

Delay Detection Factors and Sustainable Project Performance in Public Building Construction Projects in Plateau State, Nigeria

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Abstract: Construction project delays generate cascading effects on schedule reliability, cost control, resource utilisation and quality, while delayed recognition of emerging problems can reduce the opportunity for corrective intervention. This study examined the factors associated with delay detection and their relationship with project performance in public building construction projects in Plateau State, Nigeria. A quantitative cross-sectional survey was conducted among construction professionals involved in public building projects. Of 271 questionnaires administered, 245 valid responses were obtained (90.41%). Five factor groups were assessed: planning and management factors (PMF), financial and client-related factors (FCF), contractor and labour factors (CLF), material and equipment factors (MEF), and design and external factors (DEF). Descriptive statistics, Pearson correlation and multiple regression were used. All five categories recorded moderate aggregate influence, with PMF highest (3.02). Perceived adverse effects of delays were highest for time performance (4.27), followed by cost (4.20), resource utilisation (4.11) and quality (4.01). DEF had a strong positive association with delay outcomes ($r = 0.748$, $p < 0.01$). The regression model was significant and explained 57.6% of project-performance variance ($R^2 = 0.576$; adjusted $R^2 = 0.567$; $F = 64.995$, $p < 0.001$). DEF was significant ($\beta = 0.754$, $p < 0.001$), as was FCF ($\beta = -0.167$, $p = 0.005$), whereas PMF, CLF and MEF were not individually significant at the 5% level. The study demonstrates that delay management should move beyond identifying causes towards timely detection, information flow and corrective response, with implications for resource efficiency and sustainable project delivery.

Keywords: construction delays; early warning; project performance; public buildings; resource utilisation; sustainability

INTRODUCTION

The construction industry plays a fundamental role in infrastructure provision, employment generation, economic development, and the creation of the physical assets required to support social and economic activities. However, the sector continues to experience persistent challenges associated with project delays, cost escalation, inefficient resource utilisation, rework, material waste, and inadequate quality performance. These problems are particularly significant in developing countries, where weaknesses in project planning, financing, procurement, contract administration, supervision, and institutional

capacity can substantially affect project delivery. In Nigeria, construction delays have long been recognised as a major impediment to effective project delivery. Early empirical evidence identified financing and payment arrangements, poor contract management, material shortages, inaccurate estimating, and price fluctuations among important causes of construction delay and cost overruns (Mansfield et al., 1994). Similarly, Aibinu and Jagboro (2002) established that construction delays in Nigeria are strongly associated with time and cost overruns, while Aibinu and Odeyinka (2006) demonstrated that a wide range of participant-related and external factors contribute substantially to overall project delays.

More recent Nigerian evidence suggests that the problem remains persistent despite developments in construction management practices. Egwim et al. (2023), for example, identified project quality control, project scheduling, contractors' financial difficulties, political influence, site conditions, and price fluctuations among important underlying factors associated with construction delays. Their findings further indicate that late material delivery, poor decision-making, and adverse weather conditions can operate as significant mechanisms through which construction activities are disrupted. Recent evidence from Nigerian building projects likewise continues to identify client-related, financial, contractual, procurement, and external factors as important sources of delay. For example, recent research on high-rise building projects in Nigeria found client-related and external factors to be particularly prominent, with cash-flow and credit constraints representing important contributors to unanticipated delay events (Egwim et al., 2026). These findings demonstrate that construction delay remains a contemporary project-management problem rather than an issue that has been resolved through the evolution of construction management practices.

Despite the extensive literature on construction delays, an important dimension of the problem remains comparatively underexplored: the capacity of project stakeholders to detect emerging delay conditions early enough to permit effective corrective action. Much of the conventional delay literature has concentrated on identifying, ranking, classifying, and modelling the causes of delay. Although this body of knowledge is important for understanding why projects fail to meet planned completion targets, a predominantly cause-oriented perspective provides limited insight into how emerging delay conditions can be recognised during project implementation, communicated to relevant stakeholders, interpreted appropriately, and converted into timely management action. In other words, identifying the factors capable of causing delay is not necessarily equivalent to possessing the organisational and informational capability to detect the early manifestations of those factors.

This distinction is particularly important because construction delays are often progressive rather than instantaneous. A project may initially experience a relatively small deviation in material delivery, labour productivity, payment certification, design information, site access, or activity progress. If such deviation is identified promptly, its effects may be contained through rescheduling, resource reallocation, acceleration, alternative procurement, improved coordination, or other corrective measures. Conversely, when an emerging problem remains undetected or is detected only after its consequences become substantial, the resulting delay may propagate to dependent activities and ultimately develop into significant schedule and cost overruns. Thus, the effectiveness of delay management depends not only on knowledge of delay causes but also on the ability of project teams to identify relevant warning signals and initiate appropriate responses while intervention remains feasible.

The concept of early detection is therefore central to proactive construction project control. Early-warning research suggests that the value of project information depends on more than its availability; information must be generated at an appropriate time, communicated to relevant decision-makers, interpreted correctly, and translated into suitable intervention. In this context, delay detection can be conceptualised as a project-management capability involving continuous monitoring of planned versus actual performance, identification of deviations, interpretation of emerging risks, communication among project participants, and timely initiation of corrective measures. Recent developments in digital construction management reinforce this perspective. For instance, Radman et al. (2026) demonstrated that an integrated digital monitoring framework combining mobile data capture, BIM, cloud-based data integration, and Earned Value/Earned Schedule analytics can improve data continuity, forecast reliability, and earlier detection of construction delays. Their findings demonstrate the growing transition from retrospective project reporting towards real-time and proactive project control.

The distinction between delay occurrence and delay detection is particularly relevant to the present study. A delay-related condition may exist within a project without immediately producing a visible project-level delay. For example, delayed procurement, inadequate labour availability, slow decision-making, incomplete design information, or declining productivity may initially constitute warning signals rather than confirmed delays. Effective project management therefore requires mechanisms capable of recognising these signals before they develop into critical schedule deviations. The underlying study consequently distinguishes between delay-related conditions and the capacity to recognise and respond to such conditions, thereby shifting attention from a predominantly reactive approach to delay management towards a proactive project-control perspective.

This proactive perspective is also important from the standpoint of construction sustainability. The consequences of project delays extend beyond completion dates and contractual performance. Prolonged construction periods can increase labour waiting time, equipment utilisation, site overheads, energy consumption, material handling, transportation requirements, and other resource demands. Furthermore, disruption of planned work sequences can increase rework and material wastage. Evidence from Nigerian construction projects indicates that rework can adversely affect both time and cost performance, thereby creating additional resource requirements and reducing overall project efficiency (Eze & Idiake, 2018). Consequently, the early detection of emerging delays can potentially contribute to more efficient use of labour, materials, equipment, energy, and financial resources.

The sustainability implications are particularly important because construction project performance is increasingly understood as multidimensional. Successful project delivery cannot be evaluated solely according to whether a project is completed on time. Rather, contemporary construction management requires consideration of interrelated dimensions including time, cost, quality, productivity, resource efficiency, waste minimisation, and broader environmental and social outcomes. In the Nigerian context, research has identified cost and time overruns, poor quality, inadequate communication, financing constraints, material-price escalation, and stakeholder-related problems as interconnected constraints on sustainable project delivery (Tanko et al., 2017). Consequently, improving the capacity to detect emerging delays may provide benefits that extend beyond schedule control to the efficient utilisation of construction resources and the reduction of avoidable project losses.

The problem is particularly significant in public building projects, where project delivery frequently involves complex institutional, contractual, financial, and administrative arrangements. Public projects typically involve multiple stakeholders, including government clients, contractors, consultants, regulatory bodies, suppliers, financiers, and end users. Consequently, delays may emerge from the interaction of several factors rather than from a single identifiable source. Financial constraints, delayed payment, procurement procedures, variations, slow decision-making, inadequate supervision, changes in project requirements, contractor capacity, material-price fluctuations, and institutional bureaucracy can interact and reinforce one another. Evidence from Nigerian public building projects has, for example, identified contractor financial difficulties, material-price increases, and variations as prominent causes of delay, illustrating the distinctive nature of delay mechanisms within public-sector project environments.

Under such circumstances, timely delay detection becomes particularly important because the effects of an emerging problem can propagate across interconnected construction activities. A delay in procurement may interrupt labour deployment; interruption of labour may reduce productivity; reduced productivity may affect activity duration; and extended activity duration may increase equipment, supervision, and site overhead costs. Similarly, delayed decisions or approvals can prevent subsequent activities from commencing even when the required physical resources are available. This interdependency suggests that delay detection should not be regarded merely as an administrative reporting exercise but as an important mechanism for maintaining project stability and protecting project performance.

Nevertheless, existing research has predominantly examined what causes construction delays and what consequences delays produce, rather than how effectively emerging delay conditions can be detected before their consequences become severe. Aibinu and Odeyinka (2006), for example, provided important evidence concerning the numerous factors responsible for delays in Nigerian construction projects, while Aibinu and Jagboro (2002) demonstrated the adverse effects of delay on time and cost performance. Similarly, Egwim et al. (2023) advanced understanding of underlying delay factors in Nigeria by identifying groups of factors strongly associated with project delay. However, these studies leave an important conceptual and empirical question insufficiently addressed: to what extent do the factors that enable project stakeholders to detect emerging delay conditions influence actual delay outcomes and overall project performance?

This gap has become increasingly important with the emergence of digital project-monitoring technologies. Contemporary construction projects generate substantial volumes of information through schedules, progress reports, cost records, BIM models, site inspections, procurement records, mobile applications, sensors, and other digital systems. However, the mere availability of project data does not guarantee effective delay detection. Fragmented information, inconsistent reporting, poor communication, limited analytical capability, delayed data updates, and inadequate managerial responsiveness can prevent useful information from being converted into early warnings. Recent research on digital delay detection similarly identifies fragmented reporting, data uncertainty, and delayed system integration as persistent challenges to effective project monitoring, while demonstrating that integrated digital systems can support earlier detection and improved decision-making (Radman et al., 2026).

This observation reinforces the need to distinguish between data availability, information interpretation, and management response. A project organisation may possess progress data but fail to identify a significant deviation; alternatively, a deviation may be identified but not communicated to the responsible decision-maker; in other cases, a warning may be recognised but not followed by timely intervention because of institutional, financial, contractual, or managerial constraints. Effective delay detection therefore represents a chain of interconnected capabilities rather than a single monitoring activity. This conceptualisation provides a stronger basis for examining the relationship between delay-detection factors, delay outcomes, and project performance.

Within Plateau State, Nigeria, this issue warrants particular empirical investigation. Although construction projects constitute an important component of infrastructure development in the state, there is limited empirical evidence specifically examining the factors that facilitate timely detection of delays in public building projects and the extent to which such factors influence project performance. Evidence obtained from other Nigerian states or international contexts cannot necessarily be transferred directly to Plateau State because project-financing arrangements, procurement procedures, institutional structures, contractor capabilities, supervision practices, stakeholder relationships, and administrative processes may differ across locations. Consequently, there is a need for context-specific evidence capable of explaining how delay detection operates within the institutional and operational environment of public building projects in Plateau State.

Four principal gaps therefore emerge from the existing literature. First, construction-delay research has predominantly focused on identifying and ranking delay causes, with comparatively limited attention to the factors that enable project teams to detect emerging delays at an early stage. Second, empirical evidence linking delay-detection factors with multidimensional project performance remains limited, particularly in relation to time, cost, quality, productivity, and resource efficiency. Third, evidence generated from other geographical and institutional contexts cannot automatically be generalised to Plateau State because differences in financing, procurement, supervision, contractor capacity, and institutional arrangements may influence both delay occurrence and detection. Fourth, there is limited empirical research specifically addressing delay detection in public building projects in Plateau State. These gaps are consistent with the need identified in the underlying study to move beyond conventional explanations of delay and investigate the capacity of project stakeholders to recognise and respond to emerging delay conditions.

Addressing these gaps has both theoretical and practical significance. Theoretically, the study extends the conventional conceptualisation of construction delay by positioning delay detection as a project-control capability that potentially links emerging project conditions with delay outcomes and subsequent project performance. This approach shifts the analytical emphasis from a purely retrospective assessment of why delays occurred towards a more proactive examination of how project teams can identify warning signals before they develop into critical performance failures. Practically, understanding the factors that influence delay detection can assist clients, consultants, contractors, and project managers in strengthening project-monitoring and control systems. Such systems may include regular progress monitoring, milestone tracking, variance analysis, risk registers, structured reporting mechanisms, stakeholder communication protocols, digital monitoring technologies, and clearly defined escalation and intervention procedures.

The study therefore proceeds from the premise that effective delay management should begin before a project becomes critically delayed. Rather than treating delay exclusively as a post-event condition, the study considers the ability to detect emerging warning signals as an important component of proactive project management. Where project information is timely and reliable, monitoring systems are effective, stakeholders are competent, communication is efficient, and management is responsive, emerging deviations can potentially be identified and addressed before they propagate into substantial project failures. Conversely, weak detection mechanisms may allow relatively minor deviations to accumulate until they produce significant schedule overruns, cost escalation, rework, inefficient resource utilisation, and compromised quality.

Accordingly, this study investigates delay detection and its implications for the performance of public building projects in Plateau State, Nigeria. The study examines the factors that influence the detection of construction delays, evaluates the effects of delays on project performance, establishes the relationship between delay-detection factors and delay outcomes, and determines whether delay-detection factors significantly influence overall project performance. In doing so, the study contributes to the construction management literature by connecting the traditionally separate domains of delay causes, early detection, delay outcomes, and project performance, while also highlighting the potential role of proactive delay management in improving resource efficiency and supporting more sustainable construction delivery.

LITERATURE REVIEW

Construction delay as a dynamic project-control problem

Construction delay is commonly defined in relation to deviation from planned or contractual completion. Research across different contexts identifies recurring classes of causes, including financial constraints, client decisions, design changes, contractor capability, material supply, labour availability, environmental conditions and administrative processes. Nigerian studies have similarly reported financing/payment, planning, materials and contractor-management problems as recurring causes. □cite□turn0search5□turn0search9□

The critical conceptual issue is that a cause of delay and a delay-detection capability are not identical constructs. For example, late payment may be a causal condition, while financial monitoring, payment-status reporting and escalation procedures determine how early the emerging risk is recognised. Likewise, a design change is an event, whereas design review, approval tracking and information coordination constitute mechanisms through which the resulting schedule risk may be detected.

Table 1: Categories of delay-detection factors

Category	indicators represented	Control implication
PMF	planning, scheduling, supervision, monitoring/control, team coordination	strengthens visibility and coordination
FCF	fund release, contractor payment, project funding, client decisions, scope changes	reduces financial uncertainty and stoppage risk
CLF	contractor performance, labour productivity, skilled labour, absenteeism, workforce management	supports continuity and labour efficiency
MEF	material supply, price fluctuation, equipment availability/breakdown, procurement	reduces waiting, idle time and disruption
DEF	design errors/changes, drawing approvals, environmental conditions, regulatory approvals	captures interface and external risks

The five-category structure is grounded in the supplied empirical instrument and results. All categories were assessed as moderate, with PMF highest at 3.02, followed by FCF and DEF at 3.01, MEF at 2.91 and CLF at 2.90. filecite, turn4file

The Early-warning detection and response

Early-warning research emphasises monitoring, risk analysis, earned-value information, performance measurement, stakeholder analysis, project assessment, maturity assessment, lessons learned, cause-effect analysis, interface analysis and project-environment analysis. Figure 1: The supplied review also identifies text mining and project-health

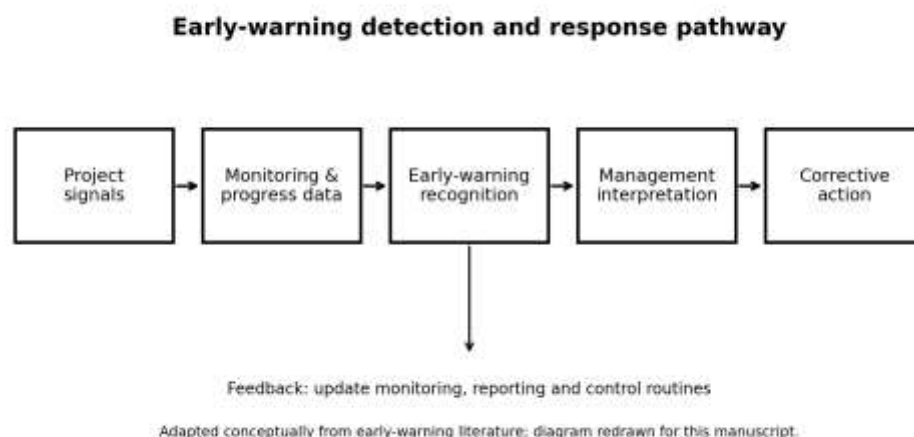


Figure 1. Early-warning detection and response pathway. Source: authors'

The early-warning process is not purely technical. Ansoff and McDonnell's filter perspective, as presented in the source study, highlights surveillance, mentality and power filters: information must be captured, recognised and authorised for action. Haji-Kazemi and colleagues similarly show that communication barriers between observers and decision-makers can prevent effective response.

Delay detection, resource efficiency and sustainable delivery

The sustainability relevance of delay detection arises from the cascading resource effects of prolonged projects. Delays may extend equipment use, increase labour waiting and material wastage, generate rework and consume additional financial resources. The empirical study found strong agreement that delays adversely affect time, cost, resource utilisation and quality. This makes early detection a potential enabling mechanism for reducing avoidable resource consumption, although the present dataset does not directly quantify embodied carbon, energy use or material-life-cycle impacts. Recent work is also moving from descriptive delay-factor ranking towards data-enabled monitoring and prediction. 2026 review reports machine-learning applications across planning, progress tracking, risk detection, delay prediction and performance monitoring, while a recent digital monitoring framework explicitly combines delay detection and visualisation. □cite□turn0search18□ Such developments support a shift from reactive delay management towards continuous project intelligence, but digital approaches should complement rather than replace organisational monitoring, professional judgement and decision authority.

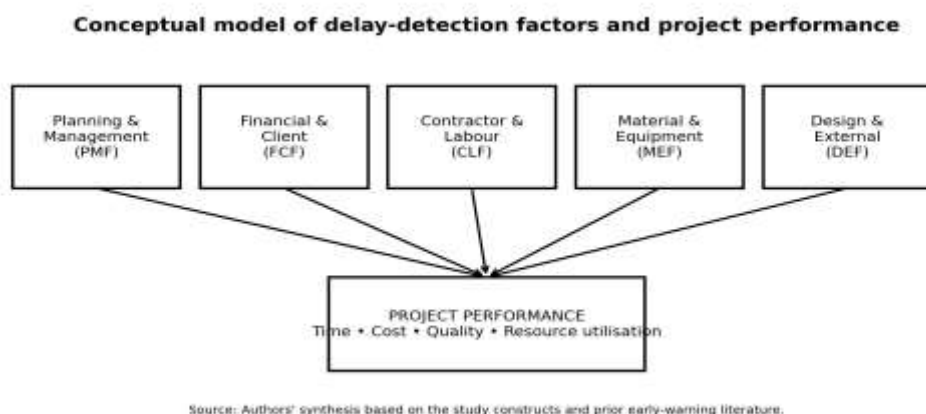


Figure 2. Conceptual relationship between delay-detection factor groups and project performance.

Project-performance dimensions

The study operationalised project performance through time, cost, quality and resource utilisation. This multidimensional approach is preferable to treating completion time alone as project success because delay can simultaneously influence financial expenditure, workmanship and resource efficiency. The source study reports that these four dimensions were selected as the principal performance indicators.

Research gap and analytical proposition

The literature therefore suggests a control chain: project conditions generate signals; monitoring and information processes determine whether signals are detected; managerial interpretation determines whether warnings are acted upon; and timely intervention can limit downstream impacts on time, cost, quality and resource use. The empirical gap is whether the identified factor groups explain variation in project performance within Plateau State's public-building context. The present study tests that relationship rather than assuming that all delay categories have equivalent effects.

METHODOLOGY

Research design

A quantitative cross-sectional survey design was adopted. The approach was appropriate because the study measured delay-related constructs numerically and examined their statistical relationships with project performance. Respondents were construction professionals involved in public building projects in Plateau State, Nigeria.

Population, sampling and respondents

The estimated population was 570 construction professionals and relevant stakeholders. Using the Krejcie and Morgan approach, a sample size of 234 was indicated. Purposive sampling was used to select respondents with direct experience of planning, execution, monitoring, supervision, and delay management. In practice, 271 questionnaires were administered.

Table 3: Valid responses were retrieved, giving a 90.41% response rate.

Characteristic	Key result
Profession	Builders 48 (19.6%); Contractors 46 (18.8%); Quantity Surveyors 42 (17.1%)
Experience	1–5 years 40 (16.3%); 6–10 years 70 (28.6%); 11–15 years 75 (30.6%); 16+ years 60 (24.5%)
Education	Degree/HND 135 (55.1%); Masters 47 (19.2%); PhD 12 (4.9%); Others 51 (20.8%)
Public-building experience	Yes 220 (89.8%)
Experience of schedule delays	Yes 233 (95.1%)

The respondent profile indicates substantial exposure to the study context: 89.8% had worked on public building projects, and 95.1% had experienced schedule delays.

Data Collection Instrument and validity and reliability

A structured questionnaire was administered face-to-face using a five-point Likert scale from 1 = strongly disagree to 5 = strongly agree. Content validity was assessed through expert review. A pilot test involving 20 respondents outside the main study area was used for reliability assessment. All reported Cronbach's alpha coefficients exceeded 0.70: PMF 0.746, FCF 0.719, CLF 0.758, MEF 0.772, DEF 0.816, and delay outcome 0.817.

Data analysis

Descriptive statistics were used to assess factor importance and delay impacts, while Pearson correlation was used to assess relationships between delay-detection factors and delay outcomes. Multiple regression was used to estimate the collective and individual effects of PMF, FCF, CLF, MEF, and DEF on project performance.

RESULTS AND DISCUSSION

Table 4: Delay-detection factors

Factor group	Aggregate mean	Interpretation
Planning and Management (PMF)	3.02	Moderate
Financial and Client-related (FCF)	3.01	Moderate
Design and External (DEF)	3.01	Moderate
Material and Equipment (MEF)	2.91	Moderate
Contractor and Labour (CLF)	2.90	Moderate

PMF recorded the highest aggregate mean (3.02), with poor coordination among project teams recording the highest individual item mean (3.06). The overall pattern indicates that respondents perceived all five categories as relevant but not uniformly dominant.

Effects of delays on project performance

The second objective of the study was to assess the effects of construction delays on the performance of public building projects in Plateau State, Nigeria. Project performance was examined across four principal dimensions: time performance, cost performance, resource utilisation, and quality performance. Respondents were asked to assess the extent to which construction delays affect each of these dimensions. The results are presented in Table 5.

Table 5: Effects of delays on project performance

Performance dimension	Aggregate mean	Interpretation
Time performance	4.27	Agreed
Cost performance	4.20	Agreed
Resource utilisation	4.11	Agreed
Quality performance	4.01	Agreed

The results presented in Table 5 indicate that respondents generally agreed that construction delays adversely affect all four dimensions of project performance. The aggregate mean scores ranged from 4.01 to 4.27, indicating a consistently strong perception of the adverse consequences of delay. Time performance recorded the highest aggregate mean (4.27), followed by cost performance (4.20), resource utilisation (4.11), and quality performance (4.01). The results therefore suggest that the most immediately perceived consequence of construction delay is deterioration in schedule performance, although its effects extend to project cost, resource efficiency, and quality.

The relatively high mean score for time performance (4.27) demonstrates that respondents strongly recognised delays as a direct threat to the achievement of planned project completion dates. This finding is reinforced by the individual item results, in which time overrun recorded the highest mean score of 4.35. The result suggests that once construction activities deviate from their planned durations,

the cumulative effect is likely to manifest as an extension of the overall project completion period. This is consistent with the established construction-delay literature, which identifies time overrun as one of the most direct and pervasive consequences of delay. Aibinu and Jagboro (2002), for example, established that construction delays significantly affect project completion time and can generate consequential disruptions to project delivery. Similarly, Aibinu and Odeyinka (2006) found that delay factors in Nigerian construction projects are closely associated with extensions of project duration. The present finding therefore confirms that time performance remains the most prominent dimension through which respondents perceive the effects of construction delay.

The cost-performance dimension recorded an aggregate mean of 4.20, indicating strong agreement that construction delays adversely affect project cost performance. The individual results provide further evidence of this relationship, with the likelihood of cost overruns recording a mean of 4.31, the second-highest individual effect identified in the analysis. This result can be explained by the additional expenditure generated when construction activities extend beyond their planned duration. Prolonged projects may incur additional site overheads, supervision costs, labour expenses, equipment-hire charges, financing costs, and exposure to material-price escalation. In addition, delays may disrupt procurement and work sequencing, thereby creating further inefficiencies and unplanned expenditure. The finding is consistent with Mansfield et al. (1994), who identified time and cost overruns as closely interconnected consequences of construction delay in Nigeria, and with Aibinu and Jagboro (2002), who demonstrated that delays can substantially increase the cost of construction projects. The present result therefore reinforces the view that schedule deterioration should not be considered independently from financial performance.

The resource-utilisation dimension recorded an aggregate mean of 4.11, demonstrating that respondents also perceived construction delays as having substantial implications for the efficient utilisation of project resources. The individual results show that prolonged equipment use recorded a mean of 4.22, while reduced overall resource efficiency recorded 4.16, inefficient labour utilisation recorded 4.14, and inefficient resource allocation recorded 4.12. Material wastage recorded a comparatively lower, although still substantial, mean of 3.91. Collectively, these findings indicate that delays can create conditions in which labour, equipment, materials, and financial resources are not deployed according to the original project plan.

The high mean for prolonged equipment use is particularly important because construction equipment generally generates costs throughout its period of deployment, irrespective of whether it is being used at optimum productivity. When project activities are delayed or disrupted, equipment may remain on site for longer than initially planned, increasing hiring, fuel, maintenance, depreciation, and operational costs. Similarly, inefficient labour utilisation may arise when workers experience waiting time because preceding activities have not been completed or required materials and information are unavailable. These conditions reduce productive working time and can contribute to lower overall project efficiency. The findings therefore support the argument that construction delay represents not merely a temporal problem but also a resource-efficiency problem, with implications for the economic and operational sustainability of project delivery.

The comparatively lower but still high mean for material wastage (3.91) suggests that respondents recognised a relationship between delay and inefficient material utilisation, although this effect was

perceived as somewhat less pronounced than the effects on time, cost, labour, and equipment. Prolonged project duration can expose materials to deterioration, repeated handling, theft, damage, or changes in project requirements. Furthermore, disruption of planned work sequences may result in materials being delivered before they are required, increasing the possibility of damage or inefficient storage. This finding is particularly relevant to sustainable construction because material wastage represents both an economic loss and an environmental burden through additional extraction, production, transportation, and disposal requirements.

The quality-performance dimension recorded an aggregate mean of 4.01, which, although the lowest of the four aggregate dimensions, still represents strong agreement that construction delays adversely affect quality performance. The result indicates that respondents considered quality to be an important consequence of delay rather than an isolated technical issue. Delays can create pressure to accelerate subsequent activities, compress planned work durations, alter work sequences, increase subcontractor coordination problems, or undertake multiple activities simultaneously. Under such circumstances, quality-control procedures may be compromised, inspections may be rushed, and rework may become more likely. The individual result showing increased rework at a mean of 4.08 provides additional support for this interpretation.

The relationship between delay and rework is particularly important because rework can create a reinforcing cycle of poor performance. An initial delay may disrupt work sequencing and increase the likelihood of errors or defective work; the resulting rework then consumes additional labour, materials, equipment, and time, which may further prolong the project. Eze and Idiake (2018) similarly demonstrated that rework can have significant implications for the time and cost performance of building projects in Nigeria. Therefore, the finding that rework received a high mean score indicates that the effects of construction delay may extend beyond the original delayed activity and generate secondary performance losses.

Overall, the results demonstrate that construction delays have multidimensional effects on public building project performance. Although time performance recorded the highest aggregate mean, the relatively high scores for cost performance, resource utilisation, and quality performance demonstrate that delay is not simply a scheduling problem. Rather, it constitutes an interconnected project-performance problem capable of generating cost escalation, inefficient resource deployment, material wastage, prolonged equipment use, labour inefficiency, rework, and quality-related consequences. The ranking of the aggregate dimensions—time performance (4.27), cost performance (4.20), resource utilisation (4.11), and quality performance (4.01) therefore indicates that delay management should adopt an integrated perspective rather than focusing exclusively on completion dates.

These findings have an important implication for the central argument of this study concerning delay detection. Since delays generate interconnected consequences across time, cost, resources, and quality, their early detection provides an opportunity for project stakeholders to intervene before these consequences become more severe. Early identification of declining productivity, delayed material delivery, prolonged equipment deployment, cost deviations, or emerging rework can allow project managers to initiate corrective actions such as resource reallocation, schedule adjustment, improved coordination, alternative procurement, or targeted supervision. Consequently, effective delay detection

should be regarded not merely as a mechanism for protecting the completion date but as a broader project-performance and resource-efficiency mechanism.

The findings are also consistent with the broader literature demonstrating that construction delays can create cascading effects across project-performance dimensions. Mansfield et al. (1994) and Aibinu and Jagboro (2002) established the strong relationship between construction delays, time overruns, and cost escalation in Nigeria, while Aibinu and Odeyinka (2006) highlighted the wide range of factors capable of generating delay and disrupting project delivery. More recent Nigerian evidence similarly demonstrates that financial, managerial, contractual, procurement, and external factors continue to contribute to construction delays and associated performance problems (Egwim et al., 2023). The present findings extend this body of knowledge by demonstrating that, from the perspective of project stakeholders in Plateau State, the consequences of delay encompass not only time and cost but also resource utilisation and quality performance.

In summary, the results provide strong empirical evidence that construction delays significantly undermine the broader performance of public building projects. Time performance was the most adversely affected dimension (aggregate mean = 4.27), followed by cost performance (4.20), resource utilisation (4.11), and quality performance (4.01). The high individual means for time overrun (4.35), cost overrun (4.31), prolonged equipment use (4.22), reduced resource efficiency (4.16), inefficient labour utilisation (4.14), inefficient resource allocation (4.12), increased rework (4.08), and material wastage (3.91) further demonstrate the multidimensional nature of delay impacts. The evidence consequently supports the need for proactive monitoring and early delay detection as part of an integrated project-control strategy for improving the performance and sustainability of public building projects in Plateau State.

Correlation analysis

Table 6 presents the correlation analysis

Factor	Correlation with delay outcome (r)	Interpretation
PMF	-0.052	Weak negative
FCF	-0.105	Weak negative
CLF	-0.071	Weak negative
MEF	-0.104	Weak negative
DEF	0.748**	Strong positive

DEF showed the strongest observed relationship with delay outcomes ($r = 0.748$, $p < 0.01$). PMF and FCF were also strongly correlated with each other ($r = 0.700$, $p < 0.01$), while CLF and MEF showed a strong correlation ($r = 0.799$, $p < 0.01$). □ filecite □ turn4file1 □

Multiple regression

Table 7: Multiple regression analysis

Statistic	Value
R	0.759
R ²	0.576
Adjusted R ²	0.567
Standard error	0.364
F	64.995
df	5, 239
p	<0.001

The regression model was statistically significant and explained 57.6% of the variation in project performance. The adjusted R² of 0.567 indicates that substantial explanatory power remained after accounting for the five predictors. The ANOVA partition was regression SS = 42.981 (df = 5), residual SS = 31.611 (df = 239), total SS = 74.592 (df = 244), with F = 64.995 and p < 0.001.

Table 8 presents the Multiple regression

Predictor	Standardised β	p-value	Decision at 5%
PMF	0.115	0.054	Not significant
FCF	-0.167	0.005	Significant
CLF	0.093	0.187	Not significant
MEF	-0.073	0.301	Not significant
DEF	0.754	<0.001	Significant

DEF had the largest standardised coefficient ($\beta = 0.754$, $p < 0.001$), whereas FCF had a significant negative coefficient ($\beta = -0.167$, $p = 0.005$). PMF, CLF and MEF did not reach the 5% significance threshold.

DISCUSSION OF RESULTS

The moderate ratings across all five factor groups indicate that delay detection in public building projects is distributed across interacting managerial, financial, workforce, supply, design, and external conditions rather than being attributable to one isolated mechanism. The prominence of planning and coordination is consistent with Nigerian and international evidence that planning, supervision, financing and stakeholder coordination are recurrent determinants of schedule performance. The high means for time, cost, resource utilisation and quality effects demonstrate that delay is multidimensional. In particular, the high resource-utilisation score supports the sustainability interpretation of the study: prolonged equipment deployment, inefficient labour utilisation, material wastage and rework represent avoidable consumption associated with project disruption. The present survey does not quantify the associated carbon or energy consequences, so these sustainability implications should be treated as resource-efficiency implications rather than measured environmental effects.

The strong DEF–delay-outcome correlation is substantively important. Design changes, design errors, approval delays and external constraints can propagate across activity interfaces and affect downstream work. Nigerian evidence similarly identifies client and external factors as important delay groups, while recent Nigerian research on high-rise construction reports client-related and external factors among prominent delay categories.

The regression results add a different layer of evidence: DEF and FCF were individually significant, whereas PMF, CLF and MEF were not significant after simultaneous entry. This should not be interpreted to mean that non-significant categories are unimportant in practice. Their bivariate and descriptive patterns, and their correlations with other predictors, indicate that delay mechanisms are interdependent. The strong PMF–FCF and CLF–MEF associations illustrate this interdependence and caution against interpreting individual regression coefficients as isolated causal mechanisms.

The study also supports the growing move towards early-warning and digital monitoring. Current construction research is increasingly using machine learning for delay prediction, progress monitoring and risk detection, while digital frameworks are integrating monitoring, visualisation and delay detection. □cite□turn0search18□ The practical implication for Plateau State is not that AI automatically solves delay, but that project organisations can progressively integrate reliable progress data, structured reporting, schedule-status information and professional judgement into earlier warning systems.

Implications for cleaner and more sustainable project delivery

The findings have three linked implications. First, early detection can reduce the duration over which disrupted activities consume labour, equipment and materials. Second, design and external-risk monitoring can reduce downstream rework and idle resource exposure when emerging changes are identified before they propagate. Third, financial monitoring can support continuity of procurement and labour mobilisation. These mechanisms align delay management with cleaner-production principles through prevention of avoidable resource consumption, although direct environmental benefits require project-level energy, material, waste or carbon measurements that were outside the present survey.

For practice, public clients should establish integrated early-warning registers linking design approvals, payment status, material procurement, work progress and external constraints. Project managers should institutionalise periodic progress reviews and escalation thresholds. Digital monitoring can subsequently be added where data quality and organisational readiness permit. The evidence base for such digital approaches is expanding, including machine-learning-enabled construction project management and delay-risk prediction.

CONCLUSIONS

This study examined delay-detection factors and project performance in public building construction projects in Plateau State, Nigeria. Five categories, PMF, FCF, CLF, MEF, and DEF, were assessed as moderate contributors to delay detection. Construction delays were perceived to adversely affect time, cost, resource utilisation and quality. DEF had the strongest relationship with delay outcomes ($r =$

0.748, $p < 0.01$), while the combined regression model explained 57.6% of project-performance variance ($R^2 = 0.576$, $F = 64.995$, $p < 0.001$). DEF and FCF were significant individual predictors. The central contribution is a shift from viewing delay only as an outcome to treating detection as a project-control capability. For public building delivery, earlier recognition of design/external and financial warning conditions can improve the opportunity for corrective action. From a cleaner-production perspective, the value lies in preventing avoidable resource use, rework and prolonged deployment. Future empirical work should validate these relationships using longitudinal project records and direct sustainability indicators.

Contribution to knowledge

This study contributes to knowledge by shifting the focus of construction-delay research from the traditional identification of delay causes to the early detection of emerging delay conditions.

- I. It provides empirical evidence from public building projects in Plateau State, Nigeria, demonstrating that delays adversely affect time, cost, resource utilisation, and quality performance.
- II. The study further highlights the link between delay and resource inefficiencies, including prolonged equipment use, labour inefficiency, material wastage, and rework. Conceptually, the study positions delay detection as a proactive project-control capability that can support timely intervention and improved project performance.
- III. The findings therefore provide a basis for developing more proactive and, potentially, digitally enabled approaches to delay monitoring and sustainable construction project delivery.

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