear, quantified picture of how design documentation quality cuts both ways. The benefits of adequate design documentation, as ranked by stakeholders, are profound (Table 3). The most significant impact is improved coordination among stakeholders (combined RII = 0.817), underscoring the documentation's role as a central design communication tool that aligns the efforts of employers, contractors, and regulators. The critical importance of coordination is further supported by research on supply chain management in construction projects, which has found that poor communication and lack of coordination among project stakeholders are major challenges that lead to project inefficiencies.

Conversely, the consequences of inadequate design

documentation are severe and skewed towards financial and quality failures (Table 4). Cost overruns (combined RII = 0.510) emerged as the most severe impact, a concern rated highest by contractors who directly face the financial repercussions of unresolved variations and rework. This was followed by poor construction quality (combined RII = 0.502), indicating that missing specifications and inspection records directly compromise workmanship. Miscommunication among stakeholders (combined RII = 0.458) was ranked third, with employers identifying it as their top concern, pointing to the design coordination chaos that ensues from poor records.

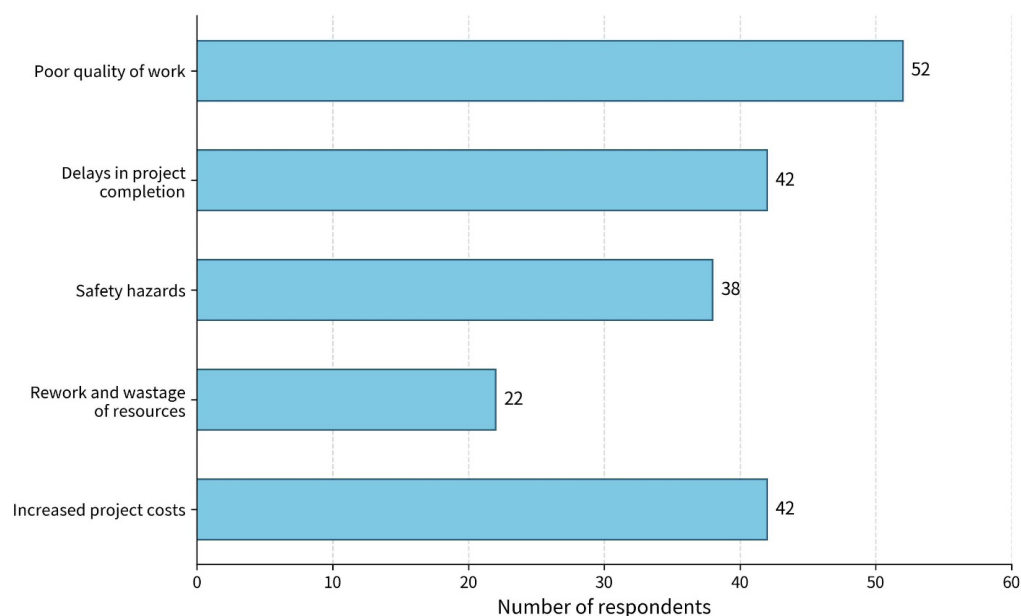
The findings from the survey and KIIs were triangulated to provide a comprehensive and robust understanding of the factors influencing design documentation practices and their impacts on project outcomes. This RII data is powerfully reinforced by direct survey responses and KII insights. When asked to identify the most frequent consequences, 54.2% of respondents cited project delays and 43.8% cited cost overruns (Figure 4), directly validating the RII rankings. The KIIs provided the narrative behind these numbers. A project engineer explained that inadequate design documentation leads to a "lack of reliable information about the project's progress," making it "difficult to track modifications," which inevitably causes delays and budget overruns. A senior divisional engineer directly linked missing O & M manuals to "improper water source selection" and "unsustainable infrastructure," showing how failures in initial design documentation cascade into long-term operational crises.

Table 3. Relative importance index (RII) and rank for the impact on project performance due to adequate construction documentation

Serial number	Impact of adequate construction documentation on project performance	Employer RII	Employer rank	Contractor RII	Contractor rank	Combined RII	Combined rank
1	Timely completion of project	0.770	6	0.736	4	0.752	5
2	Cost control and budget management	0.791	4	0.692	6	0.740	6
3	Reduction of disputes and claims	0.791	4	0.784	2	0.788	3
4	Improved quality of construction	0.796	3	0.724	5	0.758	4
5	Better coordination among stakeholders	0.835	1	0.800	1	0.817	1
6	Compliance with regulatory requirements	0.822	2	0.760	3	0.790	2

Table 4. Relative importance index (RII) and rank for the impact on project performance due to inadequate construction documentation

Serial number	Impact of inadequate construction documentation on project performance	Employer RII	Employer rank	Contractor RII	Contractor rank	Combined RII	Combined rank
1	Delays in project completion	0.413	4	0.476	5	0.446	5
2	Cost overruns	0.426	3	0.588	1	0.510	1
3	Increased disputes and legal issues	0.396	5	0.488	4	0.444	6
4	Poor quality of construction	0.435	2	0.564	2	0.502	2
5	Miscommunication among stakeholders	0.439	1	0.476	5	0.458	3
6	Regulatory compliance issues	0.396	5	0.508	3	0.454	4

**Figure 4. Consequences of inadequate documentation**

A critical finding from this analysis is the strong consensus between employers and contractors on these impacts. The absence of statistically significant differences in their perceptions, as confirmed by hypothesis testing, indicates a shared understanding of the high stakes involved. This consensus provides a solid foundation for collaborative design process reform.

4.4.2. A blueprint for design process reform: Measures to improve documentation practices

To move from diagnosis to solution, we conducted a

systematic analysis of the KIIs using NVivo 15. This software enabled a rigorous thematic analysis, moving beyond anecdotal evidence to identify the most frequent and interconnected concepts discussed by experts. The process involved coding interview transcripts and generating visualizations to uncover the underlying structure of the challenges and solutions. The importance of proper record-keeping, timely issue management, and reporting during the construction period has been similarly emphasized in studies of other Nepalese infrastructure sectors, where these practices were

found to significantly improve the efficiency of contract management.

The resulting word cloud (Figure 5) visually emphasizes the most frequently mentioned terms, with “documentation,” “training,” and “solutions” appearing prominently. This immediately highlights that the conversation was not only about problems but also about capacity-building and remedies. This finding aligns with research on retrofitting projects in Nepal, which identified “improper planning and poor site management” as major contributors to project delays, reinforcing the need for capacity building and enhanced management practices.¹⁷

A more detailed word-cluster analysis (Figure 6) revealed the strength of relationships between these concepts. The thick connections between “training → solutions → DWRI” form a central cluster, pointing to a strongly held expert view that capacity building, driven by institutional leadership, is a core part of the solution. Another dense cluster, “documentation → challenges → impacts,” visually maps the cause-and-effect relationship that was consistently described in the interviews.

These NVivo-driven insights were synthesized into a comprehensive thematic map (Figure 7), which categorizes the findings into challenges, impacts, influencing factors, and proposed solutions. This structured output forms a coherent blueprint for design documentation reform, with the following key measures:

- (i) Standardization and procedural clarity in design processes: A universal recommendation from all KII participants was the development and enforcement of standardized design documentation protocols. As the senior divisional engineer stated, “procedural

guidelines should be established to ensure proper document verification.” This directly addresses the systemic “procedural ambiguity” identified as a root cause of missing design documents.

- (ii) Investment in human capital for design documentation: The need for “training programs” was a dominant theme in the NVivo analysis. The interviews called for mandatory, structured training for both DWRI engineers and contractors on design documentation requirements and modern documentation management techniques. This addresses the “human resource factors” that the ANN model identified as the second most critical influence on design documentation quality.
- (iii) Digital transformation of design documentation: The KIIs strongly advocated for technological adoption. The contractor recommended “a digital database of all projects,” while the engineer suggested “time-bound mobile software” for real-time updates. This aligns with the “technological factors” identified in the quantitative analysis and is a practical step toward moving away from inefficient paper-based systems, improving accessibility and security. Such digital transformation directly supports design innovation by enabling better collaboration and smarter decision-making.
- (iv) Structural accountability through a dedicated documentation unit: A key structural recommendation was the establishment of a dedicated documentation office within DWRI. The contractor argued that a “dedicated team should be assigned for record-keeping” to ensure continuous oversight and accountability, thus preventing design documentation from being neglected as a secondary task.



Figure 5. Word cloud of key informant interview responses
Abbreviation: DWRI: Department of Water Resources and Irrigation.

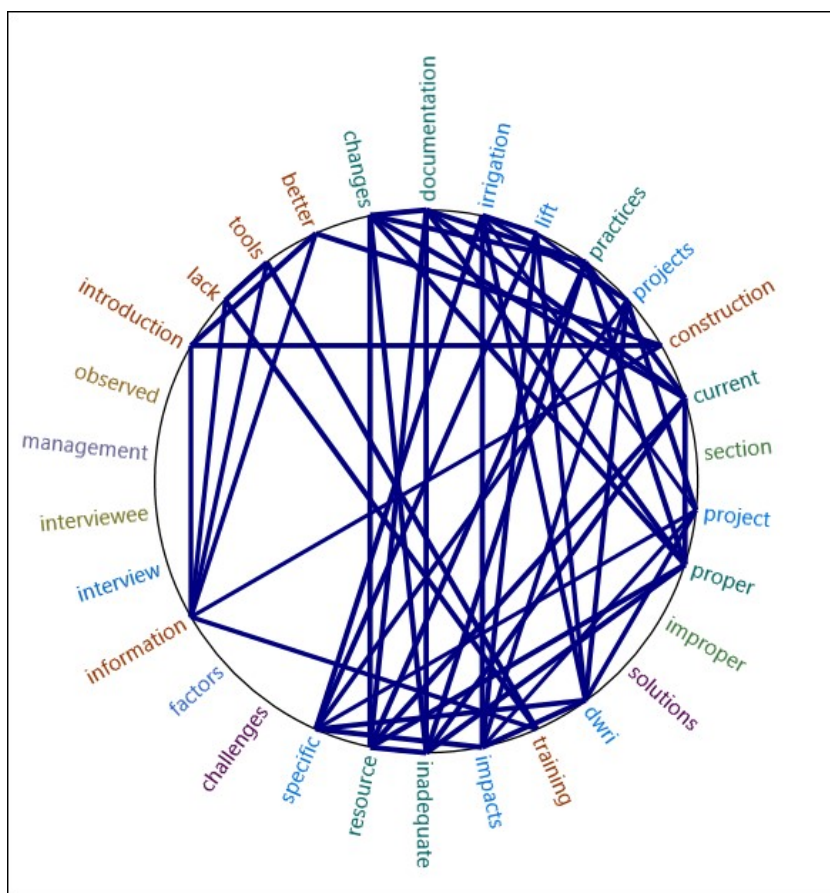


Figure 6. Word cluster network of key informant interview responses



Figure 7. Thematic analysis of key informant interview responses
Abbreviation: DWRI: Department of Water Resources and Irrigation.

- (v) Enhanced stakeholder coordination in design: The engineer highlighted that a “lack of coordination between private sector stakeholders and government bodies” hindered design progress. The proposed solution involved regular coordination meetings and workshops to foster a shared culture of design documentation excellence and break down silos that lead to miscommunication and inconsistent design practices. This aligns with findings from research on supply chain management in construction projects, which have identified integrated management between the supply chain and project site, along with good communication, as essential solutions for overcoming coordination challenges.

4.4.3. Implementation feasibility: A phased approach for resource-constrained settings

The five-point blueprint proposed above raises legitimate questions about feasibility in a context where contractors report slim profit margins and government budgets are constrained. International evidence from similar developing-country contexts highlights persistent barriers to the adoption of digital documentation, including limited digital infrastructure, low digital literacy, technology costs, and cultural resistance.^{21,26} Recent research on construction site record-keeping in Nepal confirms that key issues include “reliance on outdated paper-based documentation, lack of awareness regarding records management frameworks, insufficient training and the absence of automated systems.”²⁷

To address these constraints, we propose a three-phase implementation roadmap:

- (i) Phase 1 (short-term, 0–12 months): Zero/low-cost measures
 - Develop and disseminate standardized documentation templates and checklists (minimal cost).
 - Conduct awareness workshops using existing DWRI training infrastructure.
 - Assign documentation responsibilities explicitly in contracts (no additional cost).
 - Establish simple digital repositories using existing government cloud platforms (e.g., e-GP portal extensions).
- (ii) Phase 2 (medium-term, 12–36 months): Capacity building and process reform
 - Implement mandatory training programs for DWRI engineers and contractors.
 - Create dedicated Documentation Officer positions (reallocation of existing staff).

- Pilot digital documentation systems on 3–5 projects to demonstrate proof of concept.
- Develop public–private partnerships for technology provision.

- (iii) Phase 3 (long-term, 36+ months): Digital transformation

- Full-scale Electronic Document Management System (EDMS) implementation, potentially leveraging open-source or low-cost platforms.
- Integration with existing government systems (e-GP, financial management systems).
- Explore opportunities for international development partner support (e.g., Asian Development Bank, World Bank).

This phased approach recognizes that digital transformation is not an all-or-nothing proposition. As Mayouf and Damra²⁸ argue in the context of ISO 19650 adoption in developing countries, “a flexible, phased approach to implementation is essential: one that accounts for local practices and the current level of digital maturity, ensuring a sustainable progression toward full compliance.” Similar phased approaches to EDMS implementation have been recommended by national audit offices in other developing-country contexts.²⁶

Crucially, the findings of this study provide an evidence-based rationale for prioritizing investments. The ANN analysis identified external regulatory factors (100% normalized importance) and human resource factors (72%) as the most powerful determinants of documentation quality. This suggests that policy enforcement and workforce development—relatively low-cost interventions—should precede large-scale technology investments, which ranked lower in influence (51% for technological factors and 39% for organizational factors). This sequencing ensures that limited resources are deployed where they will yield the greatest return.

4.5. Implications for design practice and innovation

The findings of this study carry significant implications for design practice and innovation in infrastructure development, directly addressing the core themes of design innovation.

- (i) Design innovation through process reform: The systemic documentation failures identified in this study represent a fundamental gap in design process innovation. The absence of standardized protocols, dedicated documentation roles, and digital tools reflects a design practice that has not evolved to meet the demands of modern infrastructure development. The proposed five-point blueprint represents a design

innovation: a systematic rethinking of how design documentation is produced, managed, and utilized across the project lifecycle.

(ii) Technology and design integration: The recommendation for a centralized EDMS is a direct contribution to the integration of design innovation and technology. Moving from paper-based to digital documentation is not merely an efficiency improvement; it is a fundamental design innovation that enables:

- Real-time design coordination across distributed teams
- Version control and traceability of design decisions
- Integration with emerging technologies such as BIM
- Data-driven design improvement through systematic record-keeping

(iii) Sustainable infrastructure and ecosystem design: The critical role of O & M manuals in ensuring long-term infrastructure sustainability directly connects to the journal's focus on sustainable development and ecosystem design. The findings demonstrate that design documentation, particularly at the handover stage, is essential for:

- Ensuring that infrastructure functions as designed throughout its lifecycle
- Empowering local communities to maintain and operate infrastructure sustainably
- Reducing the environmental and economic costs of premature infrastructure failure
- Supporting the design of resilient water systems that serve communities for generations

(iv) Design coordination and communication: The strongest perceived benefit of adequate documentation—improved stakeholder coordination—highlights documentation's fundamental role as a medium for design communication. This finding suggests that design documentation should be understood not as bureaucratic paperwork but as the primary vehicle for design communication across the project lifecycle. Design innovation in documentation practices therefore directly enhances design coordination outcomes.

4.6. Limitations of the study

While this study provides a comprehensive diagnosis of design documentation management practices in Nepal's lift irrigation projects, several limitations should be acknowledged when interpreting its findings.

(i) Scope and generalizability: The empirical analysis is limited strictly to 50 public lift and groundwater irrigation projects implemented under a single government department (DWRI) in Nepal. The findings and proposed blueprint may not generalize directly to other infrastructure sectors such as roads, buildings, or hydropower, which operate under different regulatory frameworks, technical requirements, and stakeholder configurations. While the analytical framework, particularly the mixed-methods approach combining ANN with qualitative thematic analysis, is transferable, the specific findings should be validated in other sectors before broad generalization.

(ii) Small qualitative sample: The qualitative component relied on KIIs with only three individuals (one senior divisional engineer, one project engineer, and one experienced contractor). While these informants were strategically selected for their unique, comprehensive knowledge of the project portfolio, this small sample cannot capture the full diversity of perspectives across all stakeholders, including employers, contractors, local users, and Water User Association representatives across 50 separate projects. The qualitative data serve to contextualize and explain quantitative findings (a function of triangulation) rather than to represent the full spectrum of stakeholder opinions. Future research should expand qualitative engagement to include a broader cross-section of project stakeholders.

(iii) Binary compliance checklist: The document audit evaluated compliance using a binary checklist (presence scored as 1, absence as 0). This framework, while enabling systematic and comparable assessment across 50 projects, fails to measure the actual quality, accuracy, technical reliability, or completeness of the documentation. A document marked as "present" may be incomplete, outdated, or technically inadequate. This was a necessary methodological trade-off for conducting a large-scale comparative audit. Future research should develop more nuanced quality assessment frameworks, potentially employing expert-based scoring or automated text analysis.

(iv) Artificial neural network sample size and predictive limitations: The ANN model was applied to a dataset of 50 projects and 96 survey responses, relatively small for neural network applications. While we employed strategies to mitigate overfitting (simple architecture, single hidden layer, ReLU activation, early stopping, 70/30 training-testing split, RMSE validation), the model should be understood as exploratory rather than predictive. The normalized importance rankings provide relative indicators of influence rather than

absolute measures. Future research with larger datasets could employ meta-learning, few-shot approaches, or alternative machine learning techniques (e.g., random forests, XGBoost) to enhance predictive generalizability and cross-validate these findings.

- (v) Perception-based RII and causal inference: The RII analysis was based on stakeholder perceptions of the impacts of adequate and inadequate documentation. These perceptions, while valuable, do not constitute direct causal evidence linking documentation quality to cost overruns and delays. The study addresses this limitation through methodological triangulation: the RII findings are supported by (i) the document audit revealing actual compliance gaps, (ii) survey responses quantifying consequences, and (iii) qualitative interviews explaining underlying mechanisms. However, establishing definitive causality would require longitudinal tracking of documentation practices and project outcomes across time, which was beyond the scope of this exploratory study.
- (vi) Lack of cost-benefit analysis: While the study proposes a five-point blueprint including investments in EDMS and dedicated documentation officers, it does not provide a detailed cost-benefit analysis or financial feasibility assessment of these recommendations. The phased implementation approach addresses this in principle, but future research should quantify the expected return on investment for documentation improvements.
- (vii) Geographic and temporal scope: The study is limited to projects implemented through Nepal's e-GP portal from fiscal year 2075/76 onwards. Findings may not reflect practices in projects outside this period, in other geographic regions of Nepal, or in projects implemented through different procurement mechanisms. Additionally, the cross-sectional design captures documentation practices at a single point in time, whereas documentation management is a dynamic process that evolves over the project lifecycle.

5. Conclusion and recommendations

5.1. Conclusion

This study set out to dissect the state of design documentation within Nepal's DWRI lift irrigation projects, and the findings paint a picture of a design system at a crossroads. The core revelation is a compliance paradox: a widespread perception of adequacy among stakeholders masks a stark reality of systemic non-compliance with design documentation requirements. Not a single project among the 50 reviewed possessed a complete set of mandatory design documents, with forward-looking records such

as O & M manuals and QAPs being the most frequent casualties. This indicates that design documentation is treated as a retrospective administrative chore rather than a proactive tool for design management and infrastructure sustainability.

The research successfully modeled the complex web of influences on this outcome. The powerful role of external factors, primarily audit pressure and government regulation, was unequivocally confirmed as the primary driver. However, the analysis revealed that this external pressure is insufficient on its own. Its effectiveness is critically mediated by internal capacity, specifically human resource factors including staff skills, accountability, and continuity. Technological and organizational factors provide the enabling environment, but without skilled and stable personnel, even the best regulations and tools fail to support effective design documentation.

Furthermore, the study quantified the high stakes of this neglect. The consequences of poor design documentation are not abstract; they are measured in significant cost overruns and pervasive project delays. Conversely, the benefits of good design documentation are most keenly felt through smoother stakeholder coordination and fewer disputes. The strong consensus between employers and contractors on these impacts underscores a shared recognition of the problem and a solid foundation for collaborative solutions in the design process.

In summary, the design documentation deficits in DWRI projects are not a collection of isolated oversights but a symptom of deeper systemic and cultural issues, namely, procedural ambiguity in design processes, a focus on reactive compliance over proactive design management, and an institutional undervaluing of documentation's strategic role in design innovation and infrastructure lifecycle management. These findings align with recent research in other developing-country contexts, where similar patterns of documentation deficiency have been identified as primary contributors to cost overruns and delays.^{20,21,29}

5.2. Recommendations

To bridge the gap between the current state and a more efficient, accountable, and sustainable future of design documentation practice, the following integrated set of recommendations is proposed:

- (i) Institutionalize standardization and training in design documentation
 - Action: DWRI, in collaboration with PPMO, must develop and mandate a simplified, standardized design documentation toolkit,

including checklists, templates, and a clear responsibility matrix for all project phases. This represents a fundamental design innovation in project management processes.

- Action: Implement compulsory, practical training programs for DWRI engineers, contractors, and consultants focused on the importance, preparation, and management of key design documents, especially O & M manuals and QAPs. This builds human resource capacity for effective design documentation.

(ii) Establish structural accountability for design records

- Action: Create a dedicated Documentation Officer position within DWRI for all major projects. This role would be solely responsible for ensuring the completeness, quality, and timely submission of all design records, serving as the single point of accountability for the integrity of design documentation.

(iii) Accelerate digital transformation of design documentation through phased implementation

- Action: Prioritize the development and implementation of a centralized EDMS. However, recognize that full-scale EDMS deployment in resource-constrained settings requires a phased approach.
- Phase 1 (immediate): Leverage existing government digital platforms (e.g., e-GP portal extensions) for document storage and retrieval. Develop standardized digital templates.
- Phase 2 (12–24 months): Pilot EDMS on a subset of projects; build internal capacity through training; develop public–private partnerships.
- Phase 3 (24+ months): Full-scale EDMS implementation with integration into broader government systems.
- A cloud-based platform would revolutionize design record-keeping, ensuring secure storage, easy retrieval, and version control. However, implementation must be sensitive to local digital readiness, as evidenced by recent research on digital record adoption in comparable developing-country contexts.^{26,30} This digital transformation directly supports design innovation by enabling better collaboration, real-time updates, and integration with emerging technologies such as BIM, whose adoption in Nepal remains nascent but is growing.³⁰

(iv) Foster a culture of collaborative design oversight

- Action: Move beyond punitive audits by establishing joint review committees that include DWRI officials, contractor representatives, and end-user (Water User Association) representatives. These committees should conduct periodic, forward-looking reviews of design documentation to proactively identify and resolve issues, strengthening design coordination across stakeholders.

(v) Leverage the artificial neural network model for targeted design process intervention

- Action: Use the findings of this study to guide resource allocation for design process improvement. Given the high influence of human resources and external factors, DWRI should first focus its reform efforts on workforce development and clarifying regulatory expectations, as these will yield the greatest return on investment for design documentation quality.

5.3. Recommendations for further study

Future research can build upon this foundation in several ways:

- A longitudinal study to assess the implementation and impact of the recommended design documentation measures within DWRI.
- An exploration of the feasibility and design of lightweight, mobile-based digital documentation solutions tailored for remote project sites in Nepal, contributing to design innovation in resource-constrained settings.
- A comparative analysis of design documentation management practices across different public infrastructure sectors (e.g., roads, buildings) to identify transferable best practices and common challenges.
- Research on the integration of design documentation with emerging technologies such as BIM to support digital design coordination in Nepalese infrastructure projects.
- A feasibility study examining the applicability of the ISO 19650 information management framework in Nepal's public infrastructure sector, building on emerging evidence that this international standard offers a scalable, structured approach to sustainable information management in developing countries when implemented with sensitivity to local contexts and digital maturity levels.²⁸

Acknowledgments

The authors acknowledge the Department of Water Resources and Irrigation (DWRI), Nepal, for providing access to project documents and facilitating data collection. We also thank all survey respondents and key informants for their valuable time and insights.

Funding

None.

Conflict of interest

The authors declare they have no competing interests.

Author contributions

Conceptualization: All authors

Data curation: All authors

Formal analysis: All authors

Investigation: All authors

Methodology: All authors

Project administration: All authors

Resources: All authors

Software: All authors

Supervision: All authors

Validation: All authors

Visualization: All authors

Writing—original draft: All authors

Writing—review & editing: All authors

Ethics approval and consent to participate

Formal clearance from a national ethics review board was not required as this study was a low-risk evaluation of professional practices, overseen and approved by the DWRI. Verbal informed consent was obtained from all participants after the study's purpose and their rights were explained. Participation was voluntary, and respondents were free to withdraw at any time.

Consent for publication

All participants provided verbal informed consent for the publication of anonymized data. No identifying information of any participant appears in this manuscript.

Availability of data

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Further disclosure

The authors acknowledge the use of an AI-powered language model (OpenAI's GPT-4) for assistance with language refinement and structural editing. All research

design, data collection, analysis, interpretation, and intellectual content remain the sole responsibility of the authors. The final manuscript has been thoroughly reviewed and approved by all authors.

References

1. Chappell D, Powell-Smith V. *Building contract claims*. Oxford, UK: Wiley-Blackwell; 2005.
doi: 10.1002/9780470759325
2. Project Management Institute. *A guide to the project management body of knowledge (PMBOK® guide)*, 7th ed. Newtown Square, PA, USA: Project Management Institute; 2021.
3. Kerzner H. *Project management: A systems approach to planning, scheduling, and controlling*, 12th ed. Hoboken, NJ: Wiley; 2017.
4. Nepal, Office of the Auditor General. Preliminary Audit Findings of DWRI for the projects IRBIWRMP. Kathmandu: Office of the Auditor General; 2024.
5. Love PED, Irani Z, Edwards DJ. A Rework Reduction Model for Construction Projects. *IEEE Trans Eng Manage*. 2004;51(4):426-440.
doi: 10.1109/TEM.2004.835092
6. Duy Nguyen L, Ogunlana SO, Thi Xuan Lan D. A study on project success factors in large construction projects in Vietnam. *Eng Constr Archit Manag*. 2004;11(6):404-413.
doi: 10.1108/09699980410570166
7. Fisk ER, Reynolds WD. *Construction project administration*, 10th ed. Upper Saddle River, NJ: Pearson; 2013.
8. Hughes W, Champion R, Murdoch J. *Construction Contracts*. London: Routledge; 2015.
doi: 10.4324/9781315695211
9. PPMO/GoN. Standard Bidding Document (SBD-1S2E): Works (Without Prequalification), Single Stage Two Envelope Bidding Process, 2025. Accessed June 15, 2026. <https://www.ppmo.gov.np/>
10. Eastman C, Teicholz P, Sacks R, Liston K. *BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers*, 2nd ed. Hoboken, NJ: Wiley; 2018.
11. Silva GA, Warnakulasooriya BN, Arachchige B. Criteria for Construction Project Success: A Literature Review In: 13th International Conference on Business Management (ICBM). University of Sri Jayewardenepura, Sri Lanka; 2016.
doi: 10.2139/ssrn.2910305
12. Obasanjo Olubukola A, Babalola O, Waheed Adeyemi K. A Review of Importance of Construction Documents on Project Delivery. *IJLTEMAS*. 2024;XIII(IV):28-41.
doi: 10.51583/IJLTEMAS.2024.130405

13. Alshibly H, Chiong R, Bao Y. Investigating the Critical Success Factors for Implementing Electronic Document Management Systems in Governments: Evidence From Jordan. *Inf Syst Manag*. 2016;33(4):287-301.
doi: 10.1080/10580530.2016.1220213
14. Jacques de Sousa L, Poças Martins J, Sanhudo L. Predicting construction project compliance with machine learning model: case study using Portuguese procurement data. *ECAM*. 2024;31(13):285-302.
doi: 10.1108/ECAM-09-2023-0973
15. Melzner J, Zhang S, Teizer J, Bargstädt HJ. A case study on automated safety compliance checking to assist fall protection design and planning in building information models. *Constr Manag Econ*. 2013;31(6):661-674.
doi: 10.1080/01446193.2013.780662
16. Ashworth A, Hogg K, Higgs C. *Willis's practice and procedure for the quantity surveyor*, 13th ed. Oxford, UK: Wiley-Blackwell; 2013.
17. Bhattarai SK, Rayamajhi L, Lamichhane S, Arayal S. Navigating Delays: A Comprehensive Study of Public Building Retrofitting Projects in Kathmandu Valley. *JUTEC Eng Manag*. 2024;2(01):37-52.
doi: 10.36344/utecem.2024.v02i01.004
18. GON/PPMO. Public Procurement Act, 2063 (2007), 2017. Accessed June 15, 2026. <https://ppmo.gov.np/>
19. Cheng T, Teizer J. Real-time resource location data collection and visualization technology for construction safety and activity monitoring applications. *Autom Constr*. 2013;34:3-15.
doi: 10.1016/j.autcon.2012.10.017
20. Sospeter NG. A categorization of factors affecting quality of design documentation in Tanzanian construction projects. *J Eng Des Technol*. 2025;23(1):228-248.
doi: 10.1108/jedt-02-2023-0040
21. Govender N, Laryea S, Watermeyer R. Blueprint to Success: Project Managers' Perspectives on Key Factors Influencing Construction Document Quality in South Africa. *J Constr Eng Manag*. 2025;151(11).
doi: 10.1061/JCEMD4.COENG-16710
22. Projul. Construction documentation best practices. 2024. Accessed June 15, 2026. <https://projul.com/blog/construction-project-documentation-guide/>
23. ASEE, "Managing Project Documentation Across Multiple Regulatory Standards," American Society for Engineering Education, 2024. Accessed June 15, 2026. <https://asee.io/blog/managing-project-documentation-across-multiple-regulatory-standards/>
24. Bhattarai SK, Silwal N, Sharma M, Lohani A, Kafle M. Integrated hybrid NSGA-III-MOPSO model for sustainable time-cost optimization in residential building construction in Nepal. *Asian J Civ Eng*. 2026;27:3547-3564.
doi: 10.1007/s42107-026-01682-y
25. Buzauova TM, Yelubayeva AN, Toleubayeva SB. Assessing the Impact of Making Adjustments to Design Documentation on the Production Process. *Mater Mech Eng Technol*. 2024;4:84.
doi: 10.52209/2706-977X_2024_4_84
26. Sibanda M, Schellnack-Kelly I. Perceptions Regarding the Use of Digital Records in Zimbabwe's Public Sector. *Mousaion South Afr J Inf Stud*. 2025.
doi: 10.25159/2663-659X/17326
27. Neupane U, Jaisi BP. An assessment of record keeping practices at construction sites: Nepalese perspectives. *Rec Manag J*. 2025;35(3):277-295.
doi: 10.1108/RMJ-06-2024-0014
28. Mayouf M, Damra T. Smooth drive or rough road? The role of ISO 19650 in developing countries. *Constr Manag*. Accessed June 15, 2026. <https://constructionmanagement.co.uk/smooth-drive-or-rough-road-the-role-of-iso-19650-developing-countries/>
29. Nepal S, Neupane N, Koirala S, *et al*. Integrated assessment of irrigation and agriculture management challenges in Nepal: An interdisciplinary perspective. *Heliyon*. 2024;10(9):e29407.
doi: 10.1016/j.heliyon.2024.e29407
30. Shrestha M, Subedi S, Giri OP, Alagirisamy M. Assessing Awareness of Building Information Modeling (BIM) among AEC Professionals in Nepal. *Eng Technol Appl Sci Res*. 2024;14(6):18973-18980.
doi: 10.48084/etasr.9098

Appendix

A1. Artificial neural network architecture details

The ANN model used in this study was a multilayer perceptron model with the following architecture:

- Input layer: Eight neurons (corresponding to the eight influencing factors)
- Hidden layer 1: 12 neurons (activation function: ReLU)
- Hidden layer 2: eight neurons (activation function: ReLU)
- Output layer: one neuron (documentation quality score)
- Training/testing split: 70%/30%
- Training algorithm: Backpropagation with Adam optimizer
- Learning rate: 0.001
- Number of epochs: 1,000

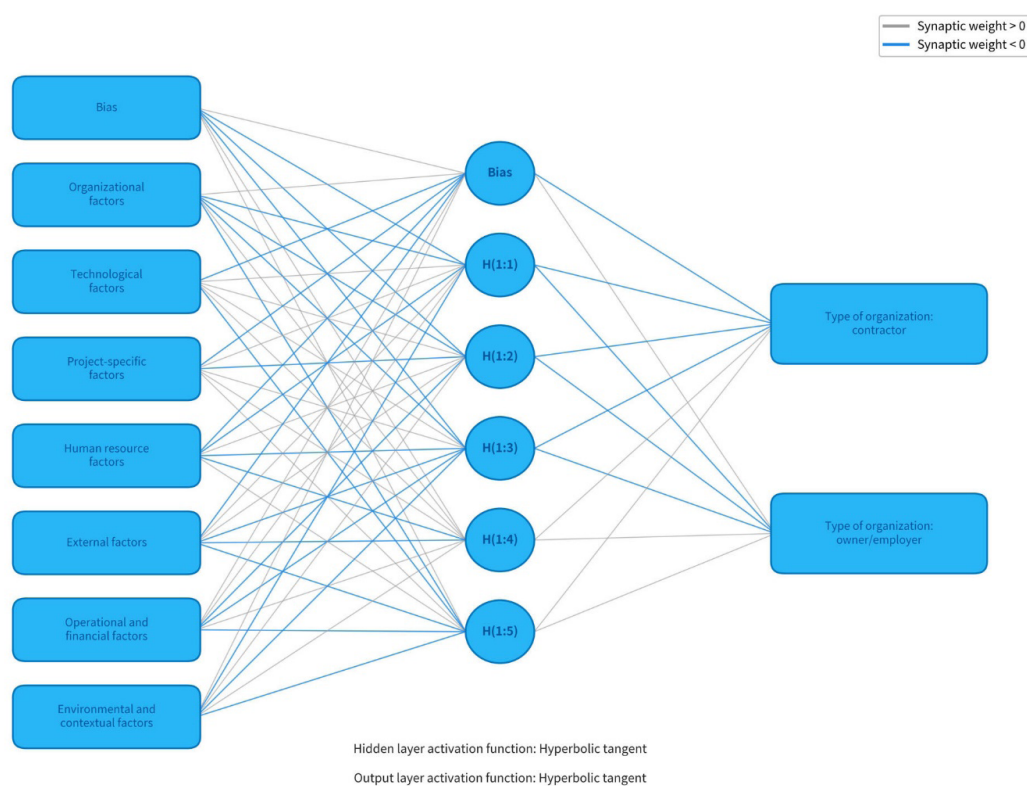


Figure A1. Artificial neural network for Run 3

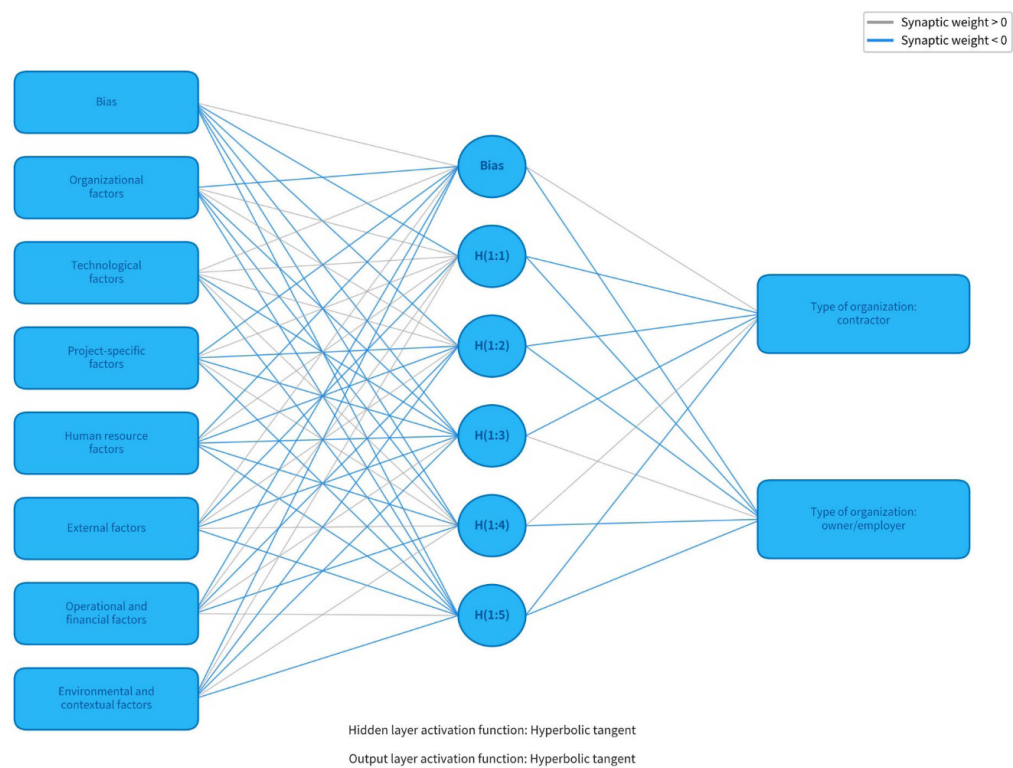


Figure A2. Artificial neural network for Run 5