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Integrative Digital–Leadership Framework for Mitigating Performance Inefficiencies in Road Construction Projects

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ABSTRACT

This study aims to develop an integrative digital leadership framework to mitigate performance inefficiencies in road construction projects by examining how digital technologies and leadership practices can jointly improve project delivery. A qualitative research design was adopted within a constructivist paradigm. Data were collected through semi-structured interviews with 12 experienced professionals drawn from government agencies, private consulting firms, and contracting organisations involved in road construction in Ghana. The data were analysed using Braun and Clarke's thematic analysis to identify recurring patterns related to inefficiencies, socio-technical conditions, digital adoption, and leadership competencies. The study found that project inefficiencies manifest mainly as delays, rework, fragmented coordination, slow approvals, weak supervision, and poor information flow. It also revealed that the effectiveness of digital tools depends on organisational readiness, technical competence, institutional support, and leadership capability. Road sector stakeholders should embed digital tools within routine project management, strengthen digital training, improve accountability systems, and develop leadership competencies in digital literacy, coordination, and change management. Sustainable improvement in road construction performance depends on aligning digital capability with effective leadership and coordinated governance. The study offers an original socio-technical framework that integrates digital drivers, leadership competencies, and performance outcomes within road construction practice.

Keywords: Digital Leadership, Road Construction Projects, Performance Inefficiencies, Digital Technology Adoption, Socio-Technical Systems.

INTRODUCTION

Road construction projects remain central to economic integration, territorial accessibility, and public service delivery (Walther *et al.*, 2024). Yet, their performance continues to be undermined by recurring inefficiencies, including cost overruns, delays, fragmented communication, low productivity, safety lapses, and weak inter-organisational coordination (Kumar and Kumari, 2025; Abdelalim *et al.*, 2024). Recent scholarship shows that digital technologies can improve planning accuracy, real-time monitoring, information visibility, and operational control in construction environments, while leadership shapes whether such technologies are meaningfully embedded in practice rather than treated as isolated technical add-ons (Wang et al., 2024; Qadir et al., 2025; Chen et al., 2025). In road projects, particularly, technologies such as BIM, drones, IoT-enabled monitoring, mobile field applications, and automated surveying systems are increasingly relevant because they address the complexity, spatial dispersion, and data intensity of infrastructure delivery (Rehman and Islam, 2023; Nielsen et al., 2024; Sajid et al., 2025).

Much of the literature examines digital adoption, leadership capability, or project inefficiency as separate strands, with limited conceptual integration of how socio-technical alignment and leadership behaviour jointly shape project performance. This leaves an important knowledge gap, especially in road construction, where technology–organisation misfit, weak digital readiness, resistance to change, and poor coordination frequently undermine implementation outcomes. Consequently, the absence of an integrative explanatory framework constrains both theory development and practical intervention.

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Against this background, this study aims to develop an integrative digital leadership framework for mitigating performance inefficiencies in road construction projects. Specifically, it examines the socio-technical foundation of digital leadership integration, reviews digital technology adoption in road construction, analyses leadership competencies required for digital transformation, and develops a framework explaining how digital leadership synergy can improve project performance. The study contributes by linking socio-technical systems theory, the Technology–Organisation–Environment perspective, and transformational leadership principles to explain how digital tools and leadership competencies operate as mutually reinforcing levers for performance improvement.

The remainder of this paper is structured into four sections: a literature review establishing the theoretical and empirical foundations; a methodology outlining the research design; findings and discussion of the results; study implications for policy, research, and practice; and, finally, conclusions.

LITERATURE REVIEW

This literature review provides the intellectual foundation for examining how digital technologies and leadership interact to mitigate performance inefficiencies in road construction projects. The section synthesises relevant theoretical and empirical literature to explain the relationships among socio-technical alignment, digital technology adoption, leadership behaviours, and project performance outcomes. In doing so, it moves beyond isolated discussions of technology or management by highlighting their interdependence within complex road construction environments. The review pays particular attention to recurring inefficiencies, including delays, cost overruns, fragmented communication, low productivity, safety lapses, and weak coordination, which continue to affect infrastructure delivery. It also evaluates how contemporary scholarship has addressed these challenges through digital transformation, leadership capability development, and integrated organisational practices. By identifying dominant themes, areas of convergence, and unresolved gaps in the literature, this section establishes the rationale for the study's integrative digital leadership framework. The review is therefore structured to progress from theoretical grounding to empirical insights and finally to the conceptual synthesis that underpins the study.

Socio-Technical Systems Theory for Digital Leadership Integration in Road Construction

Socio-Technical Systems (STS) Theory provides a powerful explanatory lens for understanding how digital construction technologies and leadership jointly influence performance outcomes in road construction project management (Appelbaum, 1997). The central argument of STS is that every project environment comprises interdependent social and technical subsystems whose alignment determines system effectiveness (Bauer and Herder, 2009). In road construction, the technical subsystem includes digital tools such as BIM, drones, IoT-enabled monitoring platforms, automated surveying systems, and digital scheduling applications. In contrast, the social subsystem encompasses project managers, engineers, equipment operators, organisational culture, skills, behavioural orientation, and leadership structures (Rehman and Islam, 2023). STS posits that isolating these subsystems produces suboptimal performance; instead, technological interventions must be embedded within compatible social processes to yield productivity gains. Mumford (2006) emphasises that socio-technical systems succeed only when design and implementation account for the "interdependent technical and social subsystems" whose joint behaviour determines system performance. In the context of road construction, this means that investments in advanced digital tools cannot automatically resolve inefficiencies unless workers understand how to use the technologies and leadership fosters a culture that embraces digital transformation.

A key contribution of STS theory is the principle of joint optimisation, which asserts that project outcomes are maximised when both human and technical systems are optimised simultaneously, rather than prioritising one at the expense of the other (Appelbaum, 1997). Many road construction projects adopt digital innovations such as GPS-grade control systems or digital site-log platforms without adjusting organisational routines, supervisory roles, or communication structures. This misalignment often creates "technology–organisation gaps" that undermine performance, resulting in delays, rework, safety lapses, and inefficient resource deployment (Thirumal *et al.*, 2024). As Baxter and Sommerville (2010) argue, socio-technical failures frequently occur not because technologies malfunction, but because organisations fail to integrate new tools with existing work practices and stakeholder behaviours. In road projects, joint optimisation requires synchronising digital workflows with labour competencies, supervision methods, cross-team coordination mechanisms, and collaborative leadership styles.

STS theory further explains the concept of human–technology fit, which is essential for interpreting why performance inefficiencies persist even when organisations adopt advanced technologies (Appelbaum, 1997). When digital tools outpace worker readiness—whether due to limited digital literacy, inadequate training, low motivation, or resistance to change—misfits emerge, creating new inefficiencies. Studies show that poorly implemented digital systems introduce complexity, increase cognitive load, and generate operational errors when users are unprepared or when workflows are not redesigned (Lyell and Coiera, 2016). In road construction operations, the introduction of BIM-based project controls or automated material tracking can increase frustration, slow decision-making, and even trigger work stoppages if personnel do not understand the functions or if the systems are incompatible with existing routines (Alsehaimi *et al.*, 2024). STS theory, therefore, reinforces the need for leadership that supports learning, training, user engagement, and adaptation as integral components of digital transformation.

Leadership plays a central coordinating role in balancing the social and technical subsystems within STS. Effective project leaders act as integrators by influencing culture, motivating workers, aligning objectives, mediating resistance, and ensuring that digital tools complement rather than disrupt established work patterns (Musaigwa and Kalitanyi, 2024). Research in construction management shows that leadership behaviour determines whether digital innovation becomes institutionalised or rejected (Zulu *et al.*, 2023; Gao and Gao, 2024). From an STS perspective, leadership must cultivate participatory approaches, build trust, and facilitate communication channels that enable workers to understand new technologies and adapt them to local contexts. Baxter and Sommerville (2010) highlight that without leadership-driven sensitisation and awareness mechanisms, socio-technical integration efforts fail because stakeholders do not recognise the value of new systems or misunderstand their implications for work practice.

STS theory also identifies several socio-technical barriers that frequently constrain the uptake of digital technologies in construction environments. These include resistance to change, cultural rigidity, fragmented workflows, inadequate training, unclear communication structures, and poor cross-disciplinary coordination (Furxhi, 2021). Such barriers are well-documented in digital construction literature, where researchers emphasise that digitalisation is as much a social process as a technical one (Dauda *et al.*, 2024). In road construction, heavy reliance on manual routines, entrenched supervisory hierarchies, and low-technology organisational culture intensify these challenges. STS highlights the need for flexible structures, adaptable work practices, and collaborative leadership to overcome these barriers.

Digital Technologies Adoption in Road Construction Projects

Digital technology adoption in road construction projects has become a major concern in contemporary construction management scholarship because the sector continues to experience entrenched performance inefficiencies, including cost overruns, time delays, rework, fragmented communication, low productivity, and weak quality control (Wang *et al.*, 2024). Within this context, digitalisation is increasingly framed not merely as a technological upgrade but as a structural response to inefficiency in infrastructure delivery. Digital construction technologies are core enablers of improved planning accuracy, real-time monitoring, automation, data visibility, and coordination across the project life cycle (Mayouf *et al.*, 2024; Qadir *et al.*, 2025). In road construction, these technologies include Building Information Modelling, Geographic Information Systems, drones, Internet of Things sensors, telematics, automated surveying systems, cloud-based collaboration platforms, and mobile field applications (Rehman and Islam, 2023). Their collective significance lies in their capacity to transform dispersed, equipment-intensive, and data-heavy road project environments into more integrated and information-responsive systems.

Although construction digitalisation is advancing globally, road infrastructure projects tend to lag behind vertical building projects in terms of the speed and depth of implementation (Kineber *et al.*, 2024). This is partly because road projects are spatially extensive, environmentally exposed, operationally fragmented, and often delivered through multiple contractual interfaces, which complicates digital integration (Soltani *et al.*, 2025). Nevertheless, this review indicates a steady upward trend in adoption. BIM is increasingly applied in highway alignment design, bridge-component clash detection, and lifecycle planning, while GIS supports route mapping, terrain analysis, and geospatial coordination; drones enhance topographic surveying, volumetric measurement, and progress tracking; and IoT-enabled tools together with telematics are emerging for asphalt temperature monitoring, soil compaction assessment, equipment performance tracking, and fleet coordination in haulage and earthmoving operations (Rehman, 2025; Nielsen *et al.*, 2024). These developments suggest that digital adoption is moving beyond isolated experimentation toward broader operational relevance in road infrastructure projects.

A critical insight is that digital adoption is not uniform throughout the project lifecycle. At the feasibility and design stages, BIM and GIS dominate because they support modelling, scenario analysis, and design coordination (Alsehaimi *et al.*, 2025). During the construction phase, drones, mobile field applications, automated surveying technologies, and sensor systems become more prominent due to their usefulness in site monitoring, inspection, reporting, and process control (Sajid *et al.*, 2025). In the operation and maintenance phase, digital asset management systems and predictive maintenance applications become increasingly important, as they help optimise infrastructure performance over time. This phase-specific pattern indicates that digitalisation in road construction is highly contextual rather than generic (Khoshkenar and Nassereddine, 2024). Technology choices depend on the nature of the task, project complexity, site conditions, and the level of organisational readiness. Large and complex highway projects generally require greater digital integration because they involve more interfaces, technical dependencies, and coordination risks (Suvvari and Saxena, 2023). In contrast, smaller road projects may rely only on basic mobile tools or low-cost digital devices.

The drivers of digital adoption identified are technological, organisational, and environmental. From a technological perspective, adoption is shaped by perceived usefulness, ease of use, interoperability, automation capability, and expected performance benefits (Faiz *et al.*, 2024; Alkaabi *et al.*, 2025). In road construction, perceived usefulness is especially associated with improved geospatial accuracy, real-time visibility of progress, safer site observation through remote sensing, and more reliable planning data (Rao *et al.*, 2022). Organisational drivers include digital readiness, staff competence, prior technology experience, an innovative culture, and top management commitment (Mihu *et al.*, 2023). Firms that possess stronger internal capacity and leadership support are more likely to integrate digital systems meaningfully into project processes. External drivers also matter, especially where clients, regulatory agencies, donor institutions, or national digital policies create pressure for more transparent, data-driven, and standardised project delivery systems (Barroso and Laborda, 2022).

High capital costs for software, equipment, system maintenance, and licensing remain a significant constraint, particularly for small and medium-sized contractors operating under narrow profit margins (Thomas and Weiss, 2021). Digital literacy gaps, shortage of skilled operators, inadequate training, and fear of technological displacement can all reduce acceptance and effective implementation (Siriwardhana *et al.*, 2025). Resistance to change persists in many construction settings because traditional work routines remain deeply embedded in project culture. These include fragmented digital standards, weak interoperability across tools, poor ICT infrastructure in remote project locations, and limited policy coherence regarding digital construction requirements. In developing-country contexts, these constraints are even more pronounced, making adoption not only a technical issue but also an organisational and governance challenge.

Leadership Behaviours and Competencies in Digital Technology Integration

Leadership behaviours and competencies are increasingly recognised in construction management as decisive factors in determining whether digital transformation produces meaningful improvements in project performance (Ongena *et al.*, 2024). In road construction projects, where teams are multidisciplinary, communication channels are fragmented, operational uncertainty is high, and implementation environments are often hierarchical, leadership becomes the central human mechanism through which digital technologies are accepted, coordinated, and institutionalised (Abdul-Fatawu *et al.*, 2024). This position reflects the broader socio-technical understanding that technologies function effectively only when supported by human agency, strategic guidance, and organisational learning. Thus, leadership is not peripheral to digitalisation in road construction; it is integral to the realisation of digital value in practice (Hariyani *et al.*, 2025).

Transformational leadership is especially significant because it helps build commitment to innovation, articulates a compelling future direction, and motivates teams to move beyond established practices (Gupta, 2025). In road construction, where resistance to process change can be high, leaders who inspire confidence and communicate a strong digital vision are more likely to reduce scepticism and increase buy-in (Chukwuma and Zondo, 2024). Participative leadership is equally valuable because it encourages collaboration, shared problem-solving, and learning across professional boundaries (Toufighi *et al.*, 2024). This is important in road projects, where contractors, consultants, engineers, supervisors, and client representatives must navigate complex information flows and time-sensitive decisions. Leadership that creates psychological safety and supports experimentation allows project actors to engage with unfamiliar digital tools more constructively (Putra *et al.*, 2025).

Successful digital implementation requires leaders to communicate early, consistently, and transparently about the purpose of digital tools, the expected workflow changes, and the benefits to project delivery (Chen *et al.*, 2025; Lakhamraju, 2025). Clear communication reduces uncertainty, prevents misinformation, and aligns stakeholders around shared digital objectives. In road construction environments, where communication failure frequently contributes to delays, rework, and poor coordination, this behaviour becomes particularly critical (Alsulamy, 2022). Closely related to communication is vision-setting, which enables leaders to link digital technologies to broader goals such as efficiency, safety, quality enhancement, and sustainability (Cheng *et al.*, 2025). When leaders frame technologies such as BIM, drones, or automated monitoring systems as instruments for long-term project improvement rather than as isolated technical impositions, staff are more likely to view digitalisation as meaningful and relevant (Najibifar *et al.*, 2025).

Empowering leadership encourages autonomy, collaborative learning, and responsible experimentation, all of which are necessary when new technologies are introduced into project environments (Jada *et al.*, 2019). Workers and middle-level project staff often need the freedom to test, adapt, and refine digital tools in real-world site conditions. Leaders who create that space strengthen digital confidence and promote local innovation (Abhari, 2025). In parallel, coaching and mentoring support individual and collective upskilling, particularly where employees have limited prior exposure to digital systems (Tzavaras and Davalas, 2022). Such support is essential in road construction settings where differences in technical competence can slow collective adoption. Leaders who understand the basic capabilities, limitations, and strategic relevance of digital technologies are more credible, better able to make informed decisions, and more effective in modelling desired behaviours (Rakovic *et al.*, 2024). Digital literacy among leaders is therefore no longer optional; it has become a competency that directly shapes the quality of implementation (Lauring *et al.*, 2025).

Strategic thinking is crucial because leaders must interpret the long-term value of digitalisation and align technological investment with project and organisational objectives. In the context of road construction, this means understanding how digital systems can reduce inefficiencies such as delays, rework, poor information flow, or safety incidents. Technology awareness complements this by allowing leaders to appreciate what specific tools can and cannot do, thereby supporting better selection, integration, and application decisions. Change management competence is equally critical. Since digital adoption often disrupts routines, roles, and reporting systems, leaders must be able to sequence change, address concerns, mobilise support, and maintain continuity during transition. Without these capabilities, digital initiatives can easily lose momentum or face internal resistance.

Integrative Digital-Leadership Synergy Framework

The proposed integrative framework, illustrated in Figure 1, synthesises evidence from the preceding objectives to propose a socio-technical model that positions digital technologies and leadership competencies as mutually reinforcing mechanisms for mitigating performance inefficiencies in road construction project management. Road construction projects remain highly susceptible to delays, cost overruns, safety lapses, and inefficient coordination due to their fragmented structures and multi-stakeholder interfaces (Alshihri *et al.*, 2022). Contemporary literature increasingly acknowledges that technological deployment alone does not automatically translate into performance improvement unless it is embedded within enabling leadership practices and organisational contexts (Alshihri *et al.*, 2022). This framework responds to this gap by integrating digital capability enhancement with human-centred leadership mechanisms, thereby creating a balanced socio-technical system that enhances operational efficiency, safety, and quality.

The first component of the framework focuses on the drivers of digital adoption in road construction. Studies have consistently identified factors such as organisational readiness, perceived usefulness of digital tools, digital literacy levels, project complexity, and external regulatory pressure as major determinants of digitalisation (Arnaud et al., 2024; Mihu *et al.*, 2023). In road projects, technologies such as Building Information Modelling (BIM), drones, laser scanning, IoT sensors, mobile field applications, and GPS-enabled machinery enhance planning accuracy, site documentation, material tracking, and real-time monitoring (Rao *et al.*, 2022). The left section of Figure 1 depicts these digital drivers as foundational antecedents that drive the transition from traditional construction practices to data-enabled, automated project workflows.

The second major component emphasises leadership behaviours and competencies as critical enablers of successful digital transformation. Research demonstrates that project leadership influences technology acceptance, cross-disciplinary collaboration, communication quality, team learning, and resistance to change (Pawar and Dhumal, 2024). Leadership qualities such as vision articulation, digital awareness, emotional intelligence, empowerment, adaptability, and proactive problem-solving help bridge the gap between the availability of technology and its effective use (Tagscherer and Carbon, 2023). As shown in Figure 1, these leadership competencies are strategically positioned alongside digital drivers to reflect their mediating role in facilitating technology integration.

The central pathway of the framework highlights technology integration processes, including aligning digital tools with project functions, providing structured training, establishing data governance, ensuring system interoperability, and embedding digital routines into daily operations. Literature indicates that integration requires iterative learning cycles, leadership reinforcement, and well-structured adoption strategies to ensure consistent utilisation and value realisation (Musaigwa and Kalitanyi, 2024). In Figure 1, this process is visualised as a converging flow from both digital drivers and leadership competencies, signalling their reciprocal influence in shaping effective implementation.

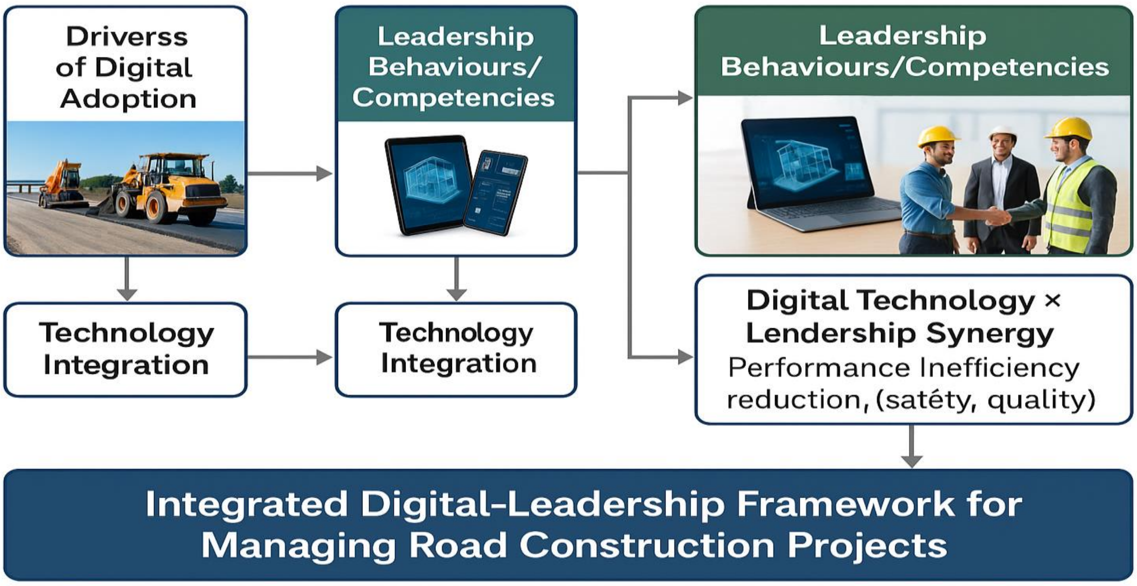
A distinctive contribution of the model lies in the articulation of mechanisms of synergy, representing the interaction channels through which leadership enhances digital capabilities and digital tools strengthen leadership effectiveness. Mechanisms such as continuous training, a supportive digital culture, collaborative decision-making, accountability systems, and transparent communication have been highlighted as essential to construction innovation (Rinchen *et al.*, 2024). The framework visualises this as the merging of digital technology integration and leadership behaviour, creating a synergistic space that reduces performance inefficiencies.

The performance improvement channels demonstrate the expected outcomes of this integration. Digital-leadership synergy reduces delays through real-time visibility, improves communication among dispersed teams, strengthens safety management through predictive analytics, and minimises cost overruns through accurate resource tracking and improved planning (Pawar and Dhumal, 2024). Additionally, enhanced coordination reduces interface conflicts between contractors, consultants, and supervising agencies, which represent persistent challenges in road project delivery.

The framework will be developed through empirical testing, theoretical comparison, and stakeholder validation. Insights from digital maturity assessments, leadership behaviour analyses, and inefficiency patterns identified in earlier phases will be cross-referenced with socio-technical systems theory, the Technology–Organisation–Environment model, and transformational leadership principles. Validation workshops with engineers, contractors, project managers, and regulatory stakeholders ensured contextual relevance to Ghana's road construction environment.

In sum, the framework will deliver a comprehensive Integrative Digital-Leadership Synergy Model that positions digital technologies and leadership as interconnected levers rather than isolated variables. By linking digital drivers, leadership competencies, integration processes, and performance outcomes, the model provides a practical, theoretically grounded pathway to mitigate inefficiencies in road construction project management, particularly in developing-country contexts.

Figure 1. Proposed Integrative Digital-Leadership Conceptual Framework



Source: Authors Construct, 2026.

METHODOLOGY

This study adopted a qualitative research design and was grounded in the constructivist research paradigm to examine how digital capabilities and leadership practices can be integrated to mitigate performance inefficiencies in road construction projects. The constructivist paradigm was considered appropriate because the study sought to understand inefficiency in road construction as a socially and organisationally embedded phenomenon, shaped by leadership behaviours, institutional arrangements, communication systems, and the extent of digital technology adoption (Creswell and Poth, 2018). From this perspective, inefficiencies in road construction are not viewed merely as technical or operational failures, but as outcomes influenced by the interactions of project actors, management systems, and organisational realities. Within this framework, qualitative research was suitable because it enabled the researcher to explore practitioners' interpretations, experiences, and professional judgments regarding the causes of inefficiency and the practical role of leadership and digital tools in improving project performance.

A purposive sampling technique was used to identify participants directly involved in road construction project planning, delivery, supervision, regulation, and digital operations. This approach was appropriate because the study required information-rich respondents capable of providing informed and experience-based insights into inefficiency drivers, leadership challenges, and the role of digital systems in road project implementation. The respondents were selected from key institutional environments within the road sector to ensure representation across the major actors involved in project delivery. In total, twelve participants were included in the study and anonymised as R1 to R12. They were drawn from government agencies, private consulting firms, and private contracting organisations. Their positions included Project Manager, Highway Engineer, Resident Engineer, Site Manager, Construction Manager, Supervising Engineer, Contract Manager, Transport Infrastructure Officer, Consultant Engineer, Operations Manager, Policy and Regulatory Officer, and Geomatics or GIS Specialist. These professional categories reflected the technical, managerial, regulatory, and digital dimensions of road construction practice. The respondents had between 8 and 21 years of professional experience, indicating substantial industry exposure and enhancing the credibility of the data obtained, as shown in Table 1.

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Semi-structured interviews were used as the primary data collection instrument because they provided a flexible yet focused means of eliciting detailed accounts from respondents. The interview format allowed the researcher to pursue the central concerns of the study while also probing deeper into issues raised by participants based on their professional experience. The interview guide was developed from the study objective and informed by literature on project performance, leadership in construction, and digital transformation in infrastructure delivery. Questions explored participants' views on common sources of inefficiency in road projects, including weak coordination, communication breakdowns, delayed approvals, inadequate supervision, fragmented information flow, limited monitoring systems, low digital uptake, and institutional constraints affecting performance. Additional questions examined how leadership practices influence coordination, decision-making, accountability, and the adoption or use of digital tools across project stages. Interviews were conducted with participants' consent, audio-recorded, and later transcribed verbatim to preserve the accuracy and richness of the responses (Morris, 2015).

The collected interview data were analysed using Braun and Clarke's six-phase thematic analysis. This analytical approach was selected because it offers a systematic and rigorous process for identifying, organising, and interpreting recurring patterns within qualitative data. Analysis began with repeated reading of the transcripts to become familiar with the data and to identify preliminary patterns related to inefficiency, leadership practice, and digital integration. The generation of initial codes from the interview material followed this. The coding process was both inductive and deductive. It was inductive because important issues emerged directly from participants' narratives, and deductive because the analysis was guided by the study's conceptual focus on leadership, digital capabilities, and project performance inefficiencies (Birt et al., 2016). Related codes were then grouped into broader categories and refined into themes that explained how leadership weaknesses, digital limitations, and institutional conditions interact to shape inefficiencies in road construction projects. Cross-case comparison was also used to examine similarities and differences in respondents' views across government agencies, consulting firms, and contracting organisations. This helped to identify common inefficiency patterns as well as differing institutional perspectives on responsibility, barriers to improvement, and readiness for digital transformation. The final themes formed the basis for developing an integrative framework to address performance inefficiencies by aligning digital capabilities and leadership practices in road construction projects.

Ethical principles were observed throughout the study to ensure the protection, dignity, and rights of participants. Informed consent was obtained from all respondents before the interviews. Participation was voluntary, and respondents were assured of confidentiality and anonymity. To protect their identities, all participants were assigned codes from R1 to R12 instead of using personal or organisational names. Interview recordings, transcripts, and related research materials were securely stored and used strictly for academic purposes. These ethical measures were necessary to promote openness during the interviews and to maintain the integrity and trustworthiness of the research process.

Table 1: Respondent Demographics

ID	**Role**	**Firm Category**	**Years**
R1	Project Manager	Government Agency	18
R2	Highway Engineer	Private Consulting Firm	12
R3	Resident Engineer	Government Agency	15
R4	Site Manager	Private Contractor	14
R5	Construction Manager	Private Contractor	17
R6	Supervising Engineer	Government Agency	20
R7	Contract Manager	Private Consulting Firm	13

R8	Transport Infrastructure Officer	Government Agency	16
R9	Consultant Engineer	Private Consulting Firm	19
R10	Operations Manager	Private Contractor	12
R11	Policy and Regulatory Officer	Government Agency	21
R12	Geomatics/GIS Specialist	Private Consulting Firm	8

Source: Field Survey, 2026

RESULTS PRESENTATION

This section presents the qualitative results from interviews with 12 experienced professionals from government agencies, private consulting firms, and private contracting organisations involved in road construction projects. The findings are organised around four major themes derived from the interview questions: performance inefficiencies in practice, socio-technical conditions influencing the adoption of digital technology, leadership behaviours required for digital transformation, and the integration of technology and leadership into a practical framework. The presentation focuses strictly on participants' reported experiences and views, using direct respondent expressions to illustrate recurring patterns, similarities, and areas of emphasis across the different professional roles and institutional categories represented in the study.

Theme 1: Performance Inefficiencies as Delays, Rework, Coordination Gaps, and Slow Decisions

Respondents described performance inefficiencies in road construction projects as recurring delays, repeated rework, weak coordination, slow approvals, poor activity sequencing, and interruptions to site operations. These inefficiencies were reported across government agencies, consulting firms, and contracting organisations.

R1 stated that "approvals, site instructions, and contractor actions do not move at the same pace, so delay becomes normal."

R3 similarly reported that "performance problems become obvious when drawings, supervision expectations, and actual ground conditions do not align."

R5 added that "rework, idle labour, and poor coordination between subcontractors are common signs of inefficiency on site."

Respondents also identified poor communication between project actors as a major manifestation of inefficiency.

R2 noted that "there is often a disconnect between design intentions and field execution."

R6 stated that "many inefficiencies are not from lack of effort, but from poor coordination and delayed corrective action."

R10 observed that "operations slow down when teams are waiting for decisions, clarifications, or site instructions."

Institutional and procedural inefficiencies were also reported.

R8 explained that "project delivery becomes inefficient when reporting, supervision, and decision-making are not linked together."

R11 stated that "weak accountability and delayed approvals allow performance problems to persist longer than they should."

Theme 2: Socio-Technical Conditions Influencing Digital Technology Adoption and Effectiveness

Respondents reported that the adoption and effectiveness of digital technologies are shaped by organisational readiness, staff competence, infrastructure availability, management support, and willingness to change established work practices. Digital tools were seen as useful, but their effectiveness depended on the environment within which they were introduced.

R2 stated that "digital tools can improve tracking and design review, but only when teams trust the data and use the systems consistently."

R7 similarly noted that "technology adoption is shaped by firm culture because many actors still prefer conventional reporting methods."

R12 added that "GIS and other spatial tools are useful, but their value is reduced where technical capacity and data management are weak."

Respondents also pointed to inadequate training and inconsistent use of digital systems.

R4 reported that "some technologies are introduced, but staff are not properly prepared to use them in day-to-day project work."

R9 stated that "digital systems are often available, but not fully integrated into supervision and project control."

R10 observed that "technology does not improve performance when people see it as extra work instead of part of the job."

Infrastructure, policy, and institutional arrangements were also identified as shaping adoption.

R6 stated that "digital uptake depends on whether the organisation is ready with the systems, support, and discipline to sustain it."

R11 noted that "without policy backing and institutional commitment, digital initiatives remain inconsistent."

Theme 3: Leadership Behaviours and Competencies Needed for Digital Transformation

Respondents identified clear vision, coordination, technical understanding, timely decision-making, staff support, and accountability as the major leadership requirements for digital transformation in road construction projects. Leadership was presented as central to whether digital tools become useful operational instruments or remain underused.

R1 stated that "leaders must understand both construction practice and digital systems, otherwise technology decisions will be detached from project reality."

R6 similarly reported that "leadership now requires confidence in using real-time information for supervision and corrective action."

R10 added that "without managers who encourage learning and accountability, digital systems become reporting tools rather than performance tools."

Respondents also emphasised adaptability and openness to change.

R5 stated that "leaders must be proactive and ready to change old ways of working."

R7 noted that "digital transformation needs leaders who can influence people, not just enforce procedures."

R9 observed that "competence now includes being able to interpret project data and act on it quickly."

Collaborative and strategic leadership behaviours also featured strongly in the responses.

R3 reported that "leaders need to bring consultants, contractors, and site teams together around shared information."

R8 stated that "effective leadership must connect field realities with institutional decisions."

R11 noted that "leadership for transformation includes setting standards, ensuring compliance, and sustaining long-term change."

Theme 4: Integration of Digital Technology and Leadership into a Practical Framework for Mitigating Inefficiencies

Respondents described a practical framework as one that combines digital tools with active leadership processes for planning, monitoring, coordination, reporting, and performance improvement. The framework was viewed as needing to function across the project lifecycle and link field data to managerial action.

R3 stated that "an effective framework should connect site observations, reporting systems, and managerial decisions so that problems are identified early."

R8 similarly noted that "digital monitoring should work together with strong coordination and oversight from project leaders."

R11 added that "a workable framework must include regulatory clarity, institutional responsibility, and measurable performance standards."

Respondents also highlighted real-time monitoring, integration of project information, and routine use of digital tools.

R2 stated that "the framework should allow information from design, site progress, and supervision to be seen together."

R6 reported that "performance improves when digital tools are tied to regular review and fast decision-making."

R12 observed that "geospatial and monitoring technologies should feed directly into project control and reporting systems."

Practicality, usability, and accountability were repeatedly mentioned.

R4 noted that "the framework must be simple enough for site teams to use consistently."

R5 stated that "it should help managers detect delays, waste, and coordination problems before they escalate."

R10 added that "technology and leadership must operate together if the framework is to improve efficiency in practice."

The results showed four major themes. First, performance inefficiencies manifested as delays, rework, fragmented coordination, and slow decision-making. Second, socio-technical conditions such as skills, culture, readiness, and infrastructure shaped the adoption and effectiveness of digital technologies. Third, respondents identified leadership competencies such as vision, adaptability, coordination, accountability, and digital awareness as necessary for transformation. Fourth, respondents indicated that a practical mitigation framework should integrate digital tools with leadership processes for monitoring, coordination, and performance control.

DISCUSSION OF RESULTS

The findings indicate that performance inefficiencies in road construction are primarily manifested as delays, rework, fragmented coordination, slow approvals, and weak decision-making. This aligns with the broader construction literature, which identifies cost overruns, delays, poor communication, low productivity, and coordination failures as persistent inefficiency patterns in project delivery (Wang et al., 2024; Kumar and Kumari, 2025; Abdelalim et al., 2024). From a socio-technical perspective, the results suggest that inefficiency is not simply a site-level technical problem, but a systems problem arising from misalignment between operational activities, organisational routines, and decision structures. This supports Socio-Technical Systems Theory, which argues that project performance depends on the alignment of social and technical subsystems rather than the isolated functioning of either one (Appelbaum, 1997; Bauer and Herder, 2009; Mumford, 2006). The respondents' repeated emphasis on poor sequencing, delayed approvals, and weak accountability confirms that inefficiency in road projects is rooted in fragmented work systems rather than in isolated human error.

The second theme shows that the usefulness of digital technology is strongly conditioned by socio-technical readiness. Although respondents recognised the value of GIS, monitoring systems, and digital tracking tools, they consistently noted that these technologies are only effective when supported by organisational readiness, technical competence, management commitment, and a culture that accepts new work practices. This finding is consistent with the literature on digital adoption in road construction, which shows that technologies such as BIM, drones, IoT sensors, mobile field applications, and automated monitoring systems improve planning accuracy, coordination, and real-time control only when they are embedded within enabling organisational and human conditions (Rehman and Islam, 2023; Rao et al., 2022; Qadir et al., 2025). It also reinforces the argument that poor training, low digital literacy, and resistance to change can create technology–organisation gaps that reduce the expected benefits of digitalisation (Thirumal et al., 2024; Dauda et al., 2024; Siriwardhana et al., 2025). In this sense, the findings support the view that digital transformation in road construction is not a purely technical process but an organisational and behavioural transition.

The third theme confirms that leadership is central to whether digital transformation translates into improved project performance. Respondents identified vision, adaptability, accountability, coordination, staff support, and timely use of information as essential leadership behaviours. This closely aligns with the literature, which positions leadership as the primary human mechanism through which digital technologies are accepted, coordinated, and institutionalised in construction organisations (Ongena et al., 2024; Hariyani et al., 2025; Rakovic et al., 2024). The emphasis placed by respondents on leaders who can interpret project data, encourage learning, and connect field realities to institutional decisions is particularly consistent with studies on transformational, participative, and empowering leadership, all of which have been shown to reduce resistance to change and improve collaboration during digital transformation (Gupta, 2025; Toufighi et al., 2024; Jada et al., 2019). The findings, therefore, suggest that leadership competence in road construction now extends beyond conventional supervision to include digital awareness, change management, strategic communication, and the ability to align people with emerging digital systems.

The fourth theme extends this argument by showing that respondents do not see technology and leadership as separate solutions, but as interdependent elements of a practical mitigation framework, as shown in Figure 2. Their call for a framework that links site observations, supervision, reporting systems, real-time monitoring, and managerial action directly reflects the integrative digital-leadership synergy model developed in the literature review. That model posits that digital drivers, leadership competencies, technology integration processes, and performance improvement channels must operate in concert to reduce road construction inefficiencies effectively (Pawar and Dhumal, 2024; Musaigwa and Kalitanyi, 2024; Tagscherer and Carbon, 2023). The respondents' insistence on usability, accountability, regulatory clarity, and measurable standards also supports the literature's argument that successful digital transformation requires not only tools but also governance structures, training routines, interoperability, and collaborative decision-making mechanisms. Thus, the empirical findings validate the study's conceptual position that digital technologies and leadership behaviours are mutually reinforcing levers for mitigating inefficiencies in road construction projects.

Overall, the discussion shows that inefficiencies in road construction projects are better understood as socio-technical and managerial failures than as purely technical deficiencies. The findings support the study's theoretical position that performance improvement depends on joint optimisation between digital systems, organisational readiness, and leadership capability. In practical terms, this means that road construction organisations are more likely to reduce delays, rework, communication breakdowns, and slow decisions when

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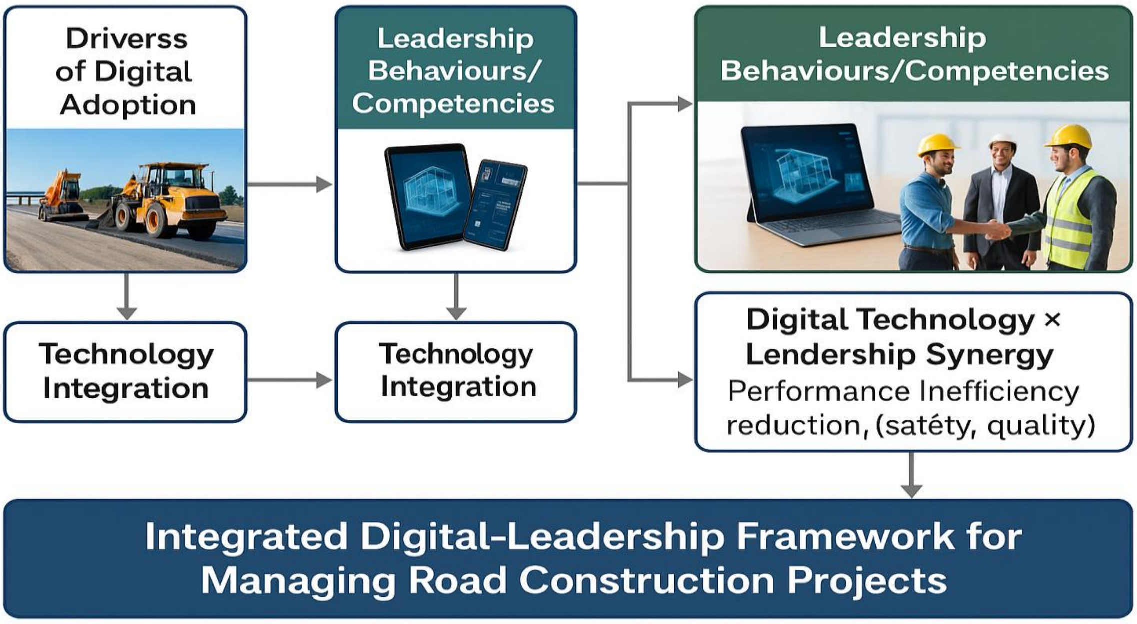
they combine digital tools with leadership behaviours that promote coordination, learning, accountability, and timely action. The study, therefore, contributes empirical support to the integrative digital-leadership framework by demonstrating that technology delivers value only when leadership activates and sustains its use within everyday project processes.

Figure 2. Empirically Refined Integrative Digital Leadership Framework for Mitigating Performance Inefficiencies in Road Construction Projects



Source: Authors' 20256.

Study Implications for Practice, Research, and Policy

The study has important implications for practice because it shows that inefficiencies in road construction are not caused only by on-site technical problems, but also by weak coordination, delayed approvals, fragmented communication, inconsistent supervision, and low digital integration. This means organisations should avoid treating digital technologies as isolated technical solutions and instead embed them within routine project management processes. In practical terms, road agencies, consultants, and contractors should establish integrated digital systems that connect design information, progress tracking, supervision records, field reporting, and decision-making. Shared dashboards, digital reporting platforms, and real-time monitoring tools should be linked to regular review meetings to identify and correct delays, rework, and coordination failures early. The findings also imply that structured user training, clearer workflow responsibilities, and stronger accountability mechanisms must accompany the use of digital technologies. Where digital tools are introduced without organisational readiness, they are likely to remain underused or be seen as additional work rather than as performance-improving systems.

The study further suggests that leadership practice must change if digital transformation is to improve road project performance. The empirical findings show that leadership is the mechanism that determines whether technology becomes useful in daily operations or remains a formality. As a result, project leaders need competencies that go beyond traditional supervision. They must be able to interpret project data, communicate a clear digital vision, coordinate multiple actors, support staff learning, and respond quickly to emerging site problems. This has direct implications for firms and public agencies because leadership development programmes should now include digital literacy, change management, collaborative decision-making, and data-based performance control. Leaders should also create working environments that encourage continuous learning and adaptation, especially where resistance to new systems remains strong. In this sense, the study implies that road construction performance can be improved more sustainably when leadership and technology work together rather than separately.

For research, the study contributes by showing that digital adoption and leadership behaviour should not be studied as separate variables when analysing road construction performance. Instead, future studies should test the interaction among digital readiness, leadership competence, and project outcomes more comprehensively. Quantitative studies could validate the proposed framework across larger samples and different infrastructure sectors, while comparative studies could examine differences between public and private project environments. Longitudinal research is also needed to understand how digital-leadership maturity develops over time and how it affects project efficiency, coordination quality, and decision speed. Further work should also develop measurable indicators for concepts such as digital readiness, leadership responsiveness, coordination efficiency, and real-time project control so that the framework can be used more effectively in performance assessment.

For policy, the findings imply that sector regulators and government institutions should move beyond general support for construction digitalisation and create enforceable systems that guide implementation. Policies should define digital reporting standards, interoperability expectations, supervision protocols, and leadership accountability requirements in road project delivery. Public procurement frameworks should also encourage the use of approved digital monitoring systems and require evidence of organisational capacity to implement them. Since the study shows that digital initiatives become inconsistent without institutional commitment and policy backing, effective policy must support technology adoption together with training, governance, and measurable compliance standards. This would help create a more coordinated and efficient road construction environment.

CONCLUSION

This study sought to develop an integrative digital leadership framework to mitigate performance inefficiencies in road construction projects. The findings show that inefficiencies in this context are not merely technical shortcomings. Still, interconnected socio-technical and managerial failures manifest as delays, rework, fragmented coordination, slow approvals, weak supervision, and poor information flow. The study demonstrates that while digital technologies such as BIM, GIS, drones, IoT-enabled monitoring systems, and mobile field applications have strong potential to improve planning, monitoring, and operational control, their effectiveness depends heavily on organisational readiness, staff competence, institutional support, and consistent integration into routine project processes.

A major contribution of the study lies in establishing that leadership is the enabling mechanism through which digital transformation produces performance gains. Leadership behaviours such as vision-setting, adaptability, accountability, collaborative coordination, digital awareness, and timely decision-making were found to be essential in embedding digital tools into practice and converting them from passive reporting mechanisms into active performance-improvement systems. In this regard, the study confirms that digitalisation and leadership should not be treated as separate solutions, but as mutually reinforcing levers within a balanced socio-technical system.

The proposed framework, therefore, offers both theoretical and practical value by linking digital drivers, leadership competencies, technology integration processes, and performance outcomes into a coherent explanatory model. Overall, the study concludes that road construction performance can be improved more sustainably when digital capability is aligned with effective leadership, institutional commitment, and coordinated project governance.

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