

Effect of Emerging Technology Adoption On Construction Planning and Scheduling Performance in Bauchi State, Nigeria

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Abstract: *The construction industry is increasingly adopting digital and emerging technologies to address persistent problems of schedule delays, cost overruns, inefficient resource utilisation and fragmented project information. However, evidence concerning whether technology adoption translates into measurable improvements in construction planning and scheduling performance remains limited in developing construction contexts. This study examines the effect of emerging technology adoption on construction planning and scheduling performance in Bauchi State, Nigeria. A quantitative cross-sectional survey was conducted among construction professionals involved in project planning, scheduling and delivery. From 265 questionnaires administered, 256 valid responses were obtained, representing a 96.6% valid response rate. Data were analysed using descriptive statistics, correlation analysis and multiple regression. The findings indicate that labour requirements ($M = 3.72$), external stakeholder influence ($M = 3.48$), cost implications ($M = 3.46$), technology adaptability ($M = 3.45$) and technology quality ($M = 3.41$) were the principal factors influencing adoption. Major adoption challenges included low awareness and leadership buy-in ($M = 4.08$), resistance to change ($M = 3.90$), and technical and integration difficulties ($M = 3.66$). The regression model was statistically significant, explaining 56.0% of the variance in construction planning and scheduling performance ($R = 0.748$, $R^2 = 0.560$, adjusted $R^2 = 0.545$, $F(8,247) = 38.742$, $p < 0.001$). Reduced delays and cost overruns ($\beta = 0.294$), enhanced efficiency ($\beta = 0.226$), data-driven decision-making ($\beta = 0.187$), project cost management ($\beta = 0.169$), and real-time updates ($\beta = 0.152$) were significant predictors. The findings demonstrate that digital technologies can improve project delivery when embedded within organisational capabilities, competent human resources and reliable information processes. The study contributes context-specific evidence from a Nigerian construction environment and highlights organisational readiness and technology integration as important conditions for converting digital adoption into planning and scheduling improvements.*

Keywords: emerging technologies, construction planning, construction scheduling. Construction 4.0, digitalisation; project performance

INTRODUCTION

Construction projects operate within a highly interdependent environment in which time, cost, resources, information, quality and stakeholder requirements must be coordinated throughout the project lifecycle. Construction planning and scheduling consequently represent fundamental project-management functions because they translate project objectives into sequences of activities, resource requirements, durations, milestones and control mechanisms. Poor planning can propagate uncertainty into procurement, labour allocation, site operations and cost control, ultimately increasing the probability of delays, rework and resource inefficiency.

The digital transformation of the construction industry has created new possibilities for addressing these longstanding problems. Construction 4.0 encompasses the application of technologies associated with Industry 4.0, including Building Information Modelling (BIM), Internet of Things (IoT), artificial intelligence (AI), machine learning (ML), cloud computing, digital twins, robotics, automation, advanced sensing and data analytics. A systematic review of Construction 4.0 research identified industrial IoT, cloud computing, big data and analytics as major technological domains, while also highlighting considerable opportunities for further development in automation and immersive technologies.

The significance of these technologies for planning and scheduling is particularly important because conventional construction planning frequently depends on fragmented information, manually updated programmes and periodic reporting. Such arrangements can make it difficult for project teams to detect deviations early and adjust activities in response to changing site conditions. Emerging digital technologies provide opportunities to establish more integrated information environments in which project information can be captured, processed, visualised and communicated more rapidly. BIM illustrates this transition. By integrating geometric, semantic and temporal information, BIM can support visualisation, sequencing, clash detection, quantity management and coordination. Recent evidence indicates that 4D BIM has expanded considerably as a mechanism for improving construction planning, resource management and error reduction, although the literature remains fragmented regarding the overall configuration of its benefits.

AI and machine learning introduce another dimension by enabling predictive analysis and automated decision support. Research on AI/ML in construction indicates applications across different stages of the project lifecycle, including prediction, risk analysis, resource management and project control. More specifically, automated scheduling research has moved beyond static programmes towards optimisation and adaptive scheduling. Yao et al. (2024), for example, investigated automated construction scheduling using deep reinforcement learning, while Kammouh et al. (2022) examined dynamic control of construction project schedules during execution.

IoT and sensor technologies further enhance this capability by connecting physical construction operations to digital information systems. Sensors, location technologies, imaging systems and other data-acquisition technologies can provide information about site activities and resource conditions, potentially allowing schedules to be updated in response to actual project progress. Nevertheless, sensor adoption remains constrained by technical, organisational and skills-related barriers. A recent

review identified barriers including advanced skill requirements, lack of standardisation and difficulties relating to data networks and management.

Digital twins represent a further development because they seek to establish a continuously connected digital representation of physical assets or construction processes. Recent research has developed taxonomies of construction digital-twin applications and identified the interaction among applications, technologies and data as a major research issue. Other reviews similarly indicate that digital-twin implementation in the built environment remains at an emerging stage and faces technological and organisational challenges.

These developments are important from a cleaner-production and sustainability perspective. Digitalisation can potentially improve resource efficiency by reducing avoidable rework, improving material and labour planning, limiting idle resources and supporting more accurate decision-making. Recent research in the *Journal of Cleaner Production* identifies digitalisation as increasingly relevant to sustainable building practices and examines multiple digital technologies in relation to their applications, opportunities and challenges. Digital technologies may therefore contribute indirectly to cleaner construction by improving the efficiency with which materials, energy, labour and information are used.

However, the technological potential should not be equated automatically with successful implementation. A comprehensive review of Construction 4.0 found a persistent gap between theoretical technology propositions and practical implementation, with high initial costs, shortages of skilled personnel, weak regulatory environments, leadership hesitation and resistance to change among the barriers limiting adoption. Consequently, technology adoption should be understood as an organisational and socio-technical process rather than merely the acquisition of software or hardware. This issue is especially relevant in developing construction markets. Nigerian construction organisations operate within environments characterised by variations in digital infrastructure, organisational capabilities, skills, investment capacity and technology awareness. Recent Nigerian studies have documented both increasing awareness of digital technologies and continuing implementation barriers (Jegade et al., 2025; Shetima et al., 2024; Usman et al., 2025). Ibrahim et al. (2026), for example, demonstrate the growing relevance of digital twins to Construction 4.0 within the Nigerian AEC sector, while also highlighting barriers to their implementation.

Despite the increasing body of international research, an important empirical gap remains. Much of the existing literature examines individual technologies, general digital transformation, or conceptual benefits. Less attention has been devoted to examining whether the combined adoption of emerging technologies translates into measurable construction planning and scheduling performance within a specific Nigerian regional context. Furthermore, evidence from Bauchi State is limited. This study therefore examines the effect of emerging technology adoption on construction planning and scheduling performance in Bauchi State, Nigeria. Rather than treating digitalisation as an inherently beneficial intervention, the study investigates both the conditions influencing adoption and the measurable performance outcomes associated with adoption.

First, technology-specific fragmentation characterises much of the existing literature. BIM, AI, IoT, digital twins and automated scheduling are often examined independently, despite increasing evidence

that their value depends on integration within broader digital ecosystems. Reviews of Construction 4.0 have identified the need to move from isolated technology applications towards integrated technological and organisational systems. Second, there is a technology–performance gap. Existing studies frequently identify potential benefits such as improved coordination, visualisation and information management, but fewer empirical studies directly quantify how technology-enabled planning and scheduling relates to project-performance outcomes.

Third, there is a contextual gap. African and Nigerian construction environments remain underrepresented in international Construction 4.0 research. A review of digital technologies in AEC found that Africa remains comparatively underrepresented in the research literature. Evidence from Bauchi State is particularly limited.

The present study addresses these gaps by examining emerging technology adoption as an integrated planning and scheduling capability and testing its relationship with construction performance using empirical data from 256 construction professionals.

LITERATURE REVIEW

Construction planning and scheduling

Construction planning is the systematic process through which project activities, methods, resources, sequencing and execution strategies are established before and during construction. Planning requires project teams to determine what must be undertaken, how activities will be executed, when they should occur, which resources are required and how activities interact. Scheduling operationalises the plan by allocating activities to specific periods and establishing logical relationships among tasks. Conventional techniques such as bar charts, critical path method and network scheduling remain important, but their effectiveness depends on the accuracy and timeliness of the information supporting them.

The dynamic nature of construction means that a schedule developed at the beginning of a project rarely remains unchanged. Weather, design changes, procurement problems, labour availability, equipment breakdowns, stakeholder decisions and unforeseen site conditions can alter the original programme. Consequently, planning and scheduling increasingly require mechanisms for continuous monitoring and adjustment.

Nwadigo et al. (2022) conceptualise construction planning and scheduling as a dynamic system affected by uncertainty, resources, technology and environmental conditions. This perspective is consistent with recent work on automated planning and control, which demonstrates the potential for technology to automate elements of the Last Planner System and support dynamic replanning. The distinction illustrated in Figure 1 is important. The contribution of emerging technologies is not simply that they replace traditional planning tools. Their greater significance lies in their ability to connect planning, monitoring, prediction and adjustment into a more continuous decision-making process.

Emerging technologies in construction

Emerging construction technologies can be conceptualised as interconnected digital and automation technologies that improve the collection, processing, communication or execution of project information.

Table 1. The Emerging technologies and their planning/scheduling applications

Technology	Principal capability	Planning and scheduling application	Expected performance pathway
BIM/4D BIM	Integrated information and visualisation	Sequencing, clash detection, activity simulation	Improved coordination and schedule reliability
AI/ML	Prediction and optimisation	Delay prediction, resource optimisation, schedule optimisation	Earlier intervention and improved decision quality
IoT/sensors	Real-time data acquisition	Progress monitoring, equipment/labour tracking	Faster deviation detection
Digital twins	Physical–digital integration	Real-time monitoring and scenario analysis	Dynamic planning and control
Cloud platforms	Information integration	Collaborative planning and document management	Reduced information fragmentation
Big data analytics	Pattern identification	Risk analysis and performance forecasting	Data-driven decision-making
Computer vision	Automated observation	Progress measurement and safety monitoring	Faster and more objective reporting
Robotics/automation	Automated execution	Repetitive activities and production control	Productivity and resource efficiency
AR/VR	Immersive visualisation	Constructability and sequencing review	Improved understanding and coordination

The literature suggests that these technologies increasingly operate as complementary rather than independent tools. BIM can provide the information structure, IoT can supply real-time data, AI can process and predict from the data, while digital twins can connect the resulting information with physical project conditions.

BIM and 4D planning

BIM represents one of the most established digital technologies within construction. Its relevance to planning derives from its capacity to connect project objects and information within a shared digital environment. The addition of time creates 4D BIM, enabling three-dimensional project information to be associated with construction activities. 4D BIM can assist project teams in visualising construction sequences before physical execution. This can improve understanding of spatial and temporal relationships and facilitate identification of potential conflicts. A recent systematic review of 4D BIM identified benefits relating to visualisation, project planning, resource management and error reduction. Nevertheless, BIM implementation is not automatically associated with improved

performance. Its effectiveness depends on information quality, interoperability, user capability, organisational commitment and integration with project processes.

Artificial intelligence and machine learning

AI and ML introduce predictive capabilities into construction management. Instead of relying exclusively on historical schedules and human judgement, AI-based systems can identify patterns within large datasets and generate predictions concerning delays, cost performance, resource requirements and other project outcomes. Recent research demonstrates increasing application of AI/ML across the construction project lifecycle. Machine learning has also been integrated with planning systems to predict schedule performance, while deep reinforcement learning has been used to automate construction scheduling decisions (Lagos et al., 2024; Yao et al., 2024).

However, AI effectiveness depends heavily on data quality. Construction organisations that do not maintain reliable historical project information may not have the datasets necessary for accurate prediction. Consequently, digital capability must be understood as involving both technological infrastructure and organisational data capability.

IoT and real-time construction monitoring

IoT enables physical objects and construction processes to generate and transmit data. Sensors can monitor location, environmental conditions, equipment utilisation, productivity and progress. This creates the possibility of comparing actual site conditions against planned activities. Real-time information is particularly valuable in dynamic construction environments because delays become more costly when detected late. Early identification allows project managers to adjust resources, resequence activities or revise procurement decisions. Nevertheless, IoT adoption requires reliable connectivity, data standards, technical skills and appropriate data-management systems. Recent research on sensor adoption highlights barriers involving skills, standardisation, data networks and user-centred design.

Digital twins and dynamic scheduling

Digital twins extend digital modelling by creating a connected representation of a physical system that can receive and process data over time. In construction, digital twins can integrate BIM, sensors, site data, analytics and visualisation. Recent literature identifies construction digital twins as an emerging field with applications across construction-site management and project lifecycle activities. Their potential relevance to scheduling arises from their ability to compare the current state of construction with planned states and support predictive analysis. This creates a potential transition from static scheduling to adaptive scheduling (Kammouh et al., 2022).

Planning quality and project performance

Project planning has long been associated with project success. Planning establishes the basis for scope definition, resource allocation, time control and risk management. Inadequate planning can create downstream problems because errors in early decisions may propagate through procurement, construction and project control. However, planning quality should not be assessed exclusively through the existence of a programme. A technically sophisticated schedule may still be ineffective if the underlying information is inaccurate, if stakeholders do not use it, or if the schedule is not updated when conditions change. This is where emerging technologies can potentially add value. Technology

can improve the frequency and accuracy of information exchange, but organisational processes determine whether such information is translated into action.

Factors influencing emerging technology adoption

The adoption of emerging technologies is influenced by economic, technological, organisational and behavioural factors. Initial investment, software licensing, hardware acquisition, training and maintenance costs can discourage adoption, especially among small and medium-sized construction organisations. Interoperability, reliability, adaptability, data quality and compatibility with existing systems influence whether new technologies can be incorporated into existing workflows. Skills, training, technology confidence and resistance to change affect actual utilisation. Technology adoption is therefore not equivalent to technology acquisition. Leadership support, organisational culture, strategic alignment and internal capacity influence the sustainability of technology implementation. Clients, consultants, contractors, regulators and other project stakeholders may influence technology adoption because construction projects depend on inter-organisational information exchange. These dimensions are supported by recent Construction 4.0 reviews identifying cost, skills, leadership and resistance to change as persistent implementation barriers. Nigerian research similarly identifies awareness and barriers as important considerations in digital technology implementation (Jegade et al., 2025; Shetima et al., 2024).

Barriers to technology adoption

The literature indicates that technology adoption can create a paradox: technologies intended to improve efficiency may initially increase organisational complexity.

The most frequently reported barriers include:

1. insufficient technical skills;
2. high initial investment;
3. resistance to organisational change;
4. lack of leadership commitment;
5. poor awareness;
6. data interoperability problems;
7. inadequate digital infrastructure;
8. uncertainty about return on investment; and
9. fragmented project responsibilities.

This means that technology adoption should not be viewed as a purely technological intervention. Instead, it represents a socio-technical transformation in which technology, people, organisational structures and processes must operate together.

Theoretical perspective

The study is primarily informed by Technology–Organisation–Environment (TOE) logic, complemented by a socio-technical perspective. The TOE framework explains technology adoption through three contexts: technological characteristics, organisational conditions and external environmental influences. This is particularly suitable because the present study identifies technology adaptability and quality, organisational awareness and leadership, labour and skills, and third-party stakeholders as factors influencing adoption.

The socio-technical perspective strengthens the framework by recognising that technological performance depends on interactions among technological systems and human/organisational systems.

The resulting theoretical proposition is:

Emerging technologies are more likely to improve construction planning and scheduling when technological capability is aligned with organisational readiness, human competence and stakeholder coordination.

MATERIALS AND METHODS

Research design

A quantitative cross-sectional survey design was adopted. The design was selected because the study seeks to measure construction professionals' perceptions and statistically examine relationships between emerging technology adoption and construction planning and scheduling performance. The study does not manipulate technology adoption experimentally; rather, it examines existing practices and reported outcomes within the construction industry.

Study area

The study was conducted in Bauchi State, Nigeria, with particular emphasis on construction professionals involved in building and infrastructure project delivery. Bauchi provides a useful regional context for examining digital construction adoption because construction activities coexist with conventional project-management practices and emerging digital technologies.

Population

The study population comprised Builders, Quantity Surveyors, Architects and Project Managers involved in construction activities.

Table 2. Population of the study

S/N	Professional category	Population
1	Builders	250
2	Quantity Surveyors	140
3	Architects	83
4	Project Managers	156
5	Total	629

Sample size and sampling

The population of 629 was used as the sampling frame. The minimum required sample was approximately 239 respondents. To increase coverage and compensate for potentially unusable questionnaires, 265 questionnaires were administered.

Proportionate stratified sampling was adopted.

Table 3. Proportionate allocation of questionnaires

S/N	Professional category	Population	Proportion
1	Builders	250	39.7%
2	Quantity Surveyors	140	22.3%
3	Architects	83	13.2%
4	Project Managers	156	24.8%
5	Total	629	100.0%

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A structured questionnaire was developed from the literature on Construction 4.0, digital construction adoption, construction planning and project performance. Responses were measured using a five-point Likert scale: 1 = strongly disagree 2=disagree=neutral=agree 5 = strongly agree. The questionnaire consisted of sections covering respondent characteristics, factors influencing technology adoption, perceived benefits, adoption challenges and performance outcomes.

Validity and reliability

Content validity was established through review by construction-management academics and experienced industry practitioners. The instrument was subsequently pilot tested among 20 construction professionals who were excluded from the main sample. Cronbach's alpha was used to assess internal consistency. A threshold of 0.70 was adopted as acceptable for exploratory and applied research.

Table 4. Reliability of study constructs

Construct	Cronbach's α	Interpretation
Factors influencing adoption	0.756	Acceptable
Benefits/challenges perception	0.762	Acceptable
Barriers to adoption	0.815	Good
Effects on project performance	0.816	Good

All coefficients exceed 0.70, indicating satisfactory internal consistency.

Data collection and response rate

Of the 265 questionnaires distributed, 256 were usable and nine were excluded because of incomplete responses.

Table 5. Questionnaire response

Category	Frequency	Percentage
Valid questionnaires	256	96.60
Invalid questionnaires	9	3.40
Not returned	0	0.00
Total administered	265	100.00

The valid response rate of 96.6% provides a strong empirical basis for the analysis.

Data analysis

SPSS was used for data analysis. Descriptive statistics were used to identify adoption factors, benefits and barriers. Pearson correlation was used to examine bivariate associations. Multiple regression was then used to determine the combined and individual effects of the technology-related predictors on construction planning and scheduling performance. The regression model was specified as:

$$CPP = \beta_0 + \beta_1 ICC + \beta_2 EE + \beta_3 RDCO + \beta_4 AS + \beta_5 RTU + \beta_6 DDDM + \beta_7 PCM + \beta_8 AQA + \epsilon$$

where:

- **CPP** = construction planning and scheduling/project performance;
- **ICC** = improved collaboration and communication;

- **EE** = enhanced efficiency;
- **RDCO** = reduced delays and cost overruns;
- **AS** = automated scheduling;
- **RTU** = real-time updates;
- **DDDM** = data-driven decision-making;
- **PCM** = project cost management;
- **AQA** = automated quality analysis.

RESULTS

Respondent characteristics

Table 6. Professional specialisation

S/N	Profession	Frequency	Percentage
1	Architect	40	15.6
2	Builder	50	19.5
3	Quantity Surveyor	45	17.6
4	Engineer	60	23.4
5	Other	61	23.8
	Total	256	100.0

The respondents represented a broad range of construction disciplines, providing multidisciplinary perspectives on planning, scheduling and technology adoption. Editorial note: the original categories overlap because “18–23” and “over 20” both include years above 20. This should be corrected in the raw dataset before final submission. The reported frequencies themselves sum to 256.

Factors influencing adoption

Table 9. Factors influencing emerging technology adoption

Factor	Mean	SD	Interpretation
Labour	3.725	1.134	High
NThird-party/stakeholder influence	3.477	0.652	High
Cost	3.459	0.806	High
Technology adaptability	3.445	0.816	High
Technology quality	3.413	0.907	High
Knowledge of technology	3.367	0.643	Moderate
Aim and functions of technology	3.080	0.957	Moderate
Leaders' opinion	2.197	0.955	Low
Time	1.741	0.847	Low

Labour requirements recorded the highest mean, followed by stakeholder influence, cost, technology adaptability and technology quality. The overall mean of 3.206 indicates a moderate level of influence. The relatively low rating for time suggests that respondents did not perceive time constraints as a

principal determinant of adoption. Similarly, the low score for leaders' opinion requires careful interpretation: it does not mean leadership is objectively unimportant; rather, respondents in this sample did not perceive leadership opinion as a dominant factor in their adoption decisions.

Perceived benefits and implications

Table 10. Benefits and implications of emerging technologies

Indicator	Mean	SD	Interpretation
Technical efficiency/issues	3.661	0.690	High
Workforce displacement	3.634	0.952	High
Enhanced productivity	3.576	0.662	High
High initial cost	3.496	0.873	High
Improved collaboration	3.493	1.160	High
Improved planning/scheduling efficiency	3.404	1.168	Moderate
Risk management	3.165	0.871	Moderate
Learning curve	3.125	0.985	Moderate
Ethical implications	3.060	0.650	Moderate

The results indicate a moderate overall perception of benefits and implications. Productivity and collaboration were positively recognised, but respondents also identified technical difficulties, workforce displacement and initial investment as important concerns. This finding is consistent with the wider Construction 4.0 literature, which cautions against assuming that digital transformation produces benefits without corresponding investment in skills, organisational change and implementation capability.

Adoption challenges

Table 11. Challenges affecting emerging technology adoption

Challenge	Mean	SD	Interpretation
Low awareness and leadership buy-in	4.080	0.777	High
Resistance to change	3.897	0.915	High
Technical/integration issues	3.661	0.976	High
High initial cost	3.297	0.853	Moderate
Lack of skills and training	3.252	0.842	Moderate

Low awareness and leadership buy-in emerged as the most prominent challenge. Resistance to change was second, followed by technical and integration difficulties. The results reinforce the argument that successful digitalisation is not determined exclusively by the availability of technology. Construction 4.0 reviews similarly identify organisational resistance, leadership hesitation, skills shortages and implementation costs as recurring barriers.

The selected technology-enabled performance variables and construction performance**Table 12.** the selected technology-enabled performance variables and construction performance

Predictor	Pearson r	Relationship
Reduced delays and cost overruns	0.712	Strong positive
Enhanced efficiency	0.689	Strong positive
Data-driven decision-making	0.641	Positive
Project cost management	0.602	Positive

The correlations indicate positive relationships between technology-enabled planning capabilities and construction performance. Reduced delays and cost overruns recorded the strongest correlation ($r = 0.712$), followed by enhanced efficiency ($r = 0.689$).

Multiple regression**Table 13. Regression model summary**

R	R ²	Adjusted R ²	Std. Error	F	df	p
0.748	0.560	0.545	0.381	38.742	8, 247	<0.001

The model explains 56.0% of the observed variance in construction planning and scheduling/project performance. The adjusted R^2 of 0.545 indicates that the explanatory power remains substantial after adjustment for the number of predictors.

Table 14. ANOVA of regression model

Source	SS	df	MS	F	p
Regression	46.824	8	5.853	38.742	<0.001
Residual	36.112	247	0.146		
Total	82.936	255			

The overall regression model is statistically significant, indicating that the predictors jointly explain a significant proportion of variation in construction performance. The strongest predictor was reduced delays and cost overruns ($\beta = 0.294$, $p < 0.001$). Enhanced efficiency was the second significant predictor ($\beta = 0.226$, $p < 0.001$). Data-driven decision-making, project cost management and real-time updates were also significant.

By contrast, improved collaboration and communication, automated scheduling and automated quality analysis were not statistically significant after controlling for the other predictors. Importantly, these results should not be interpreted as demonstrating that the non-significant technologies are ineffective. Rather, their unique contribution within this particular multivariate model was not statistically distinguishable from zero at the 5% level.

DISCUSSION

The findings provide empirical evidence that emerging technology adoption is associated with improved construction planning and scheduling performance in the Bauchi State context. The regression model explained 56% of the observed variance, indicating that technology-enabled

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capabilities represent an important component of project performance, although 44% of the variance remains attributable to factors outside the model.

The strong contribution of reduced delays and cost overruns is theoretically plausible because the central value proposition of digital planning is improved visibility and control. Technologies that provide better information regarding actual progress, resources and emerging deviations can support earlier intervention. This finding is consistent with research on dynamic scheduling and automated construction planning, where real-time information and predictive techniques are increasingly used to support schedule control.

Enhanced efficiency was also a significant predictor. This suggests that technology adoption is valuable not simply because it digitises existing processes, but because it can reduce information-processing time, improve coordination and support more efficient resource allocation. The result is consistent with systematic reviews showing that Construction 4.0 technologies can improve efficiency across construction processes.

Data-driven decision-making was another significant predictor. This result is particularly important because digital transformation is fundamentally. The findings provide empirical evidence that emerging technology adoption is associated with improved construction planning and scheduling performance in the Bauchi State context. The regression model explained 56% of the observed variance, indicating that technology-enabled capabilities represent an important component of project performance, although 44% of the variance remains attributable to factors outside the model.

The strong contribution of reduced delays and cost overruns is theoretically plausible because the central value proposition of digital planning is improved visibility and control. Technologies that provide better information regarding actual progress, resources and emerging deviations can support earlier intervention. This finding is consistent with research on dynamic scheduling and automated construction planning, where real-time information and predictive techniques are increasingly used to support schedule control.

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Data-driven decision-making was another significant predictor. This result is particularly important because digital transformation is fundamentally an information transformation process. The value of BIM, IoT, AI and digital twins is partly derived from their ability to generate, integrate and analyse project data. Without reliable information, the predictive and analytical capabilities of these technologies are constrained.

Real-time updates also demonstrated a significant effect. This finding reinforces the distinction between traditional static scheduling and digitally enabled dynamic control. Construction schedules are affected continuously by changes in resources, design, procurement and site conditions. Real-time

information can reduce the time between the occurrence of a deviation and managerial response. Project cost management was also significant. This result suggests that technology-enabled planning has implications extending beyond scheduling. Integrated digital information can support quantity management, cost forecasting, progress measurement and financial control.

The non-significance of automated scheduling is noteworthy. One possible interpretation is that automation alone does not necessarily produce improved project outcomes when organisational processes and human decision-making remain important. Recent research on automated planning similarly suggests that automation should be considered together with human and organisational factors rather than as a purely technical solution.

Similarly, improved collaboration and communication did not make a statistically significant independent contribution in the regression model despite receiving a relatively high descriptive rating. This suggests that perceived collaboration benefits may overlap with other variables, particularly efficiency and data-driven decision-making. A future study using structural equation modelling could test these possible mediation and interaction effects.

The findings regarding adoption barriers are also significant. Low awareness and leadership buy-in recorded the highest mean score, followed by resistance to change. This is consistent with international Construction 4.0 research identifying leadership hesitation and resistance to change as persistent barriers. It also corresponds with Nigerian evidence indicating continuing challenges in digital technology awareness and implementation (Jegede et al., 2025; Shetima et al., 2024).

The implication is that construction digitalisation should not be approached merely through procurement of software and hardware. Organisations require an implementation ecosystem involving leadership commitment, workforce development, process redesign, data governance and stakeholder coordination.

CONCLUSION

This study examined the effect of emerging technology adoption on construction planning and scheduling performance in Bauchi State, Nigeria, using empirical evidence from 256 construction professionals. The findings demonstrate that emerging technology adoption is significantly associated with construction performance. The regression model explained 56.0% of the observed variance, with reduced delays and cost overruns, enhanced efficiency, data-driven decision-making, project cost management and real-time updates emerging as statistically significant predictors. At the same time, the study demonstrates that technology adoption is not frictionless. Low awareness and leadership buy-in, resistance to change and technical integration difficulties were identified as major barriers. The evidence therefore suggests that the performance effects of digital construction depend not only on technological availability but also on organisational readiness and implementation capability. The study contributes regional empirical evidence to the growing Construction 4.0 literature and demonstrates why digital transformation should be linked to measurable project outcomes rather than technology adoption being treated as an end in itself. From a cleaner-production perspective, improved planning and scheduling can contribute to more efficient utilisation of labour, materials, equipment and information, potentially reducing avoidable waste and inefficiency.

Recommendations

Based on the findings, the following recommendations are proposed:

1. Develop organisational digital-readiness programmes. Construction firms should establish structured digital-transformation plans covering technology, people, processes, training and data management.
2. Since low awareness and leadership buy-in recorded the highest challenge score, senior management should integrate digital construction objectives into organisational planning and project-delivery strategies.
3. Investment should focus on technologies demonstrably connected to delay reduction, efficiency, cost control, data-driven decision-making and real-time monitoring.
4. Continuous training should cover BIM, digital project-management platforms, data analytics, AI-supported decision-making and emerging construction technologies.
5. Construction organisations should adopt digital systems capable of exchanging information across design, cost, scheduling and site-management platforms.
6. Firms with limited digital capacity should begin with targeted pilot projects before undertaking organisation-wide technology deployment.
7. . Technology investment should be evaluated not only in terms of financial return but also in relation to resource efficiency, rework reduction, waste prevention and sustainable project delivery.

Limitations and Future Research

The study is subject to several limitations.

First, the research employed a cross-sectional survey design; consequently, the results demonstrate statistical association within the observed dataset rather than experimental causality.

Second, the data were based on professional perceptions. Future research should combine survey responses with objective project records, including actual schedule variance, cost variance, labour productivity and rework data.

Third, the study was geographically restricted to Bauchi State. Comparative studies involving other Nigerian states would help determine whether the relationships identified here remain consistent across different institutional and digital-infrastructure environments.

Fourth, emerging technologies were considered collectively. Future studies should investigate BIM, AI/ML, IoT, digital twins and automated scheduling separately and then examine their interaction.

Finally, future research could employ structural equation modelling to investigate whether organisational readiness, leadership support and workforce capability mediate or moderate the relationship between technology adoption and construction performance.

Contribution to Knowledge

The study makes four principal contributions.

1. it provides empirical evidence from Bauchi State that emerging technology-enabled planning and scheduling capabilities are significantly associated with construction performance.

2. it identifies the performance pathways through which digitalisation is most strongly associated with project outcomes: reduced delays and cost overruns, enhanced efficiency, data-driven decision-making, project cost management and real-time information.
3. it demonstrates that adoption barriers are predominantly socio-technical, with awareness, leadership commitment, resistance to change and technical integration emerging as important constraints.
4. it connects construction digitalisation with cleaner-production principles by demonstrating how improved planning and scheduling can support more efficient use of labour, information and project resources.

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