

**CAPITAL UNIVERSITY OF SCIENCE AND
TECHNOLOGY, ISLAMABAD**



**Adoption of Cloud Native Platforms for Real Time
Construction Monitoring in Islamabad: Challenges
and Implementation Guidelines**

by

Muhammad Moez Arif

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degree of Master of Science

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Abstract

Cloud-native platforms have emerged as a critical enabler for real-time construction monitoring, offering significant improvements in transparency, efficiency, and decision-making in the construction industry. However, in Islamabad, where construction practices remain largely conventional and reactive, the adoption of cloud-native platforms for real-time monitoring is still negligible and fragmented. This gap contributes to persistent challenges such as project delays, cost overruns, inefficient coordination, safety hazards, and limited transparency among stakeholders. Despite increasing awareness of digital tools, there is limited empirical research that systematically examines the challenges, opportunities, and implementation strategies associated with cloud-native platform adoption in the local construction context. This study aims to identify, assess, and prioritize the key factors influencing the adoption of cloud-native platforms for real-time construction monitoring in Islamabad, and to propose a practical implementation guidelines. An extensive literature review was conducted to identify relevant factors, which were subsequently refined through expert validation using the Delphi technique involving experienced industry professionals. A structured questionnaire comprising 30 factors grouped into four major categories technological, organizational, human resource, and financial was developed and distributed among construction practitioners, resulting in 81 valid responses (response rate: 80.95%). The reliability of the questionnaire was confirmed using Cronbach's alpha ($\alpha = 0.891$), indicating excellent internal consistency, while non-parametric statistical methods were adopted due to the non-normal distribution of the data confirmed by the Shapiro-Wilk test ($p < 0.05$). The Relative Importance Index (RII) method was employed to rank the identified factors, with values ranging from 0.672 to 0.879, reflecting varying levels of influence on cloud-native platform adoption.

The results indicate that organizational- and human resource-related challenges dominate the overall rankings. Lack of organizational policies emerged as the most critical barrier (RII = 0.852), followed by lack of trained personnel (RII = 0.840) and inadequate training programs (RII = 0.822). In contrast, data security concerns and trust in automated systems were perceived as comparatively

less influential, although significant differences were observed across experience levels for data security ($p = 0.026$) and trust ($p = 0.016$). In terms of opportunities, performance-driven benefits ranked highest, with real-time monitoring improving transparency (RII = 0.879) , accelerated construction activities (RII = 0.837) , and better documentation and reporting (RII = 0.832) identified as key drivers of adoption. Sustainability-related benefits, although recognized (RII = 0.815), received comparatively lower rankings. Regarding implementation strategies, policy- and capacity-building measures were identified as the most effective solutions, with standardized digital monitoring guidelines by PEC/CDA, integration of cloud-native modules into CPD programs, and phased deployment of IoT sensors with pay-as-you-go cloud services emerging as top priorities. Based on these prioritized findings, the study proposes targeted and actionable recommendations for industry practitioners, policymakers (PEC, CDA), and academic institutions (HEC). These recommendations emphasize workforce development, policy standardization, phased implementation strategies, and institutional support to facilitate effective cloud-native platform adoption. The study provides an evidence-based guidelines to support the transition of Islamabad's construction industry toward improved transparency, efficiency, governance, and sustainable development.

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Chapter 1

Introduction

1.1 Background

The global construction industry is undergoing a digital transformation, driven by the integration of advanced technologies such as the Internet of Things (IoT), cloud computing, and real-time data analytics. These technologies have proven highly effective in improving productivity, reducing delays, and enhancing safety performance in large-scale construction projects [1]. Real-time construction monitoring systems leverage sensors, positioning technologies, and cloud platforms to capture continuous data streams on labor activity, material movement, equipment utilization, and environmental factors. This enables decision-makers to proactively manage risks, optimize workflows, and respond quickly to on-site challenges [2]. A key technological enabler for such systems is the cloud-native platform, a modern architectural approach built on microservices, containerization, and scalable orchestration tools like Kubernetes. Unlike traditional monolithic systems, cloud-native platforms provide agility, fault tolerance, and dynamic scalability, allowing real-time processing of large sensor datasets and seamless integration of field and office operations [3]. These capabilities are particularly important in complex, high-density urban construction projects where delays, rework, and coordination failures are frequent due to fragmented communication and oversight.

In the context of Islamabad, Pakistan's capital city, there has been a marked increase in high-rise and infrastructure development projects over the last decade.

From commercial hubs like the Blue Area to large-scale residential towers in areas such as Gulberg Greens, G-11, and DHA Phase-II, construction activity is rapidly intensifying. However, despite this boom, most construction monitoring practices in Islamabad remain conventional and reactive. On-site supervision is largely manual, documentation is paper-based, and data flow between contractors, consultants, and clients is often delayed or inconsistent. This results in project inefficiencies, safety hazards, and limited transparency. Islamabad's growing construction sector presents a compelling opportunity and urgent need to adopt cloud-native, real-time monitoring solutions to enhance productivity, safety, and governance. However, the absence of a structured implementation guidelines and the lack of readiness among stakeholders remain key barriers that this research seeks to address.

1.2 Research Motivation

In recent years, Islamabad has witnessed rapid urban expansion, leading to an increase in high-rise and mega construction projects. Yet, the pace of technological integration in construction monitoring remains slow. Many firms continue to rely on legacy systems or manual approaches for site supervision and progress reporting. As project complexity grows, so does the need for intelligent, real-time oversight that enhances decision-making, safety, and quality assurance. This research is motivated by the urgent need to bridge this digital divide by exploring how cloud-native technologies can be strategically adopted in Islamabad's construction sector. Developing a tailored framework for their integration could help unlock new efficiencies, foster data-driven project management, and enhance stakeholder collaboration across all phases of construction.

1.3 Problem Statement

The construction industry in Islamabad faces multiple challenges including project delays, cost overruns, safety incidents, and inefficient communication, many of

which are aggravated by the lack of real-time monitoring capabilities. Despite global shifts toward automation and digital transformation, the adoption of cloud-native platforms for real-time monitoring in Islamabad remains negligible. Most construction projects lack the technical infrastructure, organizational readiness, or practical guidance required to leverage real-time data and cloud-based analytics. Studies reveal that real-time monitoring systems, when combined with IoT and cloud computing, significantly improve visibility and control over project variables, leading to better risk mitigation and resource optimization [1,4]. Moreover, cloud-native architecture provides scalable, fault-tolerant environments suitable for handling dynamic, high-volume sensor data flows [3,5]. However, these proven benefits remain inaccessible to Islamabad's construction industry.

The problem is that no practical, context-specific guidelines exist to help construction stakeholders in Islamabad adopt cloud-native platforms for real-time monitoring. The unique technological, economic, organizational, and institutional barriers prevalent in the local context have not been systematically identified or translated into actionable guidance. Consequently, construction firms lack a clear pathway to transition from conventional monitoring practices to cloud-enabled real-time systems, putting them at risk of falling further behind globally competitive practices. Therefore, this study addresses the problem by identifying the key barriers to cloud-native adoption in Islamabad's construction sector and developing evidence-based implementation guidelines to overcome these barriers.

1.4 Research Objectives

This study aims to develop a comprehensive framework for the adoption of cloud-native platforms in real-time construction monitoring in Islamabad. The specific objectives are:

- i. To identify and categorize challenges affecting cloud-platform adoption.
- ii. To formulate strategies for adoption of digital platforms
- iii. To develop strategic implementation guidelines for cloud-native monitoring platforms.

1.5 Research Significance

This research is significant because it contributes to both academic knowledge and practical industry application. It introduces a novel cloud-native adoption guidelines tailored for Islamabad's construction sector, where digital transformation is still at an early stage. The findings will assist policymakers, construction managers, and technology providers in making informed decisions regarding the deployment of real-time monitoring technologies. Furthermore, the study enhances understanding of how cloud-native platforms can address persistent industry challenges such as delay, cost inefficiency, and safety risks.

1.6 Scope of Work and Study Limitations

The scope of this research focuses on real-time monitoring within ongoing medium-to-large-scale construction projects in Islamabad. It centers on the implementation of cloud-native systems including platforms that leverage containerization (e.g., Kubernetes), edge-cloud integration, and microservices for data processing and real-time visualization. Key stakeholders considered in the study include contractors, consultants, project managers, and system integrators working in the Islamabad metropolitan area. Limitations of this study include the reliance on questionnaire-based data collection, which may limit the depth of technical responses due to varying levels of IT literacy among construction professionals. Access to proprietary data such as sensor logs or project dashboards may be restricted due to confidentiality concerns. Furthermore, as cloud-native integration is an evolving concept in construction, its full-scale application in Islamabad may still be in nascent phases, requiring assumptions and extrapolations in making implementation guidelines.

1.7 Research Methodology

This study adopts a mixed-method approach that begins with an extensive literature review to identify knowledge gaps and formulate research questions related

to cloud-native adoption in real-time construction monitoring. A structured questionnaire is developed and distributed among professionals in Islamabad's construction sector to collect primary data. Quantitative analysis is carried out using SPSS software, where the reliability of the survey instrument is evaluated through Cronbach's Alpha, and normality of data distribution is tested using the Shapiro-Wilk test. Given the non-normal distribution, the Kruskal-Wallis test is employed to analyze differences in perceptions across professional groups. Additionally, the Relative Importance Index (RII) method is used to rank identified challenges based on their perceived significance. Insights from the data analysis inform the design of a cloud-native implementation guidelines, which is further validated through expert consultation and literature triangulation.

1.8 Thesis Structure

This thesis is structured into five main chapters:

Chapter 1 provides an introduction, outlining the research background, motivation, objectives, and methodology.

Chapter 2 presents a comprehensive literature review covering cloud-native systems, real-time monitoring, and adoption barriers in construction.

Chapter 3 explains the research methodology, including data collection techniques and statistical tools.

Chapter 4 discusses the survey results and proposes a cloud-native implementation guidelines.

Chapter 5 concludes the study with key findings, practical recommendations, and future research directions.

Chapter 2

Literature Review

2.1 Introduction

The construction industry is evolving rapidly due to the integration of digital technologies that are reshaping traditional project workflows. One of the most transformative developments in this space is the adoption of cloud-native platforms that enable real-time monitoring of construction activities. This chapter outlines the research methodology employed to investigate the adoption of cloud-native platforms for real-time construction monitoring in Islamabad. Given the emerging nature of this technological paradigm in the local construction sector, a structured and methodologically sound approach was essential to ensure the validity, reliability, and applicability of the research outcomes. This study adopts a quantitative research design to identify the key challenges, critical adoption factors, and potential guidelines that can guide industry practitioners in implementing cloud-native platforms. The overall methodology has been structured to progress logically through a sequence of interlinked stages, beginning with the formulation of research objectives, followed by the development of a structured questionnaire, data collection through purposive sampling, and detailed statistical analysis using SPSS software.

The research begins with a comprehensive identification of adoption challenge through literature review and expert consultation, which informed the structure of the questionnaire. Data were then collected from professionals in Islamabad'

construction sector including engineers, project managers, and IT specialists. The analysis phase is conducted using SPSS, where data reliability is first tested using Cronbach's Alpha, followed by normality testing to determine the appropriate statistical methods. For non-parametric data, the Kruskal-Wallis H test is applied to assess the significance of differences among various professional groups. Furthermore, the Relative Importance Index (RII) method is used to rank adoption factors by perceived importance. These sequential steps are designed to support the research objectives and enable the formulation of a context-specific framework for cloud-native platform adoption in construction monitoring. This methodology ensures that findings are both statistically rigorous and practically relevant to Islamabad's evolving construction landscape.

2.2 Conventional Construction Monitoring Practices

2.2.1 Definition and Overview

Conventional construction monitoring refers to traditional methods of overseeing construction activities through manual site visits, paper-based documentation, periodic progress reports, and face-to-face coordination meetings [6]. These methods have been the industry standard for decades and remain widely practiced in Islamabad's construction sector, where digital transformation is still in its early stages.

In conventional monitoring, site engineers and supervisors conduct physical inspections to assess work progress, identify defects, and ensure compliance with drawings and specifications. Progress is typically recorded using handwritten daily logs, printed photographs, and spreadsheet-based tracking. Communication between stakeholders (clients, contractors, consultants) occurs through scheduled meetings, email, or telephone, often leading to delays in information sharing [3].

2.2.2 Advantages of Conventional Monitoring

Despite its limitations, conventional monitoring offers certain advantages that explain its continued use, particularly in resource-constrained environments. The primary advantage is simplicity, as no specialized training or technical expertise is required for implementation. Any site engineer or supervisor can perform monitoring duties without additional education or certification. Another significant advantage is the low initial cost, as there is no need to invest in hardware, sensors, software, or cloud infrastructure the only costs are labor and basic office supplies. Conventional monitoring also allows direct observation, enabling site managers to physically inspect conditions, materials, and workmanship firsthand, using their professional judgment and years of experience to detect issues. Additionally, these methods are well-established practices understood by all stakeholders, so there is no learning curve or resistance to unfamiliar processes. Conventional monitoring has no dependency on technology, meaning work continues unaffected by internet outages, power failures, equipment malfunctions, or software bugs. Finally, immediate human judgment allows experienced supervisors to detect nuanced issues such as poor workmanship, subtle cracks, or emerging safety hazards that automated systems might easily miss [2,6].

2.2.3 Disadvantages of Conventional Monitoring

However, conventional monitoring has significant disadvantages that contribute to project delays, cost overruns, safety incidents, and coordination failures. The most critical disadvantage is delayed information, as progress data is often days or weeks old by the time it reaches decision-makers. This delay prevents timely corrective actions and allows small problems to escalate into major issues that could have been easily corrected if detected earlier [3]. Human error is another major limitation, as manual recording leads to inaccuracies, omissions, illegible handwriting, and inconsistent reporting formats across different supervisors and projects. Limited transparency is also a serious concern, as stakeholders including clients, consultants, and regulatory bodies lack real-time access to project status.

This information asymmetry often leads to disputes, mistrust, and contractual claims between parties [7].

Furthermore, conventional monitoring forces reactive management, meaning problems are identified only after they occur rather than being predicted and prevented. Safety hazards, potential delays, and quality defects are discovered too late for proactive intervention, increasing the likelihood of accidents and rework [1]. The paper-based nature of conventional methods creates significant inefficiency, as drawings, inspection reports, daily logs, and progress photos are stored as physical documents or unorganized digital files, making retrieval of historical information time-consuming and often impossible. Safety risks are also heightened because without real-time tracking, workers entering hazardous zones or equipment approaching unsafe conditions cannot be immediately detected or alerted [2, 6].

Coordination failures frequently occur due to fragmented communication between contractors, consultants, clients, and subcontractors. This fragmentation causes rework, duplicated efforts, missed handoffs, and schedule delays that could have been avoided with better information flow [7]. Conventional monitoring also offers no capability for historical data analytics, as manual records cannot be easily analyzed to identify patterns, predict future performance, or generate insights for improving future projects [6]. Finally, these methods are highly labor-intensive, requiring significant time and effort for site visits, report writing, photograph printing, data compilation, and verification. This administrative burden reduces the time supervisors can actually spend on proactive management and problem-solving.

2.3 Real-Time Monitoring in Construction

2.3.1 Evolution and Importance

The concept of real-time monitoring in construction has evolved from a luxury into a necessity. In earlier decades, construction supervision relied on static site visits, manual logs, and retrospective reporting, which delayed decision-making and often contributed to safety violations and cost overruns. As construction

projects increased in scale and complexity, the need for faster, more accurate monitoring mechanisms became increasingly evident. The evolution began with the integration of basic sensor systems, gradually shifting toward intelligent monitoring powered by IoT, cloud computing, and artificial intelligence (AI) [6]. These technologies now provide construction managers with access to live project data, offering insights into safety conditions, productivity metrics, and material logistics without the need for physical presence on-site [7].

Real-time monitoring enables a paradigm shift from reactive to proactive construction management. Instead of identifying problems after they occur, project stakeholders can now detect early warning signals, enabling preemptive responses that mitigate risk and reduce delays. This transformation enhances transparency, increases safety compliance, and ensures tighter control over quality standards [8]. The importance of real-time monitoring is especially evident in high-risk environments such as high-rise buildings or infrastructure projects where site dynamics change rapidly and a minor deviation can cascade into major setbacks [9].

2.3.2 Technologies Enabling Real-Time Monitoring

A wide array of technologies supports real-time monitoring systems, each contributing to the multidimensional understanding of site conditions. At the core are Internet of Things (IoT) sensors, which continuously capture data related to temperature, humidity, vibrations, pressure, and structural stress. These sensors are often embedded in machinery, structural components, or worker gear and are capable of transmitting data at high frequency to cloud-native platforms for analysis [10].

Unmanned Aerial Vehicles (UAVs) or drones have emerged as highly effective tools for aerial surveillance. They are used to monitor progress, detect defects, and verify design compliance. Their integration with computer vision systems further enhances accuracy in identifying anomalies [11]. Additionally, wearable devices such as smart helmets, wristbands, and vests are used to track workers' location, fatigue levels, and exposure to hazardous conditions. These devices feed data to

supervisors in real time, promoting worker safety through geofencing and emergency alert systems [12].

Edge computing complements cloud-based analysis by enabling local data processing in environments with poor connectivity. This approach minimizes latency and ensures uninterrupted monitoring even in remote or challenging terrains [13]. Data from sensors and devices are compiled on centralized dashboards typically powered by cloud-native platforms that offer customizable visualizations and alert systems for project managers. Moreover, artificial intelligence and machine learning algorithms are now being used to analyze historical and real-time data to detect patterns, predict bottlenecks, and recommend corrective actions [14].

2.3.3 Global Applications and Best Practices

Several global case studies highlight the effectiveness of real-time monitoring systems in large-scale construction projects. In Singapore, the Housing and Development Board (HDB) has mandated the use of real-time sensor systems on all public housing projects. These include tilt sensors for scaffolding, GPS trackers on equipment, and integrated dashboards for centralized supervision. The result has been a marked reduction in safety incidents and construction time [15]. In the United Arab Emirates, real-time monitoring is used extensively in mega-projects like Expo 2020 and Etihad Rail. These systems combine drone surveillance, AI-based object detection, and real-time reporting to maintain regulatory compliance and avoid time overruns [16]. In China, the deployment of 5G-enabled monitoring in highway construction has allowed real-time synchronization between multiple contractors and government agencies, leading to improved coordination and lower administrative overheads [17].

European and North American construction firms have adopted IoT networks to monitor worker health and equipment status, yielding measurable improvements in site safety and predictive maintenance capabilities [18]. Meanwhile, UK-based firms have been using predictive maintenance models, trained on real-time sensor data, to avoid costly equipment breakdowns and ensure uninterrupted site operations [19]. These international benchmarks underscore the tangible benefits of

real-time monitoring in construction. They highlight the role of digital maturity, strong regulatory backing, and cross-platform integration as critical enablers of success. Countries and firms that have institutionalized digital monitoring as part of standard operating procedures have consistently outperformed those that rely on periodic or manual updates [20].

2.4 Cloud Computing and Cloud-Native Platforms

2.4.1 Definitions and Key Features

Cloud computing is defined as the delivery of computing services including servers, storage, databases, networking, software, and analytics over the internet “the cloud” to enable faster innovation, flexible resources, and economies of scale. Users typically pay only for the services they use, which reduces operational costs and allows infrastructure scalability based on real-time demand [21]. In the context of construction, cloud platforms provide centralized data storage, real-time collaboration tools, and access to project information from any location, making them ideal for the mobile and dynamic nature of construction sites. Cloud-native platforms represent a more advanced evolution of traditional cloud systems. They are purpose-built to fully exploit cloud infrastructure by utilizing technologies such as microservices architecture, containerization (e.g., Docker), orchestration tools (e.g., Kubernetes), and Continuous Integration/Continuous Deployment (CI/CD) pipelines [22]. These platforms enable software applications to be designed, developed, deployed, and scaled independently of underlying hardware or infrastructure. In construction monitoring, this means modular digital systems can be easily updated, maintained, and customized according to the project’s unique and evolving needs.

A key attribute of cloud-native platforms is resilience they are capable of self-healing and isolating failures in one part of the system without affecting the entire platform. Additionally, automation is central to cloud-native design. With CI/CD pipelines, new analytics modules or integration points (e.g., with IoT or BIM tools)

can be deployed rapidly without interrupting live operations [23]. Elastic scalability ensures that resource consumption adapts automatically to fluctuations in data load, such as during high-frequency sensor reporting or simultaneous dashboard access by multiple stakeholders. Portability also plays a critical role: containerized applications can run across different cloud providers or hybrid environments with minimal reconfiguration [24].

2.4.2 Advantages in Construction Monitoring

The use of cloud-native platforms in real-time construction monitoring introduces significant benefits over traditional IT systems. Firstly, these platforms allow for centralized and real-time data access, which is critical for monitoring multiple construction sites or large-scale infrastructure projects. Instead of relying on isolated desktop software or site-based servers, all project data including sensor inputs, progress updates, incident reports, and BIM models can be stored and processed in the cloud, allowing stakeholders to access unified dashboards and reports from any internet-connected device [25]. Secondly, cloud-native platforms support high interoperability with a wide range of devices and software tools. For example, IoT enabled construction equipment, wearables, drones, and environmental sensors can seamlessly transmit data to the cloud platform, where it is aggregated, filtered, and visualized. This improves situational awareness and supports more informed decision-making. Furthermore, cloud-native platforms can be integrated with AI and machine learning algorithms, enabling predictive analytics to forecast delays, detect anomalies, or assess safety risks before they escalate [26].

In terms of cost-efficiency, cloud-native systems significantly reduce the need for on premise infrastructure and maintenance. They adopt a “pay-as-you-go” model, allowing construction firms to scale their computing resources in line with project demands. This flexibility is particularly beneficial for small- to medium-sized enterprises (SMEs) that may lack the capital for large IT investments [27]. Moreover, these platforms enable collaborative workflows across multidisciplinary teams and subcontractors. Documents, models, and data can be shared in real time, eliminating version control issues and reducing delays caused by miscommunication.

For example, site engineers can update progress data using mobile applications, while design teams back at the office can adjust plans accordingly. Such synchronization was difficult to achieve with earlier siloed systems [28]. Lastly, security and compliance features have matured significantly in cloud-native environments. Advanced Identity and Access Management (IAM), data encryption, and activity logs ensure secure handling of sensitive project data. Role-based permissions allow organizations to control who accesses what data, complying with industry standards and government regulations [29].

2.5 Integration of Cloud-Native Platforms with Other Technologies

Cloud-native platforms derive their transformative potential from seamless integration with other digital technologies such as Building Information Modeling (BIM), Internet of Things (IoT), Artificial Intelligence (AI), and digital twins. This integration creates a connected, intelligent ecosystem for managing real-time construction data, enabling enhanced visibility, collaboration, and decision-making. BIM-cloud integration facilitates real-time updates of models based on live field data, allowing for instant comparison between planned and actual site conditions. Such dynamic synchronization improves design accuracy, reduces rework, and enhances stakeholder coordination [30]. IoT-enabled sensors embedded in equipment and structures feed continuous data to the cloud, which can be analyzed for safety monitoring, equipment usage, or environmental compliance [31]. When coupled with AI, cloud platforms can process these large datasets to predict project risks or recommend resource adjustments [32]. The culmination of these technologies is reflected in digital twins virtual representations of physical assets that evolve in real time through cloud-linked data streams. These twins offer interactive monitoring and predictive simulations, enabling agile construction management. Globally, firms leveraging these integrated systems report significant improvements in productivity, cost savings, and risk mitigation. Their success underscores the importance of adopting interoperable, cloud-native solutions for future-ready construction practices [33].

2.6 Identification of Factors Affecting Adoption of Cloud-Native Platforms through Literature Review

Following factors are identified from 27 research papers through a systematic review of recent literature as shown in table 2.1. The studies highlight a range of technical, organizational, economic, and regulatory factors influencing the adoption of cloud-native platforms in the construction industry. Key challenges include data security and privacy concerns, interoperability issues, high initial investment costs, and lack of skilled workforce, while enabling factors include scalability, real-time collaboration, improved data accessibility, and enhanced project integration. These factors collectively shape organizational readiness and decision-making regarding cloud-native platform adoption.

TABLE 2.1: Identification of Factors Affecting Adoption of Cloud-Native Platforms

| No | Source | Key Challenges Identified |
|----|--------|---|
| 1 | [34] | - Lack of integration and communication - System scalability |
| 2 | [35] | - Data Security issues - Networking challenges |
| 3 | [36] | - Legal and regulatory complexities - Uncertainty in progress monitoring |
| 4 | [37] | - High implementation cost - Lack of Government Mandates |
| 5 | [38] | - High initial investment for setup & training - Lack of digital tools |
| 6 | [39] | - User Adoption difficulty - Technical integration |

Table 2.1: Continued from previous page

| No | Source | Key Challenges Identified |
|----|--------|---|
| 7 | [40] | <ul style="list-style-type: none"> - Transparency issues between stakeholders - Low trust among staff |
| 8 | [41] | <ul style="list-style-type: none"> - Compliance with data protection laws - Cyber security issues |
| 9 | [42] | <ul style="list-style-type: none"> - Resistance to immutable, transparent records - Lack of awareness of digital technologies |
| 10 | [43] | <ul style="list-style-type: none"> - Stick to previous practices and reluctant attitude towards adoption of new technologies - Complexity of procedures |
| 11 | [44] | <ul style="list-style-type: none"> - Hardware limitations (bulky headsets, battery) - Time and effort required |
| 12 | [45] | <ul style="list-style-type: none"> - Absence of industry-wide open standards - Data handling and storage constraints |
| 13 | [46] | <ul style="list-style-type: none"> - Harsh on-site conditions affecting devices - Internet connectivity issues |
| 14 | [47] | <ul style="list-style-type: none"> - Deep-rooted resistance to change - Skill gaps in digital technologies |
| 15 | [48] | <ul style="list-style-type: none"> - High upfront costs with uncertain ROI - High implementation cost |
| 16 | [49] | <ul style="list-style-type: none"> - Lack of stakeholders awareness - Shortage of data science/analytics skills |
| 17 | [50] | <ul style="list-style-type: none"> - Lack of clear data quality control processes - Lack of data adherence regularity framework |
| 18 | [51] | <ul style="list-style-type: none"> - Regulatory restrictions on devices - Digital devices integration issues |

Table 2.1: Continued from previous page

| No | Source | Key Challenges Identified |
|----|--------|--|
| 19 | [52] | - Limited IT budget - Lack of technical expertise |
| 20 | [53] | - High cloud storage costs for video data - Security risks for data |
| 21 | [54] | - Network configuration complexity - Insufficient training to workers |
| 22 | [55] | - Unfavorable cloud service level agreements - Lack of top management support |
| 23 | [56] | - Complex mobile app interfaces for field use - Record and documentation issues |
| 24 | [57] | - Inadequate safety measures - Legal regularity issues |
| 25 | [58] | - Complexity integrating environmental data - Lack of trust among staff |
| 26 | [59] | - Lack of awareness - Absence of cohesive national policy |
| 27 | [60] | - Lack of effective change management plans - Shortage of digitally skilled workforce |

2.7 Review of Existing Frameworks for Technology Adoption

The adoption of emerging technologies in the construction industry is often conceptualized using structured models that attempt to explain how, why, and under what conditions organizations implement innovation. Among the most widely used is the Technology Acceptance Model (TAM), which posits that perceived

usefulness and perceived ease of use are the primary drivers of individual adoption behavior [61]. However, TAM is primarily user-centered and may fall short in explaining systemic organizational and environmental factors critical in large-scale industrial contexts like construction. To address this gap, the Technology Organization Environment (TOE) framework has gained prominence. TOE emphasizes that a firm's technological infrastructure, internal readiness, and external environment all interact to shape its capacity for innovation adoption [62].

Another influential framework is the Unified Theory of Acceptance and Use of Technology (UTAUT), which synthesizes components from eight earlier models, including TAM and DOI. UTAUT introduces constructs such as performance expectancy, effort expectancy, social influence, and facilitating conditions, making it particularly relevant in collaborative environments like construction sites. However, while these frameworks offer valuable theoretical lenses, they are not tailored to the unique characteristics of the construction industry such as fragmented project delivery, regulatory challenges, and field variability. As a result, scholars have called for modified frameworks that incorporate sector-specific factors including data interoperability, digital literacy, and risk aversion [63]. In this study, these foundational models serve as a conceptual base, but the research ultimately aims to extend them to suit the context of cloud-native platform adoption in the construction sector of Islamabad.

2.8 Summary

This chapter provided a comprehensive review of the existing literature on the adoption of cloud-native platforms for real-time construction monitoring, with a focus on identifying relevant technologies, integration models, challenges, and theoretical frameworks. The discussion began with an overview of the evolution and significance of real-time monitoring in modern construction, highlighting the limitations of traditional oversight methods and the benefits of IoT, drones, wearables, and edge computing. The advantages of cloud-native platforms such as scalability, modularity, remote access, and real-time synchronization were explained in

relation to their transformative role in digitizing construction workflows. Subsequently, the chapter detailed the integration of cloud-native platforms with other digital construction tools, including BIM, AI, and digital twins, emphasizing how their convergence supports predictive analytics, collaborative planning, and risk mitigation. A critical analysis of adoption challenges was presented through a synthesis of 27 academic sources, categorized into technical, organizational, legal, and financial barriers. Furthermore, existing theoretical frameworks such as TAM, TOE, UTAUT, and DOI were reviewed to provide conceptual grounding, although their limitations in construction-specific contexts were noted.

Chapter 3

Research Methodology

3.1 Introduction

This chapter systematically outlines the methodological framework employed to investigate the adoption challenges and implementation strategy for cloud-native platforms in real-time construction monitoring within Islamabad. The methodology is structured to ensure both theoretical depth and practical relevance, aligning with the applied nature of construction technology research. A sequential, data-driven research approach is adopted, progressing logically through interconnected phases to support the development of a comprehensive and actionable implementation framework. Each phase is designed to contribute uniquely to the study's broader objective of enabling informed digital transformation within the construction sector.

The methodological structure includes an initial phase of comprehensive literature review to establish foundational knowledge and contextual understanding of technological adoption trends. This is followed by a structured process of factor identification and refinement through expert engagement, ensuring local relevance and academic validity. The core of the methodology centers around empirical investigation, supported by statistical evaluation techniques to ensure the robustness of findings. The final phases involve ranking of challenges, development of a contextual implementation guidelines, and validation of results through rigorous

analysis. The ultimate aim is to produce a scalable and evidence-based guidelines that can guide construction stakeholders in Islamabad including engineers, consultants, contractors, and policymakers in the effective integration of cloud-native monitoring technologies. The detailed procedures of this methodology are elaborated in the following sections.

3.2 Research Design

This study is philosophically grounded in pragmatism, which emphasizes actionable outcomes and the practical relevance of research findings over abstract theorization. Given the applied nature of digital adoption in construction, this paradigm offers the flexibility to explore complex, context-driven challenges while delivering insights that are implementable by practitioners. The research adopts a descriptive-analytical design, combining theoretical grounding with data-driven evaluation to bridge the gap between academic literature and on-ground construction practices in Islamabad. The methodological pathway is structured to move logically from conceptual foundations to empirical validation and ultimately to industry guidelines.

The approach follows a deductive reasoning strategy, wherein the study begins with a theoretically informed foundation derived from prior literature and proceeds toward empirical validation through structured data analysis. The research process is segmented into sequential phases: literature synthesis, identification and refinement of influencing factors, data collection from industry practitioners, and multi-stage statistical analysis. This analytical sequence supports triangulation and enhances both the internal consistency and external validity of the findings. The flow of the methodology, illustrated in Figure 3.1, outlines the interconnected stages ranging from literature review and risk factor identification to data interpretation and framework development ensuring an evidence-based progression toward conclusions and recommendations.

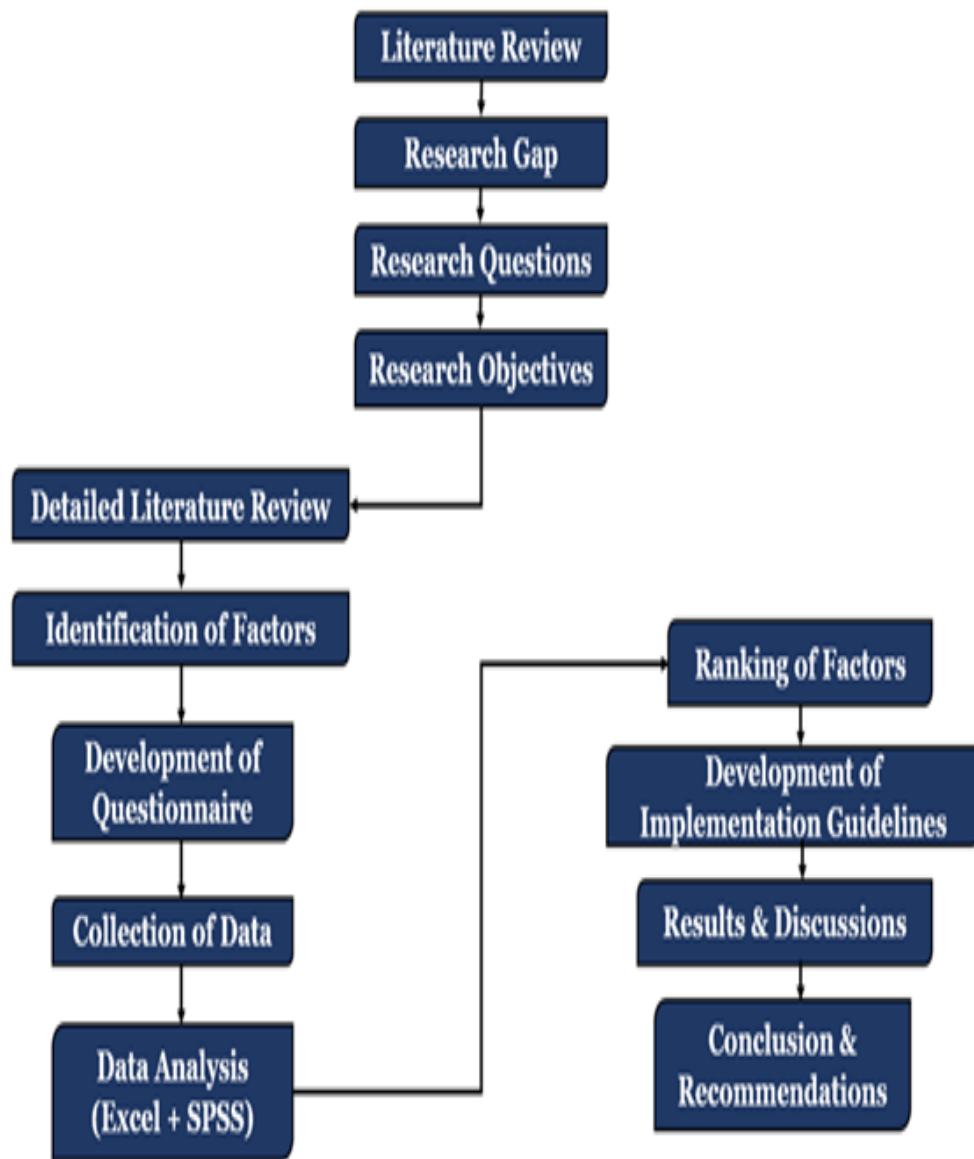


FIGURE 3.1: Systematic Diagram of Methodology

3.3 Preliminary Investigation and Literature-Based Factor Identification

The preliminary phase of this study commenced with a structured and systematic literature review aimed at identifying factors influencing the adoption of cloud-native platforms for real-time construction monitoring. Particular emphasis was placed on studies related to digital transformation in construction, cloud computing, real-time monitoring systems, and technology adoption within developing

economies, with specific consideration of the Pakistani construction context. The literature review was conducted through a stepwise process to ensure comprehensiveness, relevance, and methodological rigor [64].

Initially, extensive searches were performed across major academic databases, including Scopus, Web of Science, IEEE Xplore, and Google Scholar, focusing on publications from 2020 to 2025 to ensure contemporary relevance. Keywords related to cloud-native platforms, real-time construction monitoring, digital construction technologies, IoT-based monitoring, and technology adoption challenges were systematically applied. The initial search resulted in a broad pool of academic articles, conference proceedings, industry reports, and case studies. These sources were then screened using predefined inclusion criteria, emphasizing relevance to construction monitoring, empirical robustness, applicability to developing-country contexts, and alignment with organizational and technological adoption themes. Following this screening process, more than 27 relevant studies were selected for in-depth analysis. The synthesis stage involved systematic extraction and classification of adoption-related challenges and enabling factors. These factors were grouped into major thematic domains reflecting technological, financial, organizational, human-resource, and regulatory dimensions. Through this structured review process, an initial set of influencing factors was identified, forming a comprehensive foundation for subsequent refinement and empirical investigation. This literature-driven identification ensured that the study was grounded in existing scholarly knowledge while remaining sensitive to the operational realities of real-time construction monitoring and cloud-native platform adoption in Islamabad.

3.4 Factor Refinement Using Delphi Technique

The Delphi technique was systematically employed to validate, refine, and contextualize the preliminary factors [65] influencing the adoption of cloud-native platforms for real-time construction monitoring within Islamabad's construction industry. The expert panel was deliberately constituted to ensure balanced representation from key stakeholder groups relevant to digital construction practices. The panel included senior contractors with practical experience in large-scale projects,

project managers from leading construction firms, consulting engineers with exposure to digital monitoring systems, and academic professionals specializing in construction management and construction informatics. All participating experts possessed a minimum of ten years of professional experience within Pakistan's construction sector, ensuring informed and context-aware judgment.

Initially a questionnaire comprising 54 factors was formed and discussed with panel. Two rounds of consultation process facilitated structured expert evaluation of the initially identified 54 factors, allowing assessment of their relevance, clarity, and applicability to the local construction environment. On the basis of their expert opinion, overlapping or less significant factors, were consolidated, resulting in a reduced and focused set of 30 critical adoption factors which covers local construction industry and suitability. These factors reflect the technological, organizational, financial, human-resource, and regulatory dimensions influencing cloud-native platform adoption in Islamabad. The refined factor set formed the analytical foundation for subsequent empirical investigation and guidelines development, ensuring that the study outcomes remain both practically relevant and grounded in industry expertise.

3.5 Questionnaire Design and Data Collection

3.5.1 Questionnaire Structure

A meticulously structured questionnaire was designed to facilitate the collection of empirical data from professionals working in the construction sector of Islamabad. The primary objective of the questionnaire was to evaluate the challenges associated with the adoption of cloud-native platforms for real-time construction monitoring and to support the development of a contextual implementation framework. The instrument was divided into five key sections, each targeting a specific dimension of the study.

- i. Section 1 focused on gathering demographic and background information from respondents, including job role, years of professional experience, educational qualifications, and type of organization.

- ii. Section 2 addressed factors related to technology and tool challenges, such as integration difficulties, scalability, and system compatibility.
- iii. Section 3 concentrated on investment and budget-related challenges, highlighting financial feasibility, initial setup costs, and infrastructure limitations.
- iv. Section 4 evaluated employee and training-related challenges, focusing on digital skills, change resistance, and training availability.
- v. Section 5 assessed rules and organizational barriers, such as regulatory uncertainty, leadership commitment, and internal data governance policies.

Each of the 30 technical statements included in the questionnaire was measured using a five-point Likert scale, where 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, and 1 = Strongly Disagree. This scale was selected to ensure standardized responses, enabling robust statistical analysis and comparison across respondent groups. The questionnaire was pilot-tested for clarity and refined based on expert feedback to ensure reliability and contextual relevance to the Islamabad construction environment.

3.5.2 Data Sampling and Distribution

The data collection process was directed toward construction professionals engaged in real-time monitoring practices or digital transformation initiatives within different projects in the Islamabad-Rawalpindi metropolitan region. The sampling frame encompassed individuals from diverse professional backgrounds, including contracting companies, consultancy and engineering firms, project management bodies, regulatory authorities, and academic institutions with domain expertise in construction technology. To ensure broad representation across organizational levels and roles, a hybrid sampling strategy was adopted, combining purposive sampling to deliberately select participants with relevant expertise and snowball sampling, where initial respondents facilitated access to additional qualified professionals within their networks. This dual approach was instrumental in reaching a concentrated and relevant respondent base in a specialized research context. The

target sample size was established at 81 respondents, guided by Cochran's formula for sample size determination. This calculation was based on a 95% confidence level and a 5% margin of error, accounting for the estimated size of the active professional population in the region's construction sector. The sampling approach ensured the collection of valid, representative data suitable for the quantitative analysis techniques employed in this study.

3.6 Descriptive Analysis

Initial data analysis was conducted using descriptive statistical techniques in IBM SPSS Statistics software [66]. Frequency distributions and cross-tabulations were used to summarize the demographic characteristics of respondents and to ensure adequate representation of key stakeholder groups involved in construction projects in Islamabad, including contractors, consultants, project managers, and technical professionals. For each identified adoption challenge related to cloud-native platforms for real-time construction monitoring, mean values and standard deviations were calculated based on responses recorded on the five-point Likert scale to establish baseline perceptions regarding the importance of these challenges. Frequency analyses were further employed to identify response patterns, assess data distribution characteristics, and detect potential outliers. Additionally, comparative descriptive analysis was performed across demographic variables such as professional role, years of experience, and organizational type to gain preliminary insights into variations in stakeholder perceptions, thereby informing subsequent inferential analysis and framework development.

3.6.1 Reliability and Normality Tests

The internal consistency and reliability of the questionnaire used to assess adoption challenges related to cloud-native platforms for real-time construction monitoring were evaluated using Cronbach's Alpha coefficient, a widely accepted measure of scale reliability in survey-based research [67]. The reliability analysis produced Cronbach's Alpha values exceeding the recommended threshold of 0.70, confirming

satisfactory internal consistency among the measurement items. To determine the appropriate statistical techniques for further analysis, data normality was assessed using the Shapiro–Wilk test. The results indicated that the majority of variables did not follow a normal distribution ($p < 0.05$) [68]. Consequently, non-parametric statistical methods were deemed appropriate for subsequent analysis to accurately capture stakeholder perceptions and variability in responses related to cloud-native platform adoption within Islamabad’s construction sector.

3.6.2 Kruskal-Wallis Test

The Kruskal–Wallis test, a non-parametric statistical technique, was employed to examine differences in perceptions regarding adoption challenges of cloud-native platforms for real-time construction monitoring across various demographic groups. This test was selected due to the non-normal distribution of the data, as confirmed by the Shapiro–Wilk test. The analysis assessed variations in responses based on professional experience (0–5 years, 6–10 years, 11–15 years, and 16+ years), organizational role (such as contractor, consultant, and project manager), educational background, and predominant project type. The results provided insights into how different stakeholder groups perceive and prioritize adoption challenges, thereby informing the development of targeted strategies and a context-sensitive implementation guidelines for cloud-native platform adoption in Islamabad’s construction sector [69].

3.6.3 Relative Importance Index

The Relative Importance Index (RII) method was employed to rank the identified challenges affecting the adoption of cloud-native platforms for real-time construction monitoring based on survey responses. For each adoption factor, the RII value was calculated using the standard formula:

$$RII = \frac{\sum W}{A \times N} \quad (3.1)$$

where W represents the weight assigned by respondents on a five-point Likert scale, A denotes the highest possible weight (5), and N indicates the total number of respondents. The resulting RII values ranged between 0 and 1, with higher values reflecting greater perceived importance of a given adoption challenge. The ranked RII scores were used to prioritize critical barriers influencing cloud-native adoption in Islamabad's construction sector and served as a key input for subsequent analysis and the development of the proposed implementation framework.

3.6.4 Decision Criteria and Interpretation of Statistical Results

To ensure consistency in interpreting quantitative results, standard decision criteria were applied throughout the analysis. For reliability testing, Cronbach's Alpha values of 0.70 and above were considered acceptable for internal consistency, indicating that the questionnaire items measured the intended constructs reliably. For normality assessment, the Shapiro Wilk test was interpreted using a significance threshold of $p < 0.05$, where values below this threshold indicated non-normal distribution and justified the use of non-parametric statistical tests.

For group comparison analysis, the Kruskal Wallis H test was interpreted using the same significance threshold ($p < 0.05$). Where statistically significant differences were observed among respondent groups, the findings were interpreted in relation to practical implications for cloud-native adoption in Islamabad, particularly in terms of how perceptions vary across roles and experience levels. For challenge prioritization, Relative Importance Index (RII) scores were interpreted on a comparative basis, where higher values indicated greater perceived importance, and rankings were used to guide the prioritization logic embedded in the proposed implementation framework.

3.7 Implementation Guidelines Development

The development of the proposed cloud-native implementation guidelines was carried out using a structured and evidence-based process that integrates both

literature-driven insights and empirical findings from the Islamabad construction sector. Unlike a theoretical framework which focuses on conceptual relationships, these guidelines are designed as practical, actionable recommendations that construction stakeholders can directly follow to adopt cloud-native platforms for real-time monitoring. The purpose of these guidelines is to provide a clear, step-by-step pathway for construction stakeholders including contractors, consultants, clients, and policymakers to adopt cloud-native platforms while systematically addressing barriers specific to the local context of Islamabad.

The guideline development was conducted in four systematic stages, each building upon the previous stage to ensure rigor, relevance, and practical applicability. These stages are: (1) Guideline Inputs, (2) Prioritization of Challenges and Adoption Factors, (3) Structuring into Guideline Dimensions, and (4) Development of a Phased Implementation Roadmap. Each stage is described in detail below.

3.7.1 Stage 1: Guidelines Inputs -Literature + Delphi + Survey Findings

The first stage involved collecting and validating the foundational inputs that would inform the guidelines. This process began with an extensive systematic literature review of 27 research papers covering topics such as cloud-native platforms, real-time construction monitoring, IoT integration, and technology adoption in construction. The literature review identified an initial set of 54 factors influencing cloud-native adoption, including technical challenges (e.g., integration difficulties, scalability issues), organizational barriers (e.g., lack of policies, resistance to change), economic constraints (e.g., high costs, uncertain ROI), and regulatory challenges (e.g., lack of standards, legal uncertainties).

These 54 factors were then refined using the Delphi technique, which involved a panel of industry experts with more than ten years of experience in Islamabad's construction sector. The expert panel included senior contractors, project managers, consulting engineers, and academic professionals specializing in construction management. Through two rounds of structured consultation, overlapping or less

significant factors were consolidated, resulting in a refined set of 30 critical adoption factors that are most relevant to Islamabad's construction context.

The refined factor list was then operationalized into a structured questionnaire comprising 30 Likert-scale statements. The questionnaire was distributed to 81 construction professionals in Islamabad using purposive and snowball sampling, achieving a response rate of 80.95%. The reliability of the questionnaire was confirmed through Cronbach's Alpha ($\alpha = 0.891$), indicating excellent internal consistency. This multi-step process ensured that the guidelines are grounded in both global evidence from the literature and local practitioner perceptions from Islamabad's construction industry.

3.7.2 Stage 2: Prioritization of Challenges and Adoption Factors

The second stage focused on ranking the 30 adoption challenges based on their perceived significance as reported by survey respondents. The Relative Importance Index (RII) method was applied to convert the five-point Likert scale responses into a normalized index ranging from 0 to 1, enabling direct comparison across all factors. The RII formula used was: $RII = \Sigma W / (A \times N)$, where ΣW is the sum of weights assigned by respondents, A is the highest possible weight (5), and N is the total number of respondents (81).

The RII analysis produced a ranked list of challenges from highest to lowest importance. The highest-ranked challenges with RII values above 0.820 were treated as "critical barriers" and formed the primary focus areas of the guidelines. These critical barriers include lack of organizational policies (RII = 0.852), lack of trained personnel (RII = 0.840), inadequate training programs (RII = 0.822), limited IoT infrastructure (RII = 0.827), and absence of standard digital monitoring guidelines (RII = 0.820). The top-ranked opportunity, real-time monitoring improving transparency, achieved the highest RII value of 0.879.

This ranking approach ensured that the guidelines emphasize practical issues that most strongly affect adoption decisions in Islamabad, rather than generic barriers

commonly reported in international contexts. By prioritizing the most influential factors, the guidelines direct attention and resources to the areas where they will have the greatest impact.

3.7.3 Stage 3: Structuring into Guideline Dimensions

The third stage involved grouping the ranked factors into coherent adoption dimensions to provide a structured guidelines for implementation planning. Based on the thematic nature of the factors and the original questionnaire structure, the guideline dimensions were organized into four categories: the questionnaire structure, the framework dimensions include:

3.7.3.1 Technological and Infrastructure Readiness

This dimension addresses challenges related to connectivity, interoperability, scalability, and integration issues. Key factors in this dimension include lack of IoT sensors and hardware (RII = 0.827), poor internet connectivity on construction sites (RII = 0.793), difficulty integrating cloud-native platforms with existing systems (RII = 0.770), and complexity of setting up monitoring software (RII = 0.726). Guidelines under this dimension focus on phased IoT deployment, edge-cloud integration for offline capability, and use of portable 4G/5G solutions for sites with unreliable networks.

3.7.3.2 Financial and Investment Readiness

This dimension addresses economic barriers including setup costs, ROI uncertainty, and infrastructure budgeting. Key factors include budget constraints (RII = 0.783), high initial investment costs (RII = 0.765), additional costs for training and customization (RII = 0.758), high data storage and processing costs (RII = 0.753), and uncertainty about return on investment (RII = 0.748). Guidelines under this dimension focus on using pay-as-you-go cloud services, starting with pilot projects to demonstrate ROI, and adopting scalable architectures that allow gradual expansion based on budget availability.

3.7.3.3 Human Resource and Capability Readiness

This dimension addresses workforce-related challenges including digital skills gaps, training deficiencies, and resistance to change. Key factors include lack of trained personnel (RII = 0.840), inadequate training programs (RII = 0.822), limited awareness of cloud-native technologies (RII = 0.815), preference for traditional construction methods (RII = 0.812), and resistance to organizational change (RII = 0.776). Guidelines under this dimension focus on integrating cloud-native modules into PEC's Continuing Professional Development (CPD) programs, mandating on-site digital training before project mobilization, and updating university curricula through HEC to include hands-on cloud/IoT laboratories.

3.7.3.4 Organizational and Governance Readiness

This dimension addresses institutional barriers including leadership support, policies, data governance, and regulatory compliance. Key factors include lack of organizational policies (RII = 0.852), absence of a clear digital transformation strategy (RII = 0.817), lack of standard digital monitoring guidelines (RII = 0.820), lack of top management support (RII = 0.780), unclear data ownership and governance policies (RII = 0.768), and legal and regulatory uncertainties (RII = 0.763). Guidelines under this dimension focus on PEC issuing standardized guidelines, CDA incorporating digital monitoring requirements into tenders and approvals, and construction firms developing internal data governance policies. This dimensional structuring supports clarity and allows organizations to evaluate adoption requirements across multiple layers simultaneously. Construction firms can assess their readiness in each dimension and prioritize actions accordingly.

3.7.3.5 Development of a Phased Implementation Roadmap

The fourth and final stage involved designing the guidelines as a phased implementation roadmap to guide adoption in realistic, sequential steps. The phased approach recognizes that most construction firms in Islamabad have limited digital maturity and cannot transition to cloud-native monitoring overnight. The roadmap consists of four sequential phases, each with specific activities, outputs, and decision gates:

3.7.4 Phases

Following are four sequential phases:

3.7.4.1 Phase 1: Readiness Assessment Phase

This initial phase focuses on evaluating the organization's current state before any technology deployment. Activities include assessment of site-level internet connectivity to determine if edge-cloud integration is needed, evaluation of existing digital maturity and IT infrastructure, assessment of leadership support and organizational readiness, and analysis of cost feasibility including budget availability for pilot deployment. The output of this phase is a readiness score and gap analysis report. A decision gate follows: if the organization is ready, proceed to Phase 2; if not ready, implement remediation measures and reassess.

3.7.4.2 Phase 2: System Planning and Design Phase

This phase focuses on technical and organizational planning for the pilot deployment. Activities include selection of cloud deployment model (public, private, or hybrid), architecture planning including microservices and containerization (e.g., Docker, Kubernetes), integration strategy for IoT sensors, BIM models, and edge computing devices, and development of data governance and security policies. The output of this phase is a detailed implementation plan and system architecture design. A decision gate follows: if the plan is approved by stakeholders, proceed to Phase 3; if not, revise and resubmit.

3.7.4.3 Phase 3: Pilot Deployment and Change Management Phase

This phase involves executing a small-scale pilot project to test the guidelines in a controlled, low-risk environment. Activities include pilot project execution on a single floor or small section of a larger project, deployment of IoT sensors and cloud dashboard, training of site engineers and supervisors on the new system, stakeholder onboarding and communication, iterative improvements based on feedback,

and measurement of ROI and performance metrics (e.g., time saved, rework reduced, delays avoided). The output of this phase is demonstrated benefits and validated guidelines. A decision gate follows: if ROI is positive and stakeholders are satisfied, proceed to Phase 4; if not, revise the approach or abandon.

3.7.4.4 Phase 4: Scale-Up and Optimization Phase

This final phase involves expanding the successful pilot to organization-wide implementation. Activities include organization-wide rollout across all projects, integration with existing project management and reporting systems, continuous performance monitoring and optimization, governance enforcement and compliance auditing, and regular feedback collection for continuous improvement. The output of this phase is full cloud-native adoption across the organization. A feedback loop is established to continuously refine the guidelines based on lessons learned.

This phased structure supports gradual adoption, reduces implementation risk, and aligns with the staged digital maturity of most construction firms in Islamabad. By starting with a small pilot project using pay-as-you-go cloud services, organizations can demonstrate ROI with minimal financial risk before committing to full-scale adoption.

3.8 Summary

This chapter outlines the structured research methodology adopted to investigate the adoption of cloud-native platforms for real-time construction monitoring in Islamabad. The study follows a pragmatism-based, descriptive-analytical and deductive approach, beginning with a comprehensive literature review to identify adoption factors, followed by refinement through the Delphi technique involving industry experts. A structured questionnaire comprising 30 Likert-scale items was developed and distributed to construction professionals using purposive and snowball sampling, resulting in 81 valid responses. Data were analyzed using SPSS, including descriptive statistics, reliability testing through Cronbach's Alpha, normality assessment via the Shapiro–Wilk test, and non-parametric analysis

using the Kruskal–Wallis test. The Relative Importance Index (RII) method was employed to rank critical adoption factors, which ultimately informed the development of a context-specific implementation framework tailored to Islamabad’s construction sector.

Chapter 4

Results and Analysis

This chapter presents an analysis of data collected from a structured questionnaire survey. The survey aimed to identify the factors influencing the adoption of cloud-native platforms in the construction industry. The analysis is based on responses from 81 construction professionals, including clients, contractors, and consultants. The main goal is to identify, evaluate, and prioritize the most important adoption factors using statistical methods commonly used in construction management research. The findings are presented in the following sections: (i) respondent demographics, (ii) reliability testing (Cronbach's alpha), (iii) normality assessment (Shapiro Wilk), (iv) descriptive statistics, and (v) Relative Importance Index (RII) ranking. Non-parametric tests (Kruskal Wallis) are used, when necessary, to examine differences in perceptions across different demographic groups.

4.1 Sample Size and Response Rate

Construction professionals engaged in the planning, execution, and management of construction projects received a total of 105 questionnaires. A total of 85 responses were initially collected; however, 4 responses were excluded after screening for not meeting the criteria for the targeted respondents. This left 81 valid responses, which were analyzed to gain insights into the involvement of various stakeholders in sustainable construction projects, yielding a response rate of 80.95%. In accordance with survey-based research norms within construction management,

a response rate exceeding 70% is deemed highly favorable, reflecting substantial respondent involvement and data dependability. Following data screening and validation procedures, 81 responses were ultimately included in the final analysis, given their completeness and suitability for statistical examination. The final sample size meets the established criteria for descriptive and ranking-based analyses in construction management research, thereby supporting the validity of the findings presented in this chapter.

4.2 Demographic Characteristics of Respondents

This section summarizes the demographic profile of the respondents to ensure the sample adequately represents key stakeholders in construction project delivery.

4.2.1 Educational Qualification

The respondents were predominantly well-qualified, with Bachelor's (50.6%) and Master's (46.9%) degrees, while PhD holders accounted for 2.5% as shown in figure 4.1.

4.2.2 Organizational Type

Figure 4.2 illustrates respondents were drawn from the three primary stakeholder groups: Client (43.2%), Contractor (33.3%), and Consultant (23.5%).

4.2.3 Professional Experience

In terms of experience, 40.7% of respondents reported <5 years, followed by 10-15 years (19.8%), 5-10 years (17.3%), and both 15-20 years and >20 years (11.1% each) as shown in figure 4.3. This mix captures perspectives from early-career, mid-career, and senior professionals.

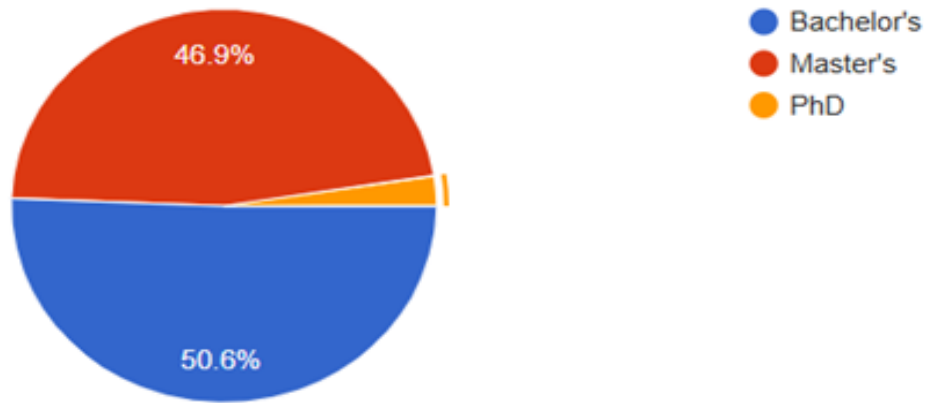


FIGURE 4.1: Education Distribution

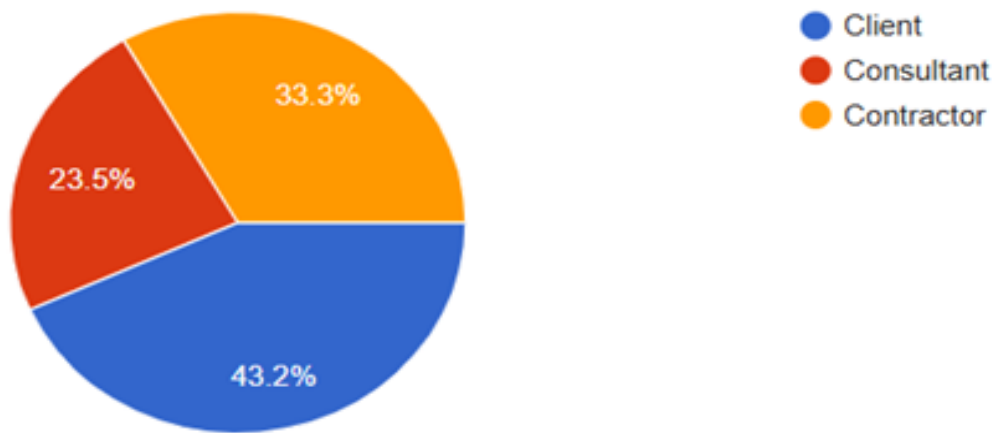


FIGURE 4.2: Organization Type Distribution

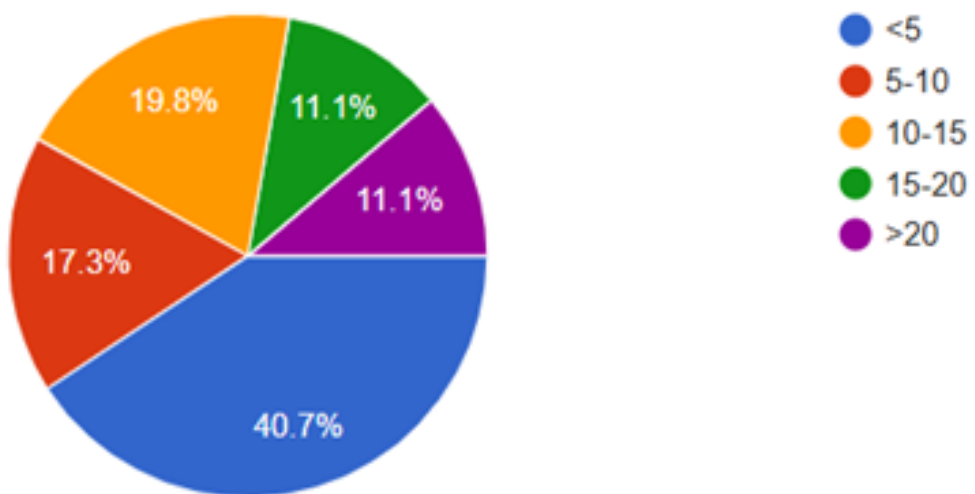


FIGURE 4.3: Experience Distribution

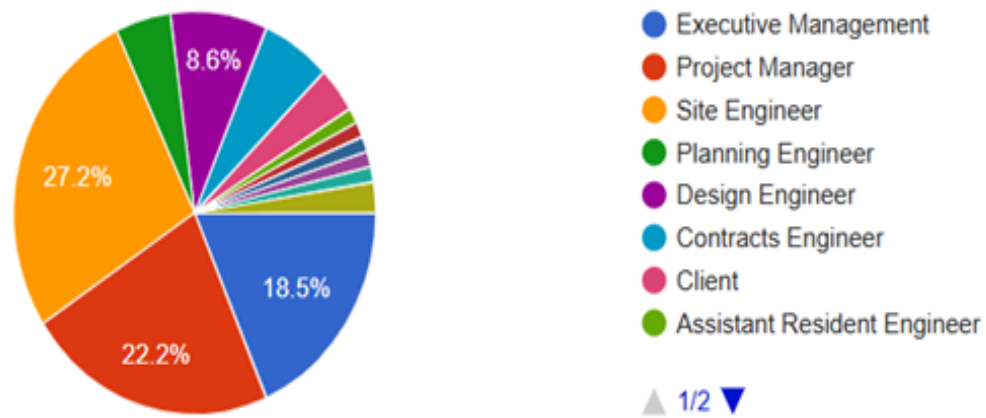


FIGURE 4.4: Role Distribution

4.2.4 Role in Construction Projects

As indicated in Figure 4.4 most common roles were Site Engineer (27.2%), Project Manager (22.2%), and Executive Management (18.5%), ensuring that both operational and strategic viewpoints were included.

4.3 Reliability Analysis

Before proceeding with detailed statistical analysis, it is essential to examine the internal consistency and reliability of the survey instrument. Reliability analysis ensures that the questionnaire items consistently measure the underlying constructs related to cloud-native platform adoption.

Cronbach's Alpha was employed to assess the reliability of the survey sections. The questionnaire consisted of 30 Likert-scale items grouped conceptually into major adoption dimensions, including technical, organizational, economic, and regulatory factors. The results of the reliability analysis as shown in table 4.1 demonstrate strong internal consistency across the overall instrument. All Cronbach's Alpha values exceed the recommended threshold of 0.70, confirming that respondents answered consistently across items within each section. The high reliability score for the overall scale (0.891) validates the use of the 5-point Likert scale and confirms that the survey instrument is statistically reliable for further descriptive, ranking, and inferential analyses. This reliability assessment provides confidence

TABLE 4.1: Reliability Statistics

| Construct | Code | Items | Cronbach's Alpha | Interpretation |
|-------------------------------------|------------------|-----------|------------------|------------------|
| Technological Factors | TF1 – TF8 | 8 | 0.861 | Good |
| Human resource and Training Factors | HRF1 – HRF7 | 7 | 0.884 | Excellent |
| Economic Factors | EF1 – EF8 | 8 | 0.821 | Good |
| Organizational and Legal Factors | OF1 – OF7 | 7 | 0.798 | Acceptable |
| Overall Adoption Factors | TF1 – OF7 | 30 | 0.891 | Excellent |

that the findings presented in subsequent sections accurately reflect respondents' perceptions regarding cloud-native platform adoption in the construction industry.

4.4 Normality Test

To determine whether parametric assumptions hold, the Shapiro–Wilk test was used to examine distributional normality. Since Likert-scale responses commonly show non-normal patterns, normality was assessed at the item level to guide the choice between parametric and non-parametric tests.

The Shapiro Wilk results indicated that the tested adoption factors exhibited p -values < 0.05 , confirming non-normal distribution for individual items as shown in table 4.2. Therefore, non-parametric methods (e.g., Kruskal Wallis) are applied where group comparisons are required.

TABLE 4.2: Normality Test Results for Selected Adoption Factors

| Code | Adoption Factor | Statistic | p-value | Distribution |
|------|--|-----------|---------|--------------|
| TF1 | Setting up new monitoring software is too complicated and time-consuming | 0.742 | < 0.001 | Non-normal |
| TF2 | Construction sites lack adequate IoT sensors and hardware | 0.788 | < 0.001 | Non-normal |
| TF3 | Poor or no internet connection on construction sites | 0.801 | < 0.001 | Non-normal |
| TF4 | Risk of project data being hacked or lost on cloud platforms | 0.884 | < 0.001 | Non-normal |
| TF5 | Cloud-native solutions can accelerate construction activities | 0.756 | < 0.001 | Non-normal |
| TF6 | Cloud platforms enable better documentation and reporting | 0.769 | < 0.001 | Non-normal |
| TF7 | Real-time monitoring improves transparency | 0.729 | < 0.001 | Non-normal |
| TF8 | Cloud platforms improve environmental sustainability | 0.778 | < 0.001 | Non-normal |
| EF1 | High initial investment costs are a major barrier | 0.815 | < 0.001 | Non-normal |
| EF2 | Uncertainty about ROI discourages adoption | 0.828 | < 0.001 | Non-normal |
| EF3 | Additional costs for training and customization are burdensome | 0.841 | < 0.001 | Non-normal |

Table 4.2 – Continued from previous page

| Code | Adoption Factor | Statistic | p-value | Distribution |
|------|--|-----------|---------|--------------|
| EF4 | Budget constraints limit investment in monitoring technologies | 0.822 | < 0.001 | Non-normal |
| EF5 | Fluctuations in project budgets make it difficult to allocate funds | 0.835 | < 0.001 | Non-normal |
| EF6 | Costs related to data storage and real-time processing are excessive | 0.839 | < 0.001 | Non-normal |
| EF7 | Limited access to financing or loans for digital technologies restricts cloud platform adoption. | 0.837 | < 0.001 | Non-normal |
| EF8 | Lack of clear cost-sharing mechanisms among project stakeholders discourages investment. | 0.846 | < 0.001 | Non-normal |
| HRF1 | Employees prefer traditional construction methods over digital platforms | 0.798 | < 0.001 | Non-normal |
| HRF2 | Lack of trained people to use and manage new technologies | 0.800 | < 0.001 | Non-normal |
| HRF3 | Site workers and managers do not trust automated system outputs | 0.890 | < 0.001 | Non-normal |

Table 4.2 – Continued from previous page

| Code | Adoption Factor | Statistic | p-value | Distribution |
|------|--|-----------|---------|--------------|
| HRF4 | Limited awareness of cloud-native technologies among professionals | 0.794 | < 0.001 | Non-normal |
| HRF5 | Different departments do not share information well | 0.821 | < 0.001 | Non-normal |
| HRF6 | Limited involvement of site staff during implementation reduces acceptance | 0.826 | < 0.001 | Non-normal |
| HRF7 | Inadequate training programs reduce effective utilization | 0.815 | < 0.001 | Non-normal |
| OF1 | Lack of organizational policies slows adoption | 0.772 | < 0.001 | Non-normal |
| OF2 | Legal and regulatory uncertainties discourage cloud adoption | 0.837 | < 0.001 | Non-normal |
| OF3 | Lack of standard guidelines for digital monitoring limits adoption | 0.819 | < 0.001 | Non-normal |
| OF4 | Using new digital tools disrupts normal work routines | 0.833 | < 0.001 | Non-normal |
| OF5 | Poor coordination between IT teams and project teams | 0.830 | < 0.001 | Non-normal |
| OF6 | Absence of a clear digital transformation strategy | 0.808 | < 0.001 | Non-normal |

Table 4.2 – Continued from previous page

| Code | Adoption Factor | Statistic | p-value | Distribution |
|------|--|-----------|---------|--------------|
| OF7 | Benefits of digital monitoring not reflected in project goals or bonuses | 0.844 | < 0.001 | Non-normal |

4.5 Descriptive Analysis of Adoption Factors

Descriptive statistics were computed to evaluate respondents' perceptions across the 30 adoption factors. Mean scores and standard deviations were calculated for each item. Overall, respondents showed strong agreement on the operational value of cloud-native approaches and simultaneously highlighted major organizational readiness constraints.

The highest-rated factor was TF7 with a mean of 4.40 (SD = 0.77), indicating strong perceived benefit. Organizational readiness barriers also ranked highly, including OF1 (Mean = 4.26) and HRF2 (Mean = 4.20). These results suggest that perceived value is strong, but adoption is primarily constrained by governance and skills capacity.

4.6 Relative Importance Index Analysis

To prioritize the adoption factors, the Relative Importance Index (RII) was computed for each item. RII converts Likert-scale responses into a normalized index ranging from 0 to 1, enabling direct comparison across all factors.

RII formula used: $RII = \text{sum of weights} / (5 \times N)$, where $N = 81$.

The RII ranking confirms that transparency, organizational policies, skills/training, and collaboration benefits are the most influential factors in shaping adoption perceptions as shown in table 4.3.

The RII ranking confirms that transparency, organizational policies, skills/training, and collaboration benefits are the most influential factors in shaping adoption perceptions.

This comprehensive RII ranking shows in table 4.4. The relative importance of all 30 risks identified in the survey, providing a complete picture of risk priorities across all categories.

TABLE 4.3: All 30 Factors by RII

| Rank | Code | Adoption Factor | Mean | RII | Overall Rank |
|------|------|--|------|-------|--------------|
| 1 | TF7 | Real-time monitoring improves transparency between contractors and clients | 4.40 | 0.879 | 1 |
| 2 | OF1 | Lack of organizational policies slows adoption of cloud-native platforms | 4.26 | 0.852 | 2 |
| 3 | HRF2 | Lack of trained people to use and manage new technologies | 4.20 | 0.840 | 3 |
| 4 | TF5 | Cloud-native solutions can accelerate construction activities | 4.19 | 0.837 | 4 |
| 5 | TF6 | Cloud platforms enable better documentation and reporting | 4.16 | 0.832 | 5 |
| 6 | TF2 | Construction sites lack adequate IoT sensors and hardware | 4.14 | 0.827 | 6 |

Table 4.3 – Continued from previous page

| Rank | Code | Adoption Factor | Mean | RII | Overall Rank |
|------|------|---|------|-------|--------------|
| 7 | HRF7 | Inadequate training programs reduce effective utilization | 4.11 | 0.822 | 7 |
| 8 | OF3 | Lack of standard guidelines for digital monitoring limits adoption | 4.10 | 0.820 | 8 |
| 9 | OF6 | Absence of a clear digital transformation strategy limits adoption | 4.09 | 0.817 | 9 |
| 10 | TF8 | Cloud platforms improve environmental sustainability | 4.07 | 0.815 | 10 |
| 11 | HRF4 | Limited awareness of cloud-native technologies among professionals | 4.07 | 0.815 | 11 |
| 12 | HRF1 | Employees prefer traditional construction methods over digital platforms | 4.06 | 0.812 | 12 |
| 13 | OF5 | Poor coordination between IT teams and project teams affects implementation | 3.98 | 0.795 | 13 |
| 14 | TF3 | Poor or no internet connection on construction sites | 3.96 | 0.793 | 14 |
| 15 | EF4 | Budget constraints limit investment in monitoring technologies | 3.91 | 0.783 | 15 |

Table 4.3 – Continued from previous page

| Rank | Code | Adoption Factor | Mean | RII | Overall Rank |
|------|------|---|------|-------|--------------|
| 16 | HRF5 | Different departments (site team, planning, and management) do not share information well | 3.90 | 0.780 | 16 |
| 17 | HRF6 | Limited involvement of site staff during technology implementation reduces acceptance | 3.88 | 0.776 | 17 |
| 18 | EF7 | Limited access to financing or loans for digital technologies restricts adoption | 3.85 | 0.770 | 18 |
| 19 | EF8 | Lack of clear cost-sharing mechanisms among project stakeholders discourages investment | 3.84 | 0.768 | 19 |
| 20 | EF1 | High initial investment costs are a major barrier | 3.83 | 0.765 | 20 |
| 21 | OF2 | Legal and regulatory uncertainties discourage cloud adoption | 3.81 | 0.763 | 21 |
| 22 | EF3 | Additional costs for training and system customization limit adoption | 3.79 | 0.758 | 22 |
| 23 | EF6 | Costs related to data storage and real-time processing are high | 3.77 | 0.753 | 23 |

Table 4.3 – Continued from previous page

| Rank | Code | Adoption Factor | Mean | RII | Overall Rank |
|------|------|--|------|-------|--------------|
| 24 | EF2 | Uncertainty about ROI discourages adoption | 3.74 | 0.748 | 24 |
| 25 | OF4 | Using new digital tools disrupts normal work routines | 3.72 | 0.743 | 25 |
| 26 | EF5 | Fluctuations in project budgets make it difficult to sustain digital investments | 3.70 | 0.741 | 26 |
| 27 | TF1 | Setting up new monitoring software is too complicated and time-consuming | 3.63 | 0.726 | 27 |
| 28 | HRF3 | Site workers and managers do not trust automated system outputs | 3.51 | 0.701 | 28 |
| 29 | OF7 | The benefits of digital monitoring are not reflected in project goals or bonuses | 3.44 | 0.689 | 29 |
| 30 | TF4 | There is a risk of project data being hacked or lost on cloud platforms | 3.36 | 0.672 | 30 |

4.7 Kruskal Wallis Test for Group Differences

Given the non-normal distribution of item-level data, the Kruskal Wallis test was used to examine whether perceptions differ significantly across demographic groups. This analysis helps identify whether experience or organizational context shapes adoption perceptions.

4.7.1 Differences by Experience Level

Experience-based differences were observed for selected factors. Two adoption concerns showed statistically significant differences across experience groups:

- TF4 : $p = 0.026$
- HRF3 : $p = 0.016$

These results suggest that more experienced professionals may evaluate security and trust-related issues differently, potentially due to greater exposure to project controls, contractual accountability, and prior technology failures.

4.7.2 Differences by Organization Type

For the selected items tested, no statistically significant differences were observed across organization type (client/contractor/consultant), indicating broadly similar perceptions of the highest-ranked adoption factors across stakeholder groups.

TABLE 4.4: Kruskal–Wallis Test Results for Differences in Adoption Factors across Demographic Groups

| Grouping Variable | Code | Adoption Factor | Kruskal Wallis | p-value | Significance |
|-------------------|------|--|----------------|---------|-----------------|
| Experience Level | TF4 | Data security risk in cloud platforms | 11.09 | 0.026 | Significant |
| Experience Level | HRF3 | Trust in automated monitoring outputs | 12.18 | 0.016 | Significant |
| Organization Type | TF7 | Real-time monitoring improves transparency | 0.03 | 0.985 | Not Significant |
| Organization Type | OF1 | Lack of organizational policies | 1.14 | 0.565 | Not Significant |

The results as shown in table 4.4 indicate that respondents experience level significantly influences perceptions related to data security and trust in automated systems, while perceptions of transparency and organizational policy barriers remain consistent across different organization types.

4.8 Strategies for Successful Implementation of Cloud-Native Platforms in Islamabad

Successful implementation of cloud-native platforms in Islamabad's construction industry requires a policy-driven and institutionally supported approach. Regulatory and professional bodies such as the Pakistan Engineering Council (PEC) and the Capital Development Authority (CDA) should play a facilitative role by introducing standardized digital monitoring guidelines and encouraging the use of cloud-based systems in project approvals and tender requirements. Construction organizations should align these external directives with internal digital transformation strategies, ensuring that cloud-native monitoring is integrated into routine project planning, reporting, and governance processes rather than treated as an isolated technological upgrade. Establishing clear data governance policies, defining roles and responsibilities, and formalizing reporting structures are critical to ensuring consistency and long-term adoption across projects in Islamabad.

A second key strategy involves capacity building and workforce readiness, as human resource limitations were identified as a major barrier to adoption. Targeted training programs focusing on cloud-native platforms, IoT-based monitoring, and real-time data interpretation should be institutionalized through PEC's Continuing Professional Development (CPD) framework and supported by higher education institutions in Islamabad. Universities and training institutes should emphasize practical, hands-on exposure to digital monitoring tools, while construction firms should adopt pilot-based implementation to gradually familiarize site engineers and managers with cloud-enabled workflows. This phased learning approach can reduce resistance to change, build trust in automated systems, and ensure that digital tools are effectively utilized at the site level.

Finally, phased technological deployment and financial feasibility planning are essential for sustainable implementation. Construction firms should adopt scalable, cloud-native architectures that allow gradual expansion of IoT sensors, data analytics modules, and dashboards based on project needs and budget constraints.

Using pay-as-you-go cloud services and pilot projects can help demonstrate measurable benefits such as improved transparency, faster decision-making, and reduced rework, thereby justifying further investment. Additionally, integrating sustainability monitoring and cybersecurity measures from the outset can enhance stakeholder confidence and regulatory compliance. Together, these strategies provide a realistic and context-sensitive pathway for advancing cloud-native adoption in Islamabad's construction sector.

4.9 Implementation Guidelines for Cloud Native Platforms

The development of the proposed guidelines is grounded in the empirical findings of this study, particularly the top ten adoption factors identified through the Relative Importance Index (RII) as shown in figure 4.5. These factors represent the most critical drivers and barriers influencing the adoption of cloud-native platforms for real-time construction monitoring in Islamabad. Since these factors achieved the highest RII scores, they reflect strong consensus among construction professionals operating within the local context. Islamabad's construction industry is characterized by rapid urban expansion, increasing project complexity, fragmented stakeholder coordination, limited digital maturity, and reliance on traditional monitoring practices. Although cloud-native technologies offer significant benefits in terms of transparency, efficiency, and sustainability, their adoption remains constrained by organizational, human, technological, and governance-related challenges. Therefore, a context-specific guidelines are required that translates empirical findings into realistic and actionable measures suitable for implementation within Islamabad's regulatory, institutional, and operational environment.

The proposed framework follows a challenge–response structure, where each high-priority adoption factor is directly addressed through targeted implementation actions. The guidelines are designed to be generic and project-agnostic, allowing its application across residential, commercial, and infrastructure projects in Islamabad, while remaining flexible enough to accommodate variations in project size and ownership.

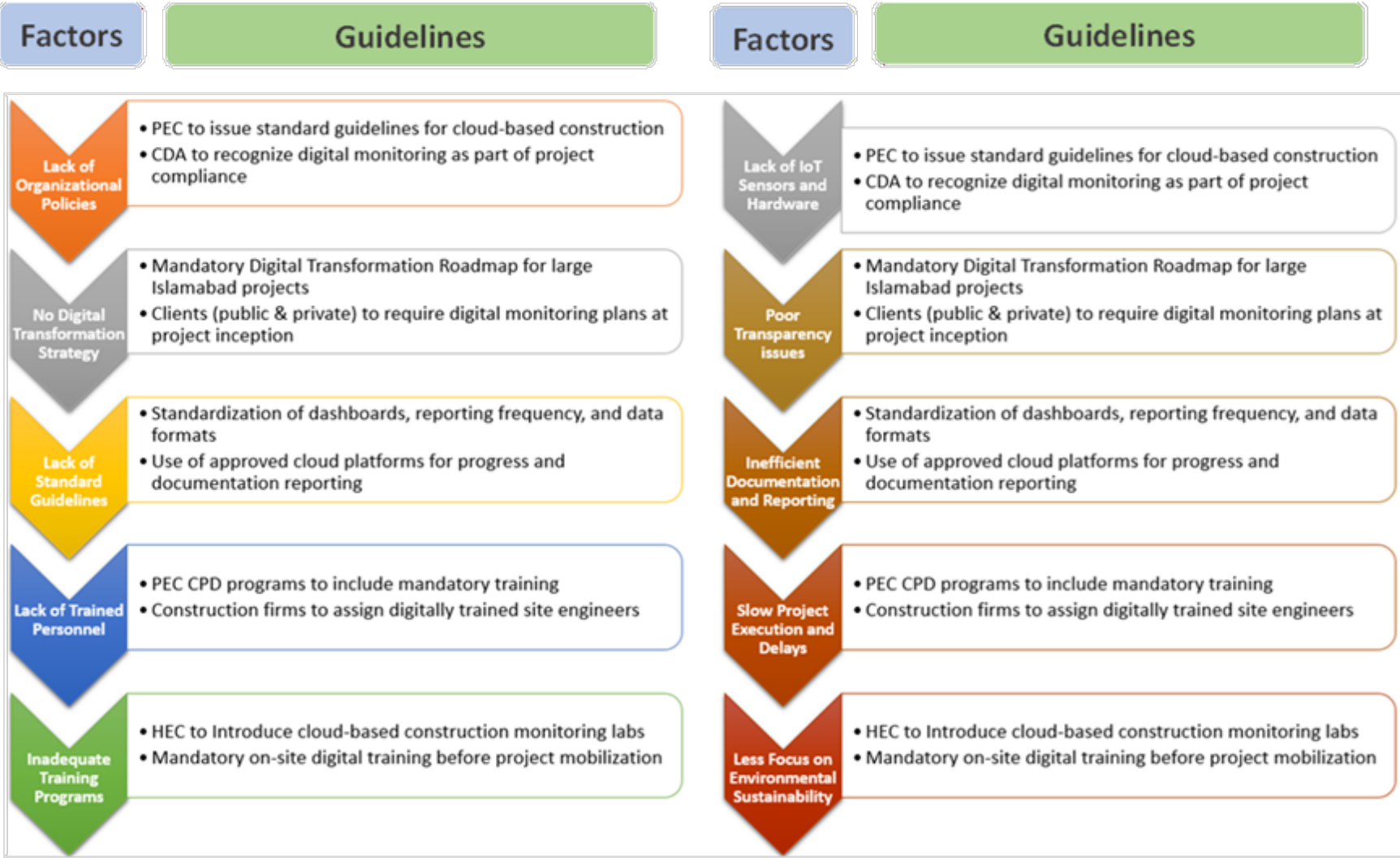


FIGURE 4.5: Implementation guidelines for cloud native platforms

4.9.1 Basis of Framework Development: Top 10 RII Factors

The framework is explicitly derived from the following top ten RII-ranked factors identified in the study:

- i. TF7: Real-time monitoring improves transparency between contractors and clients
- ii. OF1: Lack of organizational policies slows adoption of cloud-native platforms
- iii. HRF2: Lack of trained personnel to manage digital monitoring systems
- iv. TF5: Cloud-native platforms accelerate construction activities
- v. TF6: Better documentation and reporting through cloud-based systems
- vi. TF2: Construction sites lack adequate IoT sensors and hardware
- vii. HRF7: Inadequate training programs reduce effective utilization
- viii. OF3: Lack of standard guidelines for digital construction monitoring
- ix. OF6: Absence of a clear digital transformation strategy
- x. TF8: Digital platforms improve environmental sustainability

These factors were grouped into ten practical challenge areas, each supported by Islamabad-specific implementation actions involving relevant institutions and stakeholders.

4.9.2 Implementation Actions for Adoption of Cloud Native Platforms

4.9.2.1 Addressing Lack of Organizational Policies

To address the absence of formal organizational policies, regulatory and professional bodies must play an enabling role in institutionalizing cloud-native monitoring practices. The Pakistan Engineering Council (PEC) should issue standardized

guidelines for cloud-based construction monitoring to provide a formal reference for industry implementation. At the organizational level, construction firms should develop internal cloud adoption and data governance policies to standardize data management, reporting, and digital oversight. Furthermore, digital monitoring requirements should be incorporated into contract conditions and tender documentation to ensure compliance from project inception. The Capital Development Authority (CDA) can further strengthen adoption by recognizing digital monitoring compliance during project approvals and inspections.

4.9.2.2 Addressing Absence of a Digital Transformation Strategy

The lack of long-term digital planning in Islamabad's construction projects necessitates the development of structured digital transformation strategies. Construction organizations should prepare a formal Digital Transformation Roadmap outlining the phased adoption of cloud-native monitoring systems across projects. These systems should be aligned with existing project planning, scheduling, and control processes to ensure seamless integration rather than parallel workflows. In addition, project clients, particularly for large-scale developments, should require the submission of a digital monitoring plan at the project initiation stage to ensure strategic commitment to cloud-native adoption.

4.9.2.3 Addressing Lack of Standard Digital Monitoring Guidelines

Inconsistent implementation of digital monitoring across projects highlights the need for standardized industry practices. Joint efforts by the Pakistan Engineering Council (PEC) and the Capital Development Authority (CDA) are required to define minimum standards for digital construction monitoring applicable to projects in Islamabad. These standards should cover reporting formats, dashboard indicators, data update frequency, and minimum system functionality. The use of approved and interoperable cloud platforms for progress tracking and documentation should be encouraged to ensure consistency, reliability, and comparability across projects.

4.9.2.4 Addressing Lack of Trained Personnel

Skill shortages among site engineers and project managers significantly limit the effective utilization of cloud-native platforms. To address this issue, cloud-native monitoring modules should be incorporated into the Pakistan Engineering Council's Continuing Professional Development (CPD) programs. Construction firms should also ensure the deployment of digitally trained site engineers on Islamabad-based projects, particularly those involving large-scale or high-rise developments. Additionally, the promotion of professional certification programs related to construction digitization can support the development of a digitally competent workforce capable of managing real-time monitoring systems.

4.9.2.5 Addressing Inadequate Training Programs

Training in Islamabad's construction sector often lacks practical exposure to digital monitoring tools, necessitating targeted educational interventions. The Higher Education Commission (HEC) should encourage universities in Islamabad to establish cloud-based construction monitoring laboratories that provide hands-on experience with real-time systems. Furthermore, real-time monitoring tools should be integrated into civil engineering curricula to align academic learning with industry needs. Mandatory on-site digital training sessions conducted prior to project mobilization can further enhance workforce readiness and ensure effective system utilization during execution.

4.9.2.6 Addressing Lack of IoT Sensors and Hardware

The effectiveness of real-time construction monitoring is constrained by insufficient on-site sensing infrastructure. To overcome this limitation, construction firms should adopt a phased approach to deploying IoT sensors for safety, productivity, and environmental monitoring. Given the variability of site connectivity in Islamabad, the use of portable 4G/5G internet solutions can ensure continuous data transmission on sites with unreliable networks. Additionally, the adoption of edge-cloud integration can support uninterrupted monitoring in peripheral and

developing areas of the city by enabling local data processing and synchronization with cloud platforms.

4.9.2.7 Addressing Poor Transparency between Stakeholders

Limited transparency between clients, consultants, and contractors remains a major cause of disputes and delays in Islamabad's construction projects. The mandatory use of cloud-based project management portals can significantly enhance transparency by enabling real-time progress reporting and centralized information sharing. Shared dashboards accessible to all key stakeholders can improve coordination, accountability, and trust. Reducing reliance on paper-based reporting and manual site visits further supports timely decision-making and promotes a transparent project environment.

4.9.2.8 Addressing Weak Documentation and Reporting Practices

Manual documentation practices reduce data accuracy, traceability, and accessibility in construction projects. Replacing paper-based records with cloud-based digital documentation systems can improve data reliability and enable real-time access to critical project information. Centralized cloud storage of drawings, inspection reports, and progress logs ensures consistency and version control across stakeholders. Acceptance of digital records by the Capital Development Authority (CDA) and project clients for audits and approvals can further legitimize digital documentation practices and encourage widespread adoption.

4.9.2.9 Addressing Slow Project Execution and Delays

Delays in Islamabad's construction projects are often linked to delayed information flow and reactive management practices. The use of cloud dashboards to track productivity and monitor project performance in real time can enable early identification of delays and bottlenecks. Integrating real-time monitoring data with scheduling and planning tools supports proactive decision-making and timely corrective actions. Enhanced visibility of site conditions allows project teams to

respond quickly to emerging issues, thereby improving overall project execution efficiency.

4.9.2.10 Addressing Sustainability and Environmental Performance

4.9.2.10 Addressing Sustainability and Environmental Performance Sustainability monitoring in Islamabad's construction sector is often informal and insufficiently documented. Cloud-based tracking of material usage, waste generation, and rework can provide objective data to support sustainable construction practices. Aligning sustainability reporting with Pakistan Environmental Protection Agency (Pak-EPA) requirements ensures regulatory compliance and environmental accountability. The use of real-time data analytics further enables resource optimization and waste reduction, contributing to environmentally responsible and efficient project delivery.

4.10 Discussion

This chapter presented the empirical findings related to the adoption of cloud-native platforms for real-time construction monitoring in Islamabad. The discussion interprets these findings in relation to the study objectives and existing literature, while highlighting their implications for the local construction context. The results demonstrate a strong recognition of the benefits of cloud-native real-time monitoring, particularly in improving transparency, documentation accuracy, and project efficiency. The highest-ranked factor, "real-time monitoring improves transparency between contractors and clients," indicates that stakeholders in Islamabad perceive transparency as a critical weakness in current construction practices. This finding reflects the prevalent reliance on manual reporting, delayed communication, and fragmented information flow in local construction projects. The strong emphasis on transparency aligns with international studies that identify real-time data visibility as a key driver for improving trust, coordination, and decision-making in construction environments.

Despite recognizing these benefits, the findings reveal that organizational readiness remains the primary barrier to adoption. High RII rankings for factors such as lack of organizational policies, absence of digital transformation strategies, and lack of standard guidelines indicate that cloud-native adoption in Islamabad is constrained more by institutional and governance limitations than by technology itself. This suggests that construction organizations have not yet embedded digital monitoring into formal project controls, relying instead on ad-hoc or individual-driven initiatives. Similar observations have been reported in studies conducted in other developing construction markets, where digital technologies exist but lack structured organizational support. Human resource limitations also emerged as a significant challenge. The high ranking of “lack of trained personnel” and “inadequate training programs” reflects a skills gap among site engineers and project managers in Islamabad. Many professionals have limited exposure to cloud-native platforms, IoT-based monitoring, and real-time analytics, resulting in underutilization of available digital tools. This finding supports previous research indicating that workforce capability and training are critical success factors for digital transformation in construction. Without targeted training and continuous professional development, even well-designed digital systems are unlikely to deliver their intended benefits.

Technological readiness, particularly the availability of IoT sensors and site-level infrastructure, was identified as another key constraint. Construction sites in Islamabad often lack adequate sensing hardware and reliable internet connectivity, which limits the effectiveness of real-time monitoring solutions. This finding highlights the practical challenges associated with deploying cloud-native systems in dynamic and sometimes infrastructure-constrained site environments. However, the relatively lower ranking of pure technology concerns compared to organizational and human factors suggests that technological barriers are manageable if supported by proper planning and phased implementation strategies. The results also confirm that cloud-native platforms are perceived as enablers of faster project execution and improved documentation. High rankings for improved reporting and accelerated construction activities indicate that stakeholders associate real-time monitoring with proactive decision-making and reduced delays. These

findings reinforce the role of cloud-native platforms as tools for shifting construction management from reactive to proactive control, particularly in complex urban environments like Islamabad.

Sustainability-related benefits, although ranked lower than transparency and efficiency, were still recognized as important adoption drivers. The perception that digital platforms can improve environmental sustainability suggests growing awareness among construction professionals regarding resource efficiency, waste reduction, and environmentally responsible practices. This finding aligns with global trends emphasizing data-driven sustainability monitoring, but also indicates that sustainability considerations in Islamabad are still emerging and require stronger institutional integration. The Kruskal–Wallis test results further enrich the discussion by revealing that experience level influences perceptions related to data security and trust in automated systems, while perceptions of core benefits and organizational barriers remain consistent across stakeholder groups. This indicates that senior professionals may be more cautious about cybersecurity and system reliability due to greater exposure to risk and accountability. These insights highlight the importance of trust-building measures, data governance policies, and pilot implementations to enhance confidence in cloud-native systems.

Overall, the discussion highlights a clear gap between recognized benefits and actual readiness for adoption. While construction professionals in Islamabad strongly acknowledge the value of cloud-native real-time monitoring, adoption is hindered by weak organizational structures, limited training, and absence of standardized digital practices. These findings directly informed the development of the proposed Islamabad-specific cloud-native adoption framework, which translates empirical results into practical and realistic implementation strategies.

4.11 Summary

In summary, the results indicate strong agreement on the benefits of cloud-native platforms, particularly in enhancing transparency, documentation, and project collaboration. However, adoption is constrained primarily by organizational readiness

factors, notably the absence of supportive policies, insufficient training programs, and limited availability of skilled personnel. The RII ranking provides a clear prioritization of the most influential factors, while non-parametric group tests suggest that experience level can shape perceptions of trust and cybersecurity-related concerns. These findings provide the empirical foundation for the subsequent discussion chapter, where results are interpreted in relation to the literature and practical implementation strategies are proposed.

Chapter 5

Conclusion and Recommendations

5.1 Conclusion

This research aimed to investigate the adoption of cloud-native platforms for real-time construction monitoring in Islamabad and to identify the key challenges and enabling factors influencing their implementation. Using empirical data collected from 81 construction professionals operating within Islamabad's construction sector (response rate of 80.95%), the study examined organizational, technological, human, and governance-related barriers while highlighting the potential benefits of cloud-native solutions. The reliability of the survey instrument was confirmed through Cronbach's Alpha, with the overall scale achieving $\alpha = 0.891$

(Excellent),

while individual constructs ranged from 0.798 (Legal & Regulatory) to 0.884 (Organizational Factors). Normality testing using the Shapiro-Wilk test confirmed that all 30 adoption factors exhibited non-normal distribution ($p < 0.001$), justifying the use of non-parametric statistical methods. The Kruskal-Wallis test revealed that experience level significantly influenced perceptions of TF4 ($p = 0.026$) and HRF3 ($p = 0.016$), while no significant differences were observed across organization types.

The Relative Importance Index (RII) method ranked the 30 adoption factors with values ranging from 0.672 to 0.879. The findings indicate that although construction professionals strongly recognize the value of real-time monitoring, the adoption of cloud-native platforms remains limited. The most significant barrier

identified include OF1 (RII = 0.852, Mean = 4.26), HRF2 (RII = 0.840, Mean = 4.20), HRF7 (RII = 0.822, Mean = 4.11), TF2 (RII = 0.827, Mean = 4.14), and OF6 (RII = 0.820, Mean = 4.10). These challenges reflect the broader issue of low digital maturity within Islamabad's construction industry, where traditional monitoring practices still dominate project execution. Conversely, the study confirms that cloud-native platforms offer substantial opportunities for improving construction project performance in Islamabad. TF7 was identified as the most influential factor (RII = 0.879, Mean = 4.40), demonstrating its potential to improve transparency between clients, consultants, and contractors. Additional benefits include TF5 (RII = 0.837, Mean = 4.19), TF6 (RII = 0.832, Mean = 4.16), TF8 (RII = 0.815, Mean = 4.07), and more efficient project execution. These findings highlight that the primary limitation to adoption is not technological feasibility, but rather institutional readiness, workforce capability, and strategic alignment. Based on these insights, this research proposed Islamabad-specific cloud-native implementation guidelines grounded in the top ten RII-ranked factors (RII range: 0.815 – 0.879). The guidelines provide a structured and realistic pathway for transitioning from conventional construction monitoring practices to cloud-enabled real-time systems. By addressing local institutional, technical, and human resource constraints, the guidelines contribute toward improving transparency, efficiency, and governance within Islamabad's construction sector.

5.2 Recommendations

Based on the findings of this study, the following recommendations are proposed to support the successful implementation of cloud-native platforms for real-time construction monitoring in Islamabad. Regulatory and professional bodies such as the Pakistan Engineering Council (PEC) and the Capital Development Authority (CDA) should introduce standardized guidelines for cloud-based construction monitoring. Digital monitoring requirements should be incorporated into tender documents and contract conditions, particularly for large-scale and high-rise projects in Islamabad. Clear organizational policies and data governance guidelines should also be developed to formalize cloud adoption. A structured approach

to training is essential to address the shortage of skilled personnel. PEC's Continuing Professional Development (CPD) programs should include mandatory modules on cloud-native platforms, IoT-based monitoring, and real-time data analytics. In addition, construction firms should ensure on-site digital training for engineers and supervisors before and during project execution.

The Higher Education Commission (HEC) should encourage universities in Islamabad, to integrate real-time construction monitoring tools into civil engineering curricula. Practical exposure to cloud platforms and IoT-based systems will help bridge the gap between academic training and industry requirements. Construction organizations should adopt a phased approach to deploying IoT sensors, site connectivity solutions, and cloud-native platforms. The use of scalable, pay-as-you-go cloud services and pilot projects can reduce financial risk while demonstrating measurable benefits such as improved transparency and reduced delays. Cloud-based project portals should be mandated for real-time progress reporting, documentation management, and stakeholder coordination. Additionally, sustainability monitoring aligned with Pakistan Environmental Protection Agency (Pak-EPA) requirements should be integrated into cloud dashboards to support waste reduction, efficient resource utilization, and environmentally responsible construction practices.

5.3 Theoretical Implications

This study contributes to the existing body of knowledge on digital transformation in construction by providing empirical evidence on cloud-native platform adoption within a developing-country context, specifically Islamabad. While previous studies have largely focused on technologically advanced regions, this research extends the theoretical understanding of cloud-native adoption by highlighting localized barriers such as institutional inertia, skill shortages, and lack of standardized digital governance. The study also strengthens the application of technology adoption theories in construction by demonstrating how organizational readiness, human capability, and governance structures influence perceptions of cloud-native technologies. By developing a context-specific adoption guidelines, this research bridges

the gap between global cloud computing concepts and the operational realities of construction projects in Pakistan. The proposed guidelines can serve as a reference model for future studies examining real-time monitoring and cloud-native adoption in other developing urban environments.

5.4 Managerial Implications

The findings of this study offer important managerial insights for construction firms, project managers, and consultants operating in Islamabad. The adoption of cloud-native platforms can significantly improve project monitoring, decision-making speed, documentation accuracy, and stakeholder coordination. However, successful implementation requires more than technology acquisition; it demands strategic planning, workforce development, and leadership commitment. Project managers should prioritize integrating real-time monitoring into daily project controls, using cloud dashboards to track progress, identify delays early, and support proactive decision-making. Senior management must demonstrate commitment by allocating resources for training, infrastructure development, and gradual digital transition. Furthermore, improving transparency through shared cloud platforms can reduce disputes and enhance trust among project stakeholders.

Finally, collaboration between the public private sectors is essential for widespread adoption. Partnerships between construction firms, regulatory authorities, and educational institutions can support the development of standards, training programs, and pilot projects. Such collaborative efforts will play a critical role in accelerating the digital transformation of Islamabad's construction industry and ensuring the sustainable implementation of cloud-native real-time monitoring systems.

5.5 Future Research

While this study provides valuable insights into the adoption of cloud-native platforms for real-time construction monitoring in Islamabad, several areas remain

open for further investigation. Future research should explore the long-term performance impacts of cloud-native monitoring systems across the entire construction lifecycle, including operation and maintenance phases. Examining how real-time data collected during construction can support facility management, predictive maintenance, and lifecycle asset optimization would extend the practical value of cloud-native platforms beyond project completion.

Further studies should investigate the integration of cloud-native platforms with advanced digital technologies such as Building Information Modeling (BIM), digital twins, and artificial intelligence. Future research may focus on how the combined use of cloud-native systems and BIM can enhance coordination, improve resource optimization, and enable predictive decision-making in construction projects. Empirical case studies conducted on ongoing projects in Islamabad would provide deeper insights into the technical feasibility and performance benefits of such integrations.

Additionally, future research should assess the role of government policies and regulatory frameworks in accelerating cloud-native adoption within Pakistan's construction sector. Evaluating the effectiveness of existing regulations, approval processes, and institutional incentives in promoting digital transformation can help policymakers design targeted interventions. Comparative studies across major cities in Pakistan may also reveal regional variations in readiness and adoption potential, supporting the development of nationwide digital construction strategies.

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Appendix-A - Questionnaire

Adoption of Cloud-Native Platforms for Real-Time Construction Monitoring in Islamabad: Challenges and Implementation Framework

Dear Respondent,

I am a graduate student pursuing an MS in Civil Engineering (Construction Engineering & Management) at Capital University of Science and Technology, Islamabad. As part of my academic research, I am conducting a study titled:

“Adoption of Cloud-Native Platforms for Real-Time Construction Monitoring in Islamabad: Challenges and Implementation Framework.”

Cloud native platforms are like a **smart, digital command center for a construction site**. They gather live information from cameras and sensors and make it easy for the team to see everything that’s happening, right now, from any device. This survey is designed to gather insights into the factors influencing the adoption of cloud-based monitoring systems within the construction sector of Islamabad, challenges that hinders their adoption and a complete framework for its implementation. The questionnaire consists of the following five sections:

1. **Section - 1 : Demographic Details**
2. **Section - 2 : Factors Related to Technology and Tool Challenges**
3. **Section - 3 : Factors Related to Investment and Budget Challenges**
4. **Section - 4 : Factors Related to Employees and training Challenges**
5. **Section - 5 : Factors Related to Rules and Organizational Challenges**

It will take approximately **5–10 minutes** to complete this survey. Your participation is highly valuable and will contribute significantly to understanding the challenges and opportunities associated with implementing modern digital platforms in construction.

Regards,

MUHAMMAD MOEEZ ARIF

MS Civil Engineering (Student)

moezarif9@gmail.com

+92311-8937083

Email*

Please specify your qualification

*

Please specify your type of organization

*

Years of experience in construction

*

Your current role in construction projects

*

Other:

Section 2 of 5

Factors Related to Technology and Tool Challenges

This section examines technical barriers associated with cloud-native platforms, including system integration, data interoperability, connectivity, cybersecurity, and reliability of real-time monitoring tools. It focuses on how technological limitations at construction sites affect the effective adoption of cloud-based solutions.

The survey uses five-point Likert scale where **5 represents Strongly Agree, 4 represents Agree, 3 represents Neutral, 2 represents Disagree and 1 represents Strongly Disagree.**

Question

*

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

TF:1 Setting up new monitoring software (like sensors or cloud platforms) is too complicated and time-consuming.

TF:2 Construction sites lack adequate IoT sensors and hardware to support real-time data collection.

TF:3 Poor or no internet connection on our construction sites, which stops digital tools from working.

TF:4 There is a risk of project data being hacked or lost when we use online (cloud) platforms.

TF:5 Cloud-native solutions can accelerate construction timelines through better coordination

TF:6 Cloud platforms enable better documentation and reporting for compliance purposes

TF:7 Real-time monitoring improves transparency between contractors and clients
TF:8 These platforms improve environmental sustainability through better resource management.

Section 3 of 5

Factors Related to Investment and Budget Challenges

This section addresses financial constraints such as high initial investment, operational costs, uncertain return on investment, and budget limitations. It evaluates how financial risks and cost-related concerns influence decision-making regarding cloud-native platform adoption.

The survey uses five-point Likert scale where **5 represents Strongly Agree, 4 represents Agree, 3 represents Neutral, 2 represents Disagree and 1 represents Strongly Disagree.**

Question

*

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

EF:1 High initial investment costs are a major barrier to adopting cloud-native platforms.

EF:2 Uncertainty about return on investment (ROI) discourages decision-makers from adopting cloud-native solutions.

EF:3 Additional costs for training and system customization are a financial burden for firms.

EF: 4 Budget constraints limit the ability to invest in advanced monitoring technologies.

EF:5 Fluctuations in project budgets make it difficult to allocate funds for cloud-native platforms.

EF:6 Costs related to data storage and real-time data processing are perceived as excessive.

EF:7 Limited access to financing or loans for digital technologies restricts cloud platform adoption.

EF:8 Lack of clear cost-sharing mechanisms among project stakeholders discourages investment.

Section 4 of 5

Factors Related to Employees and training Challenges

This section explores human-related challenges including skills gaps, resistance to change, lack of training, and limited awareness of cloud-native technologies. It assesses how workforce readiness and training deficiencies impact the successful implementation of real-time monitoring systems.

The survey uses five-point Likert scale where **5 represents Strongly Agree, 4 represents Agree, 3 represents Neutral, 2 represents Disagree and 1 represents Strongly Disagree.**

Question

*

- Strongly agree
- Agree

- Neutral
- Disagree
- Strongly Disagree

HRF:1 Employees prefer traditional construction monitoring methods over digital platforms.

HRF:2 There is a lack of trained people who know how to use and manage these new technologies.

HRF:3 Site workers and managers do not fully trust the information or alerts that come from automated systems.

HRF:4 Limited awareness of cloud-native technologies exists among construction professionals.

HRF:5 Different departments (like site team, planning, and management) do not share information well with each other.

HRF:6 Limited involvement of site staff during technology implementation reduces acceptance.

HRF:7 Inadequate training programs reduce effective utilization of cloud-based systems.

Section 5 of 5

Factors Related to Rules and Organizational Challenges

This section focuses on organizational and regulatory barriers such as unclear policies, data governance issues, management resistance, and lack of standardized guidelines. It investigates how institutional structures and organizational culture affect the adoption of cloud-native platforms in construction projects.

The survey uses five-point Likert scale where **5 represents Strongly Agree, 4 represents Agree, 3 represents Neutral, 2 represents Disagree and 1 represents Strongly Disagree.**

Question

*

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

OF:1 Lack of organizational policies supports slow adoption of cloud-native platforms.

OF:2 Legal and regulatory uncertainties discourage cloud-based data storage and processing.

OF:3 Lack of standard guidelines for digital construction monitoring limits adoption.

OF:4 Using new digital tools often disrupts our normal work routines and creates extra steps.

OF:5 Poor coordination between IT teams and project teams affects system implementation.

OF:6 Absence of a clear digital transformation strategy limits cloud-native platform adoption.

OF: 7 The benefits of digital monitoring are not reflected in our project goals or performance bonuses.