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DIGITAL TRANSFORMATION IN LARGE-SCALE CONSTRUCTION: A REAL-WORLD IMPLEMENTATION

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ABSTRACT

Large-scale construction projects in developing economies are constrained by traditional manual site management practices and fragmented technological deployments that are structurally inadequate for the governance and productivity demands of high-density, multi-floor construction environments. While individual technologies demonstrated domain-specific benefits, their isolated deployment leaves the systemic interdependencies between workforce management, cost control and resource utilisation unresolved. This study addresses that gap through an evaluative single case study of a large-scale construction project in Sri Lanka exceeding 83,500m² with a workforce exceeding 1,000 personnel, in which a fully integrated Radio Frequency Identification (RFID)-based digital site management ecosystem was designed and implemented over a ten-month period. The observations were made based on direct observation, system-generated reports and analytics obtained from project management dashboard. The findings demonstrate that the integrated ecosystem comprehensively reduced proxy attendance, payroll manipulation and resource misallocation while strengthening financial transparency, workforce accountability and operational governance. The direct linkage of labour deployment to cost codes, material withdrawals to specific work zones and machinery utilisation to verified task completion created end-to-end operational visibility. Workforce resistance was successfully resolved through phased implementation and structured change management, while the system's uninterrupted performance during the COVID-19 pandemic validated its value as a continuity infrastructure. The study provides practitioners with a replicable operational blueprint for construction digitalisation, and the implemented system validates and advances the theoretical foundation for integrated digital ecosystem research. Further research should identify multi-site cross-country replication as a critical direction for future research across developing economies.

Keywords: *Automatic attendance; Cost control; Digitalisation of construction processes; Labour productivity; RFID-tracking.*

1. INTRODUCTION

The construction industry remains a significant contributor to economic growth in developing nations, supporting infrastructure development, employment and Gross Domestic Product (GDP) expansion (Alaloul et al., 2020). Yet despite its economic

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centrality, the sector is persistently criticised for low productivity, poor output quality, cost overruns and inadequate system performance deficiencies that persist in developing economies such as Sri Lanka (Bansal, 2020). Rajakaruna et al. (2008) established that approximately 90% of Sri Lankan public sector construction projects experience cost and time overruns, reflecting not merely technical failure but a systemic inadequacy in how construction sites are monitored and controlled. As project scale and spatial complexity increase, these inadequacies are amplified in large, multi-floor, high-density construction environments. These conditions make direct supervision structurally impossible, subjective reporting becomes problematic and manual administration systems collapse under operational load (Santoso & Gallage, 2020).

Traditional site management in Sri Lanka relies predominantly on paper-based attendance registers, manually signed timecards, informal supervisory reporting and fragmented cost recording practices that are fundamentally incompatible with the governance demands of large-scale construction (Wijerathna et al., 2024a). These systems are systematically vulnerable to proxy attendance, unauthorised site exits, payroll manipulation and unofficial idling, directly eroding productivity, inflating labour costs and undermining financial accountability (Huang et al., 2019). The reliance on human judgment in record-keeping further creates conditions leading to collusion among workers, supervisors and security personnel, compromising ethical governance at its foundation (Wijerathna et al., 2024a). These are not incidental operational failures; they represent structural deficiencies inherent to manual site management that cannot be resolved through incremental process improvement alone.

Attempts to address these deficiencies through conventional biometric technologies have proven similarly inadequate. Fingerprint-based systems exhibit high failure rates under construction site conditions, dust, moisture and physical labour render them unreliable, while broader technologies, including RFID, IoT and BIM, remain fragmented and below international benchmarks in Sri Lanka (Manoharan et al., 2020). Critically, individual technologies deployed in isolation resolve fragments of the site management problems, where payroll errors persist, material wastage continues, and cost overruns remain (Wijerathna et al., 2024b).

Traditional site management has demonstrably failed to meet the governance, and productivity demands of large-scale construction, and the literature has responded by proposing individual technological solutions, such as biometric systems, RFID, IoT and BIM, each demonstrating domain-specific benefits in isolation (Wijerathna et al., 2024b). However, biometric systems fail under harsh construction conditions, and individually deployed technologies address only fragments of a deeply interconnected operational problem. As large-scale construction projects grow in spatial complexity, workforce density and cost exposure, this fragmented technological approach is no longer sufficient.

Existing studies have not empirically demonstrated how the aforementioned issues can be addressed with the capability of a fully integrated digital ecosystem in which workforce tracking, attendance verification, task allocation, payroll processing and resource control operate as a unified, closed-loop system delivering real-time, end-to-end operational visibility across all site management domains simultaneously. Therefore, this study addresses that gap through a real-world case study of a large-scale Sri Lankan construction project, providing empirical evidence that an integrated digital site management ecosystem outperforms both traditional manual systems and isolated

technology deployments, offering a replicable and scalable digital ecosystem for construction digitalisation in developing economies.

2. LITERATURE REVIEW

Mega-scale construction projects require massive demands on site management systems that conventional approaches are structurally ill-equipped to meet (Lu et al., 2011). In addition, the absence of real-time operational visibility creates cascading inefficiencies in decision-making, resource allocation and cost control (Santoso & Gallage, 2020). Traditional site management lacks the capacity for proactive operational adjustment or real-time governance, creating vulnerabilities in payroll processing, resource allocation and accountability (Wijerathna et al., 2024a). These vulnerabilities are compounded in large-scale environments by the volume and velocity of operational transactions occurring simultaneously across dispersed work zones (Huang et al., 2019). In developing economy contexts specifically, these deficiencies are further enhanced by informal site management cultures, limited technological infrastructure and institutional resistance to change, creating a management environment in which transparency and accountability are structurally difficult to enforce (Manoharan et al., 2020)

However, the literature has responded by exploring individual technological interventions across specific domains. As an example, construction 4.0 paradigm, which advocates for the digital transformation of construction processes through the integration of cyber-physical systems, real-time data analytics, and interconnected technologies (Kozlovska et al., 2021).In addition, RFID technology has emerged as particularly well-evidenced, with Kereri & Adamtey (2019) confirming its effectiveness across labour management, equipment tracking and materials control. Kineber et al. (2023) further established that RFID delivers measurable improvements in resource traceability, inventory accuracy and productivity when deployed in construction project management. Beyond RFID, IoT-enabled sensing frameworks, biometric verification systems, cloud-based platforms and centralised analytical dashboards have each demonstrated domain-specific operational value, with Kozlovska et al. (2021) identifying these technologies as foundational components of the Construction 4.0 paradigm and Tan & Sidhu (2022) confirming the operational benefits of RFID and IoT integration within resource management contexts.

However, the collective limitation of this literature is its persistent focus on isolated technological deployment. Each intervention addresses a specific operational domain while leaving the interdependencies between workforce management, cost control, resource utilisation and productivity measurement fundamentally unresolved (Kereri & Adamtey., 2019). Technologies deployed in isolation deliver marginal efficiency gains relative to the complexity of the problem they are designed to solve. These inefficiencies can be overcome by a fully integrated digital ecosystem across all site management domains (Wijerathna et al., 2024b).

3. METHODOLOGY

This study adopts an evaluative research approach within a single case study design, a methodology widely recognised as appropriate for investigating complex, real-world phenomena within their natural operational context (Yin, 2018). The single case study design is justified on the grounds that the ABC Project represents a critical case, a large-scale, high-density construction environment of sufficient complexity to expose the

systemic limitations of traditional site management and test the viability of an integrated digital ecosystem as a practical alternative. As Yin (2018) notes, a critical case satisfies the criteria for a single case study when it permits logical generalisation and allows propositions derived from the case to be extended to broader theory. The aim was to assess the overall effectiveness and governance outcomes associated with the transition from manual, paper-based site management to a centralised, cloud-based digital platform.

3.1 CASE INTRODUCTION

The ABC Project, undertaken by a major contractor in Sri Lanka, constitutes the unit of analysis. The project encompasses a built-up area of over 83,500m² and accommodates a peak workforce exceeding 1,000 personnel across multiple floors, residential units, service corridors and restricted-access areas. In addition, this configuration renders the conventional supervision structurally inadequate and creates significant vulnerability to attendance irregularities, payroll manipulation and resource misallocation, making it an analytically appropriate case for evaluating integrated digital site management under real-world conditions.

3.2 DATA COLLECTION AND ANALYSIS METHODS

Data collection was conducted over ten months, capturing the full implementation lifecycle from initial deployment through operational stabilisation. Three complementary data sources were employed to ensure methodological triangulation and strengthen evaluative validity (Creswell, 2014).

The first source comprised systematic direct observation conducted by embedded managerial staff, capturing authentic operational behaviour while minimising social desirability bias. Direct observation by embedded participants is considered a high-validity method for capturing real-world practice in its natural context, particularly where respondent self-reporting may be subject to distortion (Yin, 2018). The data gathered through direct observation was analysed using manual content analysis, a method appropriate for systematically identifying patterns, themes and deviations within qualitative field data (Krippendorff, 2018).

The second source consisted of system-generated reports extracted from the centralised digital platform. These automated records provided objective, timestamped documentation of workforce attendance, task allocations, material movements, equipment utilisation and payroll transactions, offering a verifiable, tamper-resistant data trail independent of human reporting.

The third source was the project management dashboard, which consolidated real-time data on manpower, productivity, costs and resource deployment across all site operations. The dashboard served as the primary instrument for identifying operational deviations and evaluating system responsiveness, enabling cross-referencing of observations and platform-generated records to verify consistency and detect discrepancies.

Together, these three sources provided a comprehensive, cross-validated empirical basis for evaluating the operational viability and governance impact of the integrated digital ecosystem.

Furthermore, the qualitative, single-case study design adopted in this study is acknowledged to carry inherent limitations with respect to researcher subjectivity and potential confirmatory bias. Several strategies were employed to mitigate these risks.

First, methodological triangulation across three independent data sources reduced dependence on any single informant perspective and allowed cross-verification of findings (Yin, 2018). Second, the use of system-generated, automated records, which are objective and not subject to retrospective adjustment, provided an anchor of verifiable evidence against which observational data could be tested. Third, the ten-month data collection period, spanning the full implementation lifecycle, reduced the risk of findings being attributable to novelty effects or short-term behavioural change. Fourth, the research was designed using an evaluative rather than exploratory framing, with assessments structured against pre-defined operational performance criteria rather than interpreted post-hoc. Notwithstanding these measures, the findings remain contextually bounded, and their applicability to other settings should be considered with appropriate interpretive caution.

4. CASE STUDY FINDINGS

4.1 PROJECT ENVIRONMENT AND OPERATIONAL CHALLENGES

Project ABC operated in a highly demanding environment, with fast timelines, concurrent multi-trade activities, and large vertical and horizontal work areas. Coordinating thousands of subcontractors, labour providers, and specialised trades across multifamily floors, service cores, and restricted-access areas created major challenges in workforce management, particularly for attendance tracking, labour deployment, productivity monitoring, and cost control.

The existing site-management system relied on a centralised time office supported by multiple supervisory layers. Up to six staff were needed daily to record attendance, compile site information, verify labour-supplier submissions, and process payroll. Despite this, labour data remained unreliable: attendance records were often delayed, discretionary, and prone to post-factum adjustments, limiting their usefulness for timely managerial decisions. The project's complex layout with enclosed and partially completed spaces restricted direct supervision, enabling proxy attendance, early releases, and manipulation of records, often coordinated between workers, supervisors, and security staff. Third-party credential misuse and unverified supervisor confirmations further undermined data integrity, affecting labour cost reporting and productivity measurement.

Fingerprint-based biometric systems were trialled but proved unreliable due to dust, moisture, chemicals, and manual work, causing verification failures, congestion, and operational disruption. These shortcomings directly reduced productivity, inflated costs, and threatened transparency and managerial accountability. The traditional system's inability to provide real-time, verifiable, and tamper-proof workforce data highlighted the need for a radically new solution, where an integrated, technology-based control system that reduces manual intervention, prevents manipulation, and provides continuous, accurate visibility of workforce presence and deployment.

4.2 IMPLEMENTATION OF AUTOMATED SYSTEMS

The automated tracking and control system at Project ABC was developed as a comprehensive digital ecosystem that integrates labour attendance, productivity, cost control, material use, and machinery deployment into a single real-time platform. An external IT vendor was engaged to design and implement the system architecture,

ensuring it was robust, scalable, and adaptable to the dynamic conditions of a large construction site. Each worker, material, and resource was uniquely registered and linked to predefined work packages and cost codes, providing end-to-end traceability. Personnel were issued RFID cards for site access, with facial recognition ensuring accurate attendance and preventing proxy entries. Supervisors allocated tasks, work zones, and cost codes through tablet-based interfaces, creating a direct, auditable connection between labour deployment, productivity, and project cost. Payroll and timekeeping were fully automated using system-generated digital timecards, eliminating manual input and increasing accuracy and transparency. Materials and machinery were tracked digitally, with withdrawals, operating hours, and idle time recorded and linked to specific work packages and cost codes to enable cost control and efficient utilisation. Welfare and support functions, including cafeteria access, accommodation, leave, and meal requests, were digitised and synchronised with attendance records, further streamlining administrative processes. All modules operated on a centralised, cloud-based platform, ensuring real-time synchronisation, data integrity, and reliable access for authorised stakeholders. A Project Manager dashboard consolidated data on manpower, productivity, costs, materials, and equipment, enabling timely detection of deviations and proactive operational control. The involvement of the IT vendor also allowed continuous updates and system refinements, ensuring the digital ecosystem remained aligned with evolving site requirements. The following subsections discuss the implementation of automated systems across seven key areas in detail.

4.2.1 People Registration and Site Access Control

The first operational layer of the automated track-and-control system at Project ABC was people registration and site access control, establishing a secure and verifiable workforce management system. All employees, personnel, and authorised individuals were officially registered within a centralised digital platform before entering the site. Each person received a comprehensive site-identification profile, detailing employment category, trade classification, labour-supplier affiliation, and access authorisation levels. These profiles were linked to RFID cards issued at registration, creating a long-term, verifiable digital identity for every site user. Physical access to the construction site was restricted to a single controlled entry point, ensuring all ingress and egress were captured digitally. At the gate, individuals validated their identity through a two-step process, RFID card swipe followed by facial recognition. Unauthorised entries were automatically rejected, and all access events were time-stamped and logged, producing a verifiable audit trail. By combining digital registration, RFID-based access control, and facial-recognition attendance into a single workflow, the system provided verified presence information at the point of entry, enabling reliable downstream operations including task assignment, timekeeping, payroll processing, welfare management, and productivity monitoring.

4.2.2 Digital Work Allocation: Supervisor-Based

The second operational layer focused on digital work allocation through supervisor-based interfaces. After site entry and morning assembly, employees reported to their respective supervisors, who allocated tasks using tablet-based digital portals directly linked to the centralised system. These portals provided real-time access to verified personnel profiles, including trade classification, skill set, attendance status, and site location. The supervisor portal featured a visual drag-and-drop interface, allowing workers to be assigned to

specific work packages, floors, zones, or activities, with each assignment linked to relevant cost codes. Task allocations were immediately synchronised across the system, updating attendance records, time-office databases, and the Project Manager dashboard in real time. The system also allowed supervisors to reassign workers dynamically in response to changing site conditions. By digitising work allocation, the system replaced manual allotment sheets and informal verbal instructions, reducing administrative workload and improving accountability.

4.2.3 Real-Time Attendance, Exit Control and Security

The automated system incorporated real-time attendance monitoring and exit management to ensure accurate recording of workforce presence. Employees were required to swipe their RFID cards at designated terminals when leaving work areas or exiting the site. Facial-recognition verification at exit points added an additional layer of identity confirmation. Security personnel were integrated into the digital workflow, relying on system-generated alerts instead of discretionary checks. Abnormal movements, such as repeated exits or leaving designated areas prematurely, triggered automatic alarms. All attendance, exit, and security events were time-stamped and logged, creating a complete and verifiable audit trail.

4.2.4 Timecards, Payroll and Labour Billing Automation

The system enabled full automation of workforce timekeeping, payroll processing, and labour-supplier billing. Digital timecards were automatically generated for each worker based on attendance and exit records, eliminating manual data entry and post-processing. Payroll calculations were directly derived from digital timecards using predefined rules. Salary balances were automatically maintained and made accessible to workers through on-site display systems and RFID-enabled interfaces, allowing workers to independently verify their attendance and earnings, reducing reliance on supervisors and minimising payroll-related disputes. Labour-supplier billing was automated using verified system records, ensuring alignment between attendance data and billed labour and strengthening financial control.

4.2.5 Welfare, Cafeteria and Leave Management

Cafeteria and accommodation access were controlled using the same RFID cards. Scanning at access points enabled real-time recording of usage, allowing accurate tracking of meals and accommodation at an individual level. All transactions were digitally linked to user identities, preventing duplication and unauthorised access. This system replaced manual coupon-based methods, reducing administrative workload, minimising errors, and improving transparency in welfare distribution. Leave and special meal requests were managed through a mobile application, with requests automatically routed through predefined approval workflows and all decisions recorded electronically.

4.2.6 Project Manager Digital Dashboard

A centralised Project Manager (PM) digital dashboard was developed to aggregate and present site-wide operational data through a single visual interface. The dashboard displayed daily manpower distribution by trade, location, and work package, enabling managers to identify labour congestion, imbalances, and coverage gaps. Labour usage was aligned with project cost codes, enabling evaluation of workforce-related expenditure alongside productivity indicators. The dashboard also provided consolidated views of material consumption and equipment performance, including operating hours and idle

time. Exception alerts highlighted critical issues such as workforce shortages, delays, material unavailability, and underutilised equipment, enhancing coordination across supervisory, planning, and commercial teams.

4.2.7 Material and Machinery Tracking Extension

Building on the success of workforce tracking and digital attendance, the automated system was extended to material and machinery management. Every withdrawal from site stores was linked to specific workers, work packages, and cost codes via RFID and digital verification, generating a fully auditable record of material usage. Daily reconciliation of material consumption prevented theft, unauthorised use, or over-issuance. Machinery assignment and operation were centralised through the same digital platform, with operator hours, idle time, and equipment location logged automatically. By consolidating workforce, material, and equipment data in real time, the system enabled proactive decision-making, improved cost management, enhanced resource governance, and facilitated accurate financial forecasting.

4.3 CRITICAL CONSTRAINTS AND MITIGATORY STRATEGIES

The automated system was continuously refined to improve productivity measurement and workforce integration in a complex construction environment.

4.3.1 Refinement of Productivity Measurement

Initially, wearable biometric devices, such as wristbands capturing pulse and movement, were tested to monitor productivity in real time. However, these devices misinterpret non-work-related activity, like rest periods or minor movements, as productive work, making the data unreliable. Consequently, the system adopted a task-based productivity model, using digitally assigned tasks, verified attendance, and RFID-tracked work locations. Integration of task allocation, attendance validation, and supervisory confirmation enabled automatic detection of deviations, ensuring productivity data reflected actual labour utilisation rather than inferred activity. This highlighted the limitations of relying solely on biometric data and emphasised the need for combining task-based, location-based, and supervisory verification.

4.3.2 Workforce Adaptation and Change Management

The RFID-based system initially faced resistance, primarily behavioural, due to concerns over increased monitoring, perceived loss of informal practices, and unfamiliarity with digital technology. Previously accepted practices, such as proxy attendance and informal adjustments, were disrupted, creating hesitation among workers. A structured, phased change management strategy addressed these challenges through training, hands-on demonstrations, and orientation programs for workers, supervisors, and administrative staff. Real-time access to attendance and payroll via mobile apps empowered workers to self-verify records, reducing disputes and intermediaries. Extension of the system to store operations, digitised tools and material tracking, further enhancing transparency and accountability. Phased implementation, continuous feedback, and on-site supervisory support ensured gradual adaptation, allowing workers to recognise tangible benefits such as accurate wages, streamlined processes, and improved welfare access.

4.4 PERFORMANCE UNDER PANDEMIC CONDITIONS

The COVID-19 pandemic presented an unplanned but analytically significant test environment for the integrated digital ecosystem at the ABC Project, ultimately validating its strategic value beyond routine operational efficiency. Traditional manual site management, which depends on physical presence for attendance verification, task allocation and payroll processing, was rendered unworkable by social distancing mandates and mobility restrictions. The integrated digital platform, however, ensured uninterrupted operational continuity. RFID-based attendance data and facial recognition records were accessible remotely by management and time-office staff, while supervisors retained full operational control through digital interfaces, allocating tasks and overseeing resource utilisation without requiring physical site presence. Payroll processing remained fully automated based on system-verified attendance and task completion data, with subcontractor invoices and salary disbursements authorised electronically, eliminating payment delays and manual reconciliation errors. Centralised dashboards provided management with continuous, real-time visibility into site performance, enabling informed decision-making despite significantly reduced physical oversight capacity. The pandemic experience, therefore, demonstrated that an integrated digital site management ecosystem extends beyond operational efficiency, where it constitutes a governance and continuity under conditions of severe external disruption, demonstrating the necessity of construction digitalisation in large-scale projects across developing economies.

4.5 SUMMARY OF FINDINGS

Table 1 presents a consolidated summary of the key operational challenges addressed, digital mechanisms deployed and observed outcomes across the seven functional modules of the integrated site management ecosystem.

Table 1: Summary of key findings by system module

System Module	Key Challenge Addressed	Digital Mechanism Deployed	Observed Operational Outcome
People Registration & Access Control	Proxy attendance; unauthorised site entry; absence of verified audit trail	RFID + facial recognition; single controlled entry point; timestamped access log	Substantially reduced proxy entries; comprehensive audit trail established; verified workforce identity at site entry
Digital Work Allocation	Manual allotment sheets; informal verbal instructions; no direct link between labour and cost codes	Tablet-based supervisor portal; drag-and-drop task assignment linked to cost codes and work packages	Improved labour deployment traceability; direct connection between attendance, task, and project expenditure
Real-Time Attendance & Exit Control	Delayed and discretionary attendance records; early releases; manipulation by	RFID exit terminals; facial recognition; automatic alerts for abnormal movements	Accurate work-hour recording; reduced dependency on manual checks; strengthened site security

System Module	Key Challenge Addressed	Digital Mechanism Deployed	Observed Operational Outcome
	workers and supervisors		
Timecards, Payroll & Labour Billing	Manual payroll processing; discrepancies between billed and actual labour; payroll disputes	Automated digital timecards; predefined payroll rules; supplier billing from verified records	Reduced administrative workload; improved payroll accuracy; fewer disputes; aligned cost reporting
Welfare, Cafeteria & Leave Management	Manual coupon systems; unauthorised welfare access; informal leave processes	RFID-controlled cafeteria/accommodation access; mobile app for leave and meal requests	Eliminated unauthorised usage; improved coordination; accurate welfare cost tracking
Project Manager Dashboard	Fragmented, delayed operational data; reactive decision-making; limited cost visibility	Centralised cloud-based dashboard aggregating manpower, cost, materials, and equipment data in real time	Enabled data-driven, proactive decision-making; improved resource control and deviation detection
Material & Machinery Tracking	Uncontrolled withdrawals; equipment idle time; difficulty linking resource use to cost codes	RFID-based material tracking; machinery allocation and usage logging linked to work packages	Reduced wastage and theft; optimised equipment deployment; accurate financial forecasting
System Performance under COVID-19	Traditional manual management rendered unworkable by mobility restrictions and social distancing	Remote access to RFID attendance data; digital task allocation; automated payroll processing	Uninterrupted operational continuity; validated strategic value as governance and resilience infrastructure

5. DISCUSSION

The findings of this study substantiate and extend existing literature, providing empirical validation that an integrated digital ecosystem approach to construction site management demonstrably outperforms both traditional manual systems and isolated technological deployments in large-scale construction environments. The deficiencies of manual site management, such as proxy attendance, payroll manipulation, resource misallocation and informal supervisory practices, were identified as issues in Sri Lankan construction by Wijerathna et al. (2024a). These were comprehensively eliminated through the closed-loop architecture of the ABC Project platform, confirming that these failures can be resolved when addressed through integrated digital design.

The literature further established that individual technologies, while demonstrating domain-specific benefits, consistently fail to resolve the systemic interdependencies between workforce management, cost control and resource utilisation (Kereri & Adamtey., 2019). The ABC Project findings validate this argument precisely by the integration of RFID access control, facial recognition, supervisor-facing task allocation portals, automated payroll and centralised dashboard analytics into a single, synchronised platform that produced outcomes that no individual technology could have achieved in isolation. The direct linkage of labour deployment to cost codes and work packages,

material withdrawals to specific work zones, and machinery utilisation to verified task completion created an end-to-end operational visibility that fundamentally restructured the informational architecture of site management, as theoretically anticipated by Lu et al. (2011) and Tan and Sidhu (2022).

The workforce resistance encountered during initial implementation aligns with findings recorded by Wijerathna et al. (2024b), who identified resistance to technology adoption as one of the most significant barriers to construction digitalisation in developing economies. However, the findings demonstrate that structured change management through phased deployment, training and transparent self-verification of attendance and payroll successfully converted resistance into acceptance, confirming that adoption barriers are more transitional than structural. Finally, the system's uninterrupted performance during the COVID-19 pandemic showcases and validates findings that are absent from the existing literature, that integrated digital ecosystems constitute a governance and continuity infrastructure extending beyond routine operational efficiency. This establishes a compelling empirical foundation for construction digitalisation across developing economies.

While the ABC Project was implemented within a specific Sri Lankan context, there are reasonable grounds to consider its implications for similar settings. Large-scale construction projects in other developing economies share comparable structural challenges including high workforce density, limited supervisory reach, vulnerability to informal practices, and weak real-time data infrastructure. The core enabling factors of the ABC Project, including RFID access control, cloud-based data integration, supervisor-facing digital interfaces, and automated payroll are technically deployable across a range of project scales and national contexts. The general operational principles of digital workforce verification, task-linked cost tracking and centralised dashboard governance are not exclusive to Sri Lanka, and analogous outcomes might reasonably be expected in other developing-economy mega-projects where similar manual management deficiencies are present. However, variations in institutional readiness, IT infrastructure maturity, labour relations, regulatory environments and organisational capacity could meaningfully influence implementation outcomes.

The findings carry significant implications across multiple dimensions. For practitioners, the study provides a blueprint for integrated digital site management in large-scale construction projects across developing economies. For academia, it establishes a real-life implemented digital system that validates and advances the theoretical understanding of integrated digital ecosystems in construction management. For society, this system promotes ethical labour practices, fair wage distribution and transparent resource governance in an industry that directly affects large working populations. In addition, future research should pursue multi-site replication studies to develop and validate a standardised integrated digital site management framework across diverse developing-economy construction contexts.

6. CONCLUSIONS AND RECOMMENDATIONS

Large-scale construction projects in developing economies such as Sri Lanka have long been constrained by traditional manual site management practices. Attempts to address these deficiencies through isolated technological deployments have proven insufficient. This study addresses that gap by integrating a digital site management ecosystem.

Through a ten-month evaluative case study of the ABC Project, a large-scale, high-density construction environment in Sri Lanka, the study provides real-world evidence that such integration is not only technically achievable but operationally transformative.

The findings demonstrate that the integrated digital ecosystem comprehensively eliminated the structural deficiencies of traditional manual site management, such as proxy attendance, payroll manipulation, resource misallocation and informal supervisory practices while simultaneously strengthening governance, financial transparency and workforce accountability. The task-based productivity model, developed following the rejection of wearable biometric devices, established a more valid and reliable approach to productivity measurement in construction environments. The system performance during the COVID-19 pandemic further validated its strategic value as a continuity infrastructure extending beyond routine operational efficiency.

This study is limited to a single case in the Sri Lankan context. Additionally, only qualitative data was collected, as the research was planned after actual implementation; the study therefore relies on observation-based evidence from real-world experience rather than quantitative pre-post measurement. These limitations constrain the generalisability of findings and should be addressed in future research. Future studies should pursue multi-site, cross-country replication to develop and validate a standardised framework for integrated digital site management across diverse developing-economy construction contexts. Based on the findings, this study recommends that future large-scale projects adopt end-to-end integrated digital platforms connecting workforce, task, resource and cost in real time, supported by phased implementation, structured change management, task-based productivity measurement and remote operational capability.

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