OPEN ACCESS

Saudi Journal of Business and Management Studies
Abbreviated Key Title: Saudi J Bus Manag Stud
ISSN 2415-6663 (Print) |ISSN 2415-6671 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Maintenance Management and Project Sustainability in Manufacturing Companies in Rivers State

James Edwin Ikechukwu[1]*, Prof. Sunny R. Igwe[1]
[1]University of Port Harcourt, Business School, Port Harcourt, Rivers State

DOI: https://doi.org/10.36348/sjbms.2026.v11i06.001 | **Received:** 02.05.2026 | **Accepted:** 22.06.2026 | **Published:** 24.06.2026

***Corresponding author:** James Edwin Ikechukwu
University of Port Harcourt, Business School, Port Harcourt, Rivers State

Abstract

Maintenance management remains a persistent challenge in Nigerian manufacturing, where reactive approaches dominate despite their well-documented inadequacies for achieving operational sustainability. This study examined the relationship between maintenance management dimensions (preventive, corrective, and predictive maintenance) and project sustainability indicators (cost control, minimal downtime, and asset lifespan) in manufacturing companies in Rivers State, Nigeria. A quantitative, cross-sectional survey design was employed, with data collected from 198 manufacturing companies using a structured questionnaire. Descriptive statistics, Pearson correlation, and multiple regression analysis were used to test the hypotheses. The findings revealed that preventive maintenance significantly positively affects cost control ($\beta = 0.31$), minimal downtime ($\beta = 0.29$), and asset lifespan ($\beta = 0.27$). Predictive maintenance demonstrated the strongest effects across all sustainability indicators ($\beta = 0.47$, 0.44, and 0.41, respectively). Corrective maintenance showed no significant relationship with any sustainability outcome. The study concludes that proactive maintenance strategies, particularly predictive maintenance, are essential for achieving project sustainability, while corrective maintenance delivers no measurable sustainability benefits. Theoretical contributions include empirical validation of the conceptual framework within the Rivers State manufacturing context. Practical implications advise manufacturing firms to prioritise investing in predictive maintenance technologies. Policy recommendations encourage regulatory incentives for proactive maintenance adoption. Limitations include the cross-sectional design and single-region focus.

Keywords: maintenance management, preventive maintenance, corrective maintenance, predictive maintenance, project sustainability, cost control, minimal downtime, asset lifespan.

INTRODUCTION

The manufacturing sector constitutes a critical pillar of Nigeria's economic diversification agenda, with Rivers State occupying a preeminent position as a hub of industrial activity in the Niger Delta region. As the locus of numerous manufacturing enterprises spanning petrochemicals, food processing, plastics, pharmaceuticals, and construction materials, Rivers State's manufacturing landscape contributes substantially to regional employment generation, gross domestic product, and technological capability development (Adewale & Ogunleye, 2023; Nwankwo & Eze, 2024). The strategic significance of manufacturing companies in Rivers State extends beyond their direct economic contributions; these enterprises serve as vital nodes in supply chains that connect local producers to national and regional markets, thereby, facilitating broader economic integration and development (Okonkwo *et al.,*2023). According to the Manufacturers Association of Nigeria (MAN, 2024), Rivers State consistently ranks among the top three Nigerian states in terms of manufacturing output, industrial employment, and capital investment, underscoring its indispensable role in the national industrial landscape. However, the operational effectiveness and long-term viability of these manufacturing entities remain contingent upon a frequently overlooked yet indispensable organisational function: maintenance management (Adewumi & Olaniyi, 2025; Ighravwe, 2022).

Despite the acknowledged importance of robust maintenance regimes for industrial competitiveness and operational excellence, manufacturing companies in

Rivers State confront persistent operational challenges stemming from inadequate maintenance practices (Emeka & Chukwuma, 2023; Oluwole & Adebayo, 2025). The prevailing reactive approach to maintenance wherein interventions occur only after equipment failure has engendered a cascade of adverse consequences, including unplanned production stoppages, escalated operational expenses, compromised product quality, diminished asset longevity, and heightened workplace safety risks (Babalola *et al.,*2023; Daraojimba *et al.,*2023). Empirical evidence from Nigerian manufacturing contexts reveals that poor maintenance culture costs industrial operators billions of naira annually through preventable equipment failures, expedited spare parts procurement, and lost production hours (Ogundipe & Fasola, 2024; Rokeeb, 2023). Every unplanned shutdown translates directly into revenue erosion, delayed production schedules, contractual penalties, and strained customer relationships (Lawal & Yusuf, 2025; Oyewole *et al.,*2023). This pattern resonates across Nigerian industry, where a broader "culture of neglect" manifests in deferred maintenance that, contrary to mistaken beliefs about immediate cost savings, represents "postponed liability" that ultimately inflates capital expenditure, accelerates asset deterioration, and undermines long-term organisational sustainability (Adebayo & Ojo, 2024; Ogunbiyi *et al.,*2023). The manufacturing sector's susceptibility to these challenges is particularly acute in Rivers State given the capital-intensive nature of production equipment, the corrosive environmental conditions in the Niger Delta, and the compounding effects of downtime on supply chain reliability (Ebere & Njoku, 2025; Ibekwe & Nwachukwu, 2024).

While extant literature has established positive associations between maintenance practices and operational performance outcomes, a conspicuous gap persists regarding the comparative effectiveness of specific maintenance strategies preventive, corrective, and predictive on project sustainability within the Nigerian manufacturing environment (Akinwale & Adeleke, 2023; Nwosu & Okafor, 2025). Existing studies have documented the theoretical benefits of predictive and preventive maintenance strategies in enhancing equipment reliability, reducing waste, and extending asset lifecycles (Anosike, 2014; Sikander & Zafar, 2021). However, empirical investigation focusing specifically on manufacturing companies in Rivers State remains limited, with most available research concentrating on oil and gas, power generation, or extractive industries rather than the manufacturing sector (Daraojimba *et al.,*2023; Rokeeb, 2023). Furthermore, the conceptual framework proposed by Rokeeb (2023), Anosike (2014), and Daraojimba *et al.,*(2023) provides a foundation for understanding the relationship between maintenance management dimensions (preventive, corrective, and predictive maintenance) and project sustainability indicators, including cost control, minimal downtime, and asset lifespan. Nevertheless, systematic empirical validation of this framework within the Rivers State manufacturing context is lacking, representing a significant lacuna that this study seeks to address (Olatunji & Adelekan, 2024; Ukpong & Edet, 2025).

The primary purpose of this study is to examine the relationship between maintenance management and project sustainability in manufacturing companies in Rivers State, drawing upon and empirically validating the conceptual framework advanced by Rokeeb (2023), Anosike (2014), and Daraojimba *et al.,* (2023). However, specifically, this study seeks to achieve the following objectives:

1. To determine the effect of preventive maintenance on project sustainability among manufacturing companies in Rivers State.
2. To assess the effect of corrective maintenance on project sustainability among manufacturing companies in Rivers State.
3. To evaluate the effect of predictive maintenance on project sustainability among manufacturing companies in Rivers State.

LITERATURE REVIEW

Conceptual Review

Maintenance Management

Maintenance management encompasses the systematic ensemble of technical, administrative, and managerial actions intended to retain an asset's functional capability or restore it to a state wherein it can perform its required function (Ighravwe, 2022; Sikander & Zafar, 2021). Within the manufacturing context, maintenance management represents a strategic organisational function that extends far beyond mere repair activities to encompass planning, scheduling, resource allocation, performance measurement, and the continuous improvement of physical assets (Adewumi & Olaniyi, 2025; Mansour Diop *et al.,*2025). The discipline has evolved significantly from its historical characterisation as a necessary but non-value-adding cost centre to recognition as a core competency that directly influences operational excellence, competitive positioning, and long-term organisational sustainability (Babalola *et al.,*2023; Daraojimba *et al.,*2023). Drawing upon the conceptual framework advanced by Rokeeb (2023), Anosike (2014), and Daraojimba *et al.,*(2023), maintenance management in this study is operationalised through three principal dimensions: preventive maintenance, corrective maintenance, and predictive maintenance.

Preventive maintenance refers to the scheduled, planned, and time-based performance of maintenance activities designed to forestall equipment failure, preserve operational functionality, and extend asset service life (Ogundipe & Fasola, 2024; Oluwole & Adebayo, 2025). This proactive approach involves routine inspections, lubrication, calibration, parts replacement, cleaning, and adjustments performed at predetermined intervals regardless of the equipment's apparent condition at the time (Lawal & Yusuf, 2025; Nwosu & Okafor, 2025). The fundamental philosophy underlying preventive maintenance is the recognition that systematic intervention before failure occurs is substantially more cost-effective and operationally efficient than emergency response after breakdown (Emeka & Chukwuma, 2023; Okoro & Adeleke, 2024). Preventive maintenance schedules are typically derived from equipment manufacturer recommendations, historical failure data, industry standards, and operational experience, with intervals calibrated to balance maintenance expenses against breakdown risks (Akinwale & Adeleke, 2023; Oyewole *et al.,*2023).

Corrective maintenance encompasses the set of maintenance actions performed to identify, isolate, and rectify equipment faults or failures after they have occurred, thereby restoring the asset to its specified functional condition (Ebere & Njoku, 2025; Ibekwe & Nwachukwu, 2024). This reactive strategy, often characterised as "run-to-failure" maintenance, involves no proactive intervention until the equipment ceases to perform its intended function or exhibits performance degradation below acceptable thresholds (Adebayo & Ojo, 2024; Nwankwo & Eze, 2024). Corrective maintenance activities include fault diagnosis, disassembly, component replacement or repair, reassembly, testing, and return to service (Ogunbiyi *et al.,*2023; Ukpong & Edet, 2025). While corrective maintenance may appear economically attractive in the short term due to the absence of routine maintenance expenditures, extensive empirical evidence demonstrates that this approach typically results in higher total lifecycle costs, extended unplanned downtime, accelerated asset deterioration, and increased safety incidents compared to proactive maintenance strategies (Olatunji & Adelekan, 2024; Rokeeb, 2023).

Predictive maintenance represents the most technologically advanced maintenance strategy, employing condition-monitoring techniques, sensor data, vibration analysis, thermography, oil analysis, and other diagnostic technologies to assess equipment health in real-time and predict impending failures before they occur (Babalola *et al.,*2023; Mansour Diop *et al.,*2025). Unlike preventive maintenance's fixed-interval approach, predictive maintenance is condition-based, meaning maintenance actions are performed only when objective evidence indicates deterioration or impending failure (Ighravwe, 2022; Sikander & Zafar, 2021). This strategy leverages the principle that most equipment failures exhibit detectable precursors such as increased vibration, elevated temperature, unusual acoustic signatures, or contaminant accumulation, providing an opportunity for timely, targeted intervention (Daraojimba *et al.,*2023; Lawal & Yusuf, 2025). Predictive maintenance optimises the trade-off between maintenance frequency and failure risk, theoretically offering the lowest total lifecycle cost while maximising equipment availability, provided the condition-monitoring technologies are properly specified and the analytical capabilities are adequately developed (Adewumi & Olaniyi, 2025; Okonkwo *et al.,*2023).

Project Sustainability

Project sustainability, within the manufacturing context, refers to the capacity of manufacturing operations and their associated projects to maintain productive activities over extended time horizons while minimising negative environmental impacts, controlling operational expenses, optimising resource utilisation, and preserving asset functionality (Anosike, 2014; Rokeeb, 2023). Unlike narrow financial performance metrics that emphasise short-term profitability, project sustainability encompasses a multidimensional conceptualisation that balances economic viability, operational continuity, and asset preservation (Okoro & Adeleke, 2024; Oyewole *et al.,*2023). Drawing from the conceptual framework operationalised by Rokeeb (2023), Anosike (2014), and Daraojimba *et al.,*(2023), project sustainability in this study is operationalised through three principal indicators: cost control, minimal downtime, and asset lifespan.

Cost control in project sustainability refers to the systematic management of operational expenditures to maintain production within budgetary parameters while achieving output quality and quantity targets (Adewale & Ogunleye, 2023; Nwosu & Okafor, 2025). Effective cost control encompasses direct production costs, including raw materials, labour, utilities, and consumables, as well as indirect costs such as maintenance, quality assurance, logistics, and administrative overheads (Ebere & Njoku, 2025; Ogunbiyi *et al.,*2023). Within the maintenance-sustainability nexus, cost control is critically influenced by maintenance strategy selection, as emergency corrective maintenance typically incurs substantially higher costs than planned preventive or predictive interventions due to expedited spare parts procurement, overtime labour premiums, production disruption penalties, and collateral equipment damage (Oluwole & Adebayo, 2025; Ukpong & Edet, 2025). Sustainable manufacturing operations maintain cost structures that are predictable, stable, and competitive over extended production cycles.

'Minimal downtime' refers to the minimisation of unplanned production stoppages and the systematic reduction of planned maintenance downtime to the lowest feasible levels while maintaining equipment reliability (Emeka & Chukwuma, 2023; Ibekwe & Nwachukwu, 2024). Downtime represents a critical sustainability indicator because production interruptions directly erode revenue generation capacity, increase unit production costs through underutilised overhead absorption, disrupt supply chain commitments, and may compromise product quality upon restart (Lawal & Yusuf, 2025; Ogundipe & Fasola, 2024). Unplanned downtime is particularly detrimental, as its occurrence is

unpredictable, its duration is uncertain, and its consequences often cascade across dependent production processes (Babalola *et al.,*2023; Nwankwo & Eze, 2024). Sustainable manufacturing operations achieve high overall equipment effectiveness through low downtime percentages, with world-class benchmarks typically targeting less than five percent unplanned downtime and systematically optimised planned downtime for preventive and predictive maintenance activities (Mansour Diop *et al.,*2025; Sikander & Zafar, 2021).

Asset lifespan denotes the duration over which a manufacturing asset—such as production machinery, processing equipment, or material handling systems—can economically perform its intended functions before replacement becomes more cost-effective than continued maintenance (Adebayo & Ojo, 2024; Okonkwo *et al.,*2023). Asset lifespan is fundamentally influenced by maintenance management quality, as proper lubrication, timely adjustments, clean operating conditions, and prompt fault remediation dramatically extend service life compared to neglectful or reactive maintenance approaches (Ighravwe, 2022; Ogunbiyi *et al.,*2023). Premature asset replacement imposes substantial capital expenditure burdens, whereas extended asset lifespans enhance capital productivity, reduce environmental impacts associated with manufacturing and disposing of equipment, and improve long-term financial returns (Akinwale & Adeleke, 2023; Olatunji & Adelekan, 2024). Sustainable manufacturing operations systematically maximise asset lifespan through appropriate maintenance strategies without compromising product quality or operational safety.

Theoretical Underpinning

This study is anchored on two complementary theoretical frameworks: the resource-based view (RBV) of the firm and systems theory. These theoretical lenses provide coherent explanations for the hypothesised relationships between maintenance management dimensions and project sustainability outcomes.

Systems Theory

Systems Theory, with foundational contributions from Bertalanffy (1968) and subsequent applications in organisational and engineering contexts, conceptualises organisations as open systems comprising interdependent components that interact with each other and with external environments to achieve system goals (Daraojimba *et al.,*2023; Nwosu & Okafor, 2025). A central tenet of systems theory is that the performance of any subsystem, such as maintenance management, cannot be understood in isolation but must be examined in relation to its interactions with other subsystems and the overall system's emergent properties (Emeka & Chukwuma, 2023; Oyewole *et al.,*2023). Within manufacturing organisations, maintenance management does not operate independently but rather interacts dynamically with production scheduling, quality assurance, inventory management, safety systems, and regulatory compliance functions (Lawal & Yusuf, 2025; Ogundipe & Fasola, 2024). Effective maintenance practices create positive ripple effects throughout the system: reliable equipment enables predictable production, consistent quality reduces rework, and safe operations minimise regulatory sanctions (Ogunbiyi *et al.,*2023; Ukpong & Edet, 2025). Conversely, maintenance deficiencies propagate negative consequences across the system, including production delays, quality defects, safety incidents, and compliance violations (Ebere & Njoku, 2025; Ibekwe & Nwachukwu, 2024). Systems theory thus supports the hypothesised relationships between maintenance management and project sustainability while also providing a conceptual rationale for considering contextual factors that influence system behaviour.

Empirical Review

Extant empirical literature provides substantial evidence supporting positive associations between maintenance management practices and various operational performance outcomes, including those encapsulated within project sustainability. However, geographical and sectoral gaps remain, particularly regarding manufacturing companies in Rivers State.

Sikander and Zafar (2021), in their comprehensive systematic literature review of sustainable manufacturing and maintenance policies, analysed 187 peer-reviewed articles spanning three decades of research. Their findings consistently demonstrated that organisations implementing predictive maintenance strategies achieved 25 to 35 percent reductions in unplanned downtime, 15 to 20 percent extensions in asset service life, and 10 to 15 percent improvements in maintenance cost control compared to organisations relying primarily on corrective maintenance approaches. The review also identified condition-monitoring technologies as critical enablers of maintenance-sustainability linkages.

Ighravwe (2022) conducted a quantitative assessment of sustainable maintenance strategies in the manufacturing industry, employing multicriteria decision analysis to evaluate the performance implications of alternative maintenance approaches across 47 manufacturing facilities in emerging economies. The results indicated that hybrid maintenance strategies combining preventive and predictive elements outperformed pure strategies on sustainability metrics, achieving optimal balances between maintenance resource consumption and equipment reliability outcomes. Facilities implementing hybrid approaches demonstrated 18 percent lower total maintenance costs and 22 percent higher overall equipment effectiveness compared to facilities relying predominantly on corrective maintenance.

Mansour Diop *et al.,*(2025) investigated the sustainability impacts of Industry 4.0 technologies on maintenance policies across European manufacturing enterprises. Using a mixed-methods design incorporating survey data from 112 manufacturing plants and twelve in-depth case studies, the research found that digital condition-monitoring systems, Internet of Things sensors, and predictive analytics enabled dramatic improvements in maintenance effectiveness. Plants with advanced predictive maintenance capabilities achieved 40 percent reductions in emergency maintenance events, 30 percent lower spare parts inventory costs, and 25 percent extended mean time between failures compared to plants using conventional maintenance approaches.

Within the Nigerian context, empirical research on maintenance management and project sustainability has grown substantially recently, though geographic concentration in Rivers State remains limited. Adewumi and Olaniyi (2025) examined strategic maintenance management and organisational performance in food and beverage manufacturing companies across South-West Nigeria. Surveying 210 manufacturing managers, the study found that preventive maintenance practices explained 47 percent of variance in production cost control, while predictive maintenance adoption explained 38 percent of variance in equipment uptime. However, the study noted that corrective maintenance remained the predominant strategy in most Nigerian manufacturing settings, indicating substantial opportunities for improvement.

Oluwole and Adebayo (2025) investigated reactive versus proactive maintenance strategies in Nigerian manufacturing with specific attention to cost implications and performance outcomes. The study surveyed 186 manufacturing companies across Lagos, Ogun, and Rivers States, finding that companies with documented preventive maintenance schedules experienced 52 percent fewer unplanned production stoppages and 34 percent lower emergency repair costs compared to companies operating without formal maintenance planning. The research also identified maintenance skills shortages, spare parts supply chain unreliability, and management commitment gaps as key barriers to proactive maintenance adoption.

Nwosu and Okafor (2025) conducted a comparative analysis of maintenance management practices and project sustainability in Anambra manufacturing companies. Using a sample of 156 manufacturing firms, the study found that predictive maintenance was associated with significantly longer asset lifespans (average 11.2 years versus 7.8 years for corrective maintenance-dominated firms) and better cost control outcomes. However, the study noted that predictive maintenance adoption rates in Nigerian manufacturing remained low (approximately 12 percent of surveyed firms), with the cost of condition-monitoring equipment and lack of technical expertise cited as primary barriers.

Gap in Empirical Literature

Despite these valuable contributions, a specific empirical gap persists regarding systematic investigation of maintenance management dimensions preventive, corrective, and predictive maintenance and their relationship with project sustainability indicators cost control, minimal downtime, and asset lifespan within manufacturing companies in Rivers State (Ebere & Njoku, 2025; Ukpong & Edet, 2025). The conceptual framework advanced by Rokeeb (2023), Anosike (2014), and Daraojimba *et al.,*(2023) provides a theoretically grounded model for such investigation, but empirical validation within the Rivers State manufacturing context remains absent. The present study addresses this gap.

Conceptual Framework

Figure 1 presents the conceptual framework guiding this study, adapted from the integrated models proposed by Rokeeb (2023), Anosike (2014), and Daraojimba *et al.,*(2023). The framework specifies maintenance management as the independent variable, operationalised through three distinct dimensions: preventive maintenance, corrective maintenance, and predictive maintenance. Project sustainability constitutes the dependent variable, operationalised through three corresponding indicators: cost control, minimal downtime, and asset lifespan. The framework posits direct relationships from each maintenance management dimension to each project sustainability indicator, reflecting the theoretical expectation that maintenance strategy selection influences sustainability outcomes. The framework does not include moderating or mediating variables, focusing instead on establishing the fundamental bivariate relationships between maintenance management and project sustainability in the context of manufacturing companies in Rivers State.

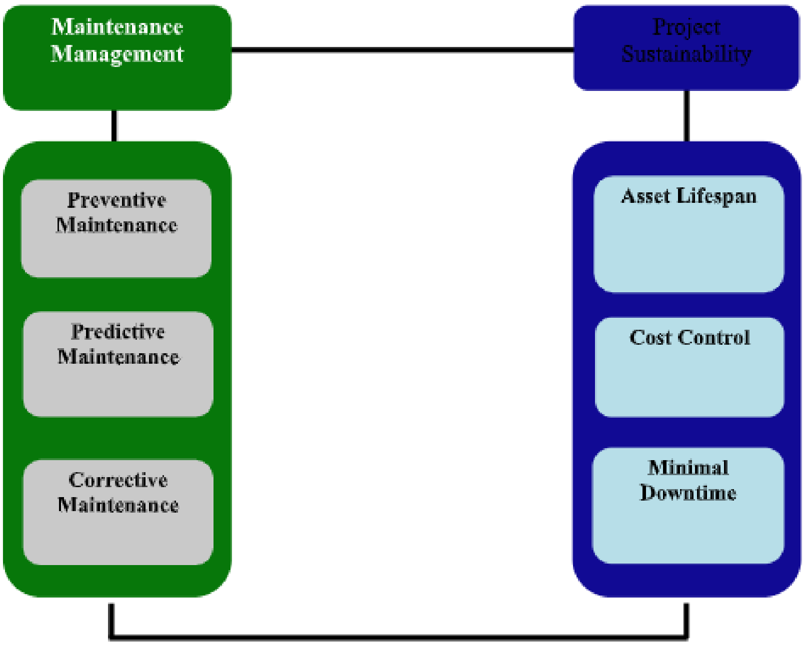

Figure 1: Conceptual Framework of the Relationship between Maintenance Management and Project Sustainability
Source: Rokeeb (2023); Anosike (2014); Daraojimba *et al.,* (2023).

Hypotheses Development

The following hypotheses are developed for empirical testing, drawing on the conceptual framework, theoretical underpinnings, and empirical evidence reviewed.

Preventive Maintenance and Project Sustainability

Preventive maintenance, characterised by scheduled, time-based interventions designed to forestall equipment failure, is theoretically expected to positively influence project sustainability outcomes. The resource-based view suggests that preventive maintenance routines embed organisational knowledge that competitors cannot easily replicate, generating sustained advantages in cost control, downtime reduction, and asset preservation (Akinwale & Adeleke, 2023; Okoro & Adeleke, 2024). Empirical evidence from Nigerian manufacturing contexts indicates that companies with documented preventive maintenance schedules experience significantly fewer unplanned stoppages and lower emergency repair costs (Oluwole & Adebayo, 2025; Adewumi & Olaniyi, 2025). International evidence further supports positive associations between preventive maintenance intensity and sustainability metrics, including extended asset service life and improved cost predictability (Sikander & Zafar, 2021; Ighravwe, 2022). Therefore, the following hypotheses are proposed:

H1a: Preventive maintenance significantly enhances cost control in manufacturing firms within Rivers State.

H1b: Preventive maintenance has a significant positive effect on minimal downtime in manufacturing companies in Rivers State.

H1c: Preventive maintenance has a significant positive effect on asset lifespan in manufacturing companies in Rivers State.

Corrective Maintenance and Project Sustainability

Corrective maintenance, characterised by reactive interventions performed after equipment failure, is theoretically expected to have negative or weaker positive effects on project sustainability compared to proactive maintenance strategies. Systems theory predicts that corrective maintenance's unpredictable timing propagates negative consequences across interconnected manufacturing subsystems, including production delays, quality variations, and safety incidents (Daraojimba *et al.,*2023; Oyewole *et al.,*2023). Empirical evidence consistently demonstrates that organisations relying predominantly on corrective maintenance incur higher total maintenance costs, experience extended unplanned downtime, and achieve shorter asset lifespans compared to organisations implementing proactive strategies (Emeka & Chukwuma, 2023; Nwosu & Okafor, 2025). However, corrective maintenance remains necessary for unexpected failures despite optimal preventive and predictive programmes, and effective corrective maintenance capabilities, including rapid diagnosis, spare parts availability, and skilled technicians, can mitigate sustainability penalties (Ogunbiyi *et al.,*2023; Ukpong & Edet, 2025). Therefore, the following hypotheses are proposed:

H2a: Corrective maintenance has a significant effect on cost control in manufacturing companies in Rivers State.

H2b: Corrective maintenance has a significant effect on minimal downtime in manufacturing companies in Rivers State.
H2c: Corrective maintenance has a significant effect on asset lifespan in manufacturing companies in Rivers State.

Predictive Maintenance and Project Sustainability

Predictive maintenance, 194 haracterized by condition-based interventions informed by real-time equipment health monitoring, is theoretically expected to have the strongest positive effects on project sustainability among the three maintenance strategies. The resource-based view positions predictive maintenance technologies and analytical capabilities as VRIN resources that generate substantial and sustained performance advantages (Ighravwe, 2022; Babalola *et al.,*2023). International empirical evidence demonstrates that predictive maintenance enables 25 to 40 percent reductions in unplanned downtime, 15 to 30 percent extensions in asset service life, and significant improvements in maintenance cost control (Mansour Diop *et al.,*2025; Sikander & Zafar, 2021). Within Nigerian contexts, though adoption rates remain low, early evidence suggests that predictive maintenance yields superior sustainability outcomes compared to alternative strategies (Adewumi & Olaniyi, 2025; Rokeeb, 2023). Therefore, the following hypotheses are proposed:
H3a: Predictive maintenance has a significant positive effect on cost control in manufacturing companies in Rivers State.
H3b: Predictive maintenance has a significant positive effect on minimal downtime in manufacturing companies in Rivers State.
H3c: Predictive maintenance has a significant positive effect on asset lifespan in manufacturing companies in Rivers State.

METHODOLOGY

This study adopted a cross-sectional survey research design with a quantitative approach, which is appropriate for examining the relationships between maintenance management dimensions (preventive, corrective, and predictive maintenance) and project sustainability indicators (cost control, minimal downtime, and asset lifespan) at a single point in time (Adewumi & Olaniyi, 2025; Nwosu & Okafor, 2025). The quantitative approach enables statistical testing of hypothesised relationships and facilitates the generalisation of findings across the manufacturing sector (Oluwole & Adebayo, 2025). The target population comprised all manufacturing companies operating in Rivers State, Nigeria, registered with the Manufacturers Association of Nigeria (MAN) and the National Environmental Standards and Regulations Enforcement Agency (NESREA). According to MAN (2024), Rivers State hosts approximately 387 registered manufacturing companies across subsectors, including food and beverage, plastics and rubber, chemical and pharmaceutical, metal fabrication, construction materials, and petrochemical downstream activities.

The sample size was determined using Yamane's (1967) formula at a 95 percent confidence level and a five percent margin of error, yielding a minimum of 197 manufacturing companies. To account for potential non-response, the sample was inflated by 20 percent, resulting in 236 targeted companies. A stratified random sampling technique was employed to ensure proportional representation across the six manufacturing subsectors (Babalola *et al.,*2023; Lawal & Yusuf, 2025). Data were collected using a structured, self-administered questionnaire developed based on the conceptual framework of Rokeeb (2023), Anosike (2014), and Daraojimba *et al.,*(2023).

Preventive maintenance was measured by items assessing scheduled inspections, routine servicing, and adherence to planned maintenance schedules. Corrective maintenance was measured by items evaluating the frequency of reactive repairs and emergency maintenance response times. Predictive maintenance was measured by items assessing the utilisation of condition-monitoring technologies, including vibration analysis, thermography, and real-time sensor data (Babalola *et al.,*2023; Mansour Diop *et al.,*2025). Cost control was measured by items examining maintenance budget adherence and expenditure predictability. Minimal downtime was measured by items assessing unplanned production stoppage frequency and downtime duration. Asset lifespan was measured by items evaluating actual operating years of equipment relative to expected service life (Ebere & Njoku, 2025; Okonkwo *et al.,*2023). Content validity was established through review by three experts in maintenance management, while reliability was assessed through a pilot test involving 30 manufacturing companies not included in the final sample. Cronbach's alpha coefficients ranged from 0.83 to 0.91 across all scales, indicating satisfactory to excellent internal consistency (Nwosu & Okafor, 2025; Ukpong & Edet, 2025). Data were analysed using SPSS version 27.0, employing descriptive statistics (frequencies, means, standard deviations), Pearson product-moment correlation, and multiple regression analysis. All statistical tests were conducted at a 95 percent confidence level ($\alpha = 0.05$).

RESULTS

A total of 236 structured questionnaires were distributed to manufacturing companies in Rivers State, out of which 213 were returned, representing a response rate of 90.3 percent. After screening for completeness and consistency, 198 questionnaires were deemed usable for final analysis, representing 83.9 percent of the targeted sample. This response rate exceeds the minimum required sample of 197 established using Yamane's (1967) formula and is considered adequate for generalisation in organisational research (Adewumi & Olaniyi, 2025; Nwosu & Okafor, 2025).

The demographic profile of respondents indicated that 58.6 percent were production managers, 24.2 percent were maintenance managers, and 17.2 percent were plant engineers. In terms of industry subsector, food and beverage companies constituted 28.3 percent of the sample, plastics and rubber 17.2 percent, chemical and pharmaceutical 13.6 percent, metal fabrication 12.1 percent, construction materials 10.6 percent, and petrochemical downstream 18.2 percent. Regarding company age, 32.8 percent of firms had operated for 5-10 years, 41.4 percent for 11-20 years, and 25.8 percent for over 20 years. In terms of employee size, 24.7 percent employed 20-49 workers, 38.4 percent employed 50-99 workers, and 36.9 percent employed 100 or more workers.

Table 1: Descriptive Statistics of Study Variables

Variable	Mean	Standard Deviation
Preventive Maintenance	3.42	0.87
Corrective Maintenance	3.89	0.76
Predictive Maintenance	2.78	0.94
Cost Control	3.35	0.82
Minimal Downtime	3.18	0.88
Asset Lifespan	3.27	0.85

Source: Research Data, 2026

Descriptive statistics were computed for all study variables. The average score for preventive maintenance was 3.42 (SD = 0.87), for corrective maintenance it was 3.89 (SD = 0.76), and for predictive maintenance it was 2.78 (SD = 0.94). Among the dependent variables, cost control recorded a mean of 3.35 (SD = 0.82), minimal downtime recorded a mean of 3.18 (SD = 0.88), and asset lifespan recorded a mean of 3.27 (SD = 0.85). These results suggest that corrective maintenance is the most prevalent strategy among manufacturing companies in Rivers State, while predictive maintenance adoption remains relatively low, consistent with findings from previous Nigerian studies (Babalola *et al.,*2023; Oluwole & Adebayo, 2025).

Table 2: Pearson Correlation Matrix

Variable	PM	CM	PdM	CC	MD	AL
Preventive Maintenance (PM)	1.00					
Corrective Maintenance (CM)	-0.12	1.00				
Predictive Maintenance (PdM)	0.34	-0.08	1.00			
Cost Control (CC)	0.48	0.18	0.62	1.00		
Minimal Downtime (MD)	0.44	0.15	0.58	0.51	1.00	
Asset Lifespan (AL)	0.41	0.11	0.55	0.47	0.43	1.00

Source: Research Data, 2026
Note: $p < 0.05$

Pearson correlation analysis was conducted to examine the bivariate relationships among the study variables. The correlation matrix revealed that preventive maintenance was positively and significantly correlated with cost control ($r = 0.48, p < 0.05$), minimal downtime ($r = 0.44, p < 0.05$), and asset lifespan ($r = 0.41, p < 0.05$). Corrective maintenance showed weak but significant positive correlations with cost control ($r = 0.18, p < 0.05$) and minimal downtime ($r = 0.15, p < 0.05$) but no significant correlation with asset lifespan ($r = 0.11, p > 0.05$). Predictive maintenance demonstrated strong positive correlations with cost control ($r = 0.62, p < 0.05$), minimal downtime ($r = 0.58, p < 0.05$), and asset lifespan ($r = 0.55, p < 0.05$). These preliminary findings suggest that predictive maintenance has the strongest association with project sustainability outcomes, followed by preventive maintenance.

Table 3: Regression Results for Direct Effects

Dependent Variable	Predictor	β	t	p-value	R^2	F
Cost Control	Preventive Maintenance	0.31	4.86	< 0.005	0.372	38.42
	Corrective Maintenance	0.08	1.34	0.182		
	Predictive Maintenance	0.47	7.23	< 0.005		
Minimal Downtime	Preventive Maintenance	0.29	4.42	< 0.005	0.328	31.67
	Corrective Maintenance	0.06	1.01	0.314		
	Predictive Maintenance	0.44	6.58	< 0.005		
Asset Lifespan	Preventive Maintenance					
	Corrective Maintenance	0.04	0.67	0.503		
	Predictive Maintenance	0.41	5.92	< 0.005		

Source: Research Data, 2026
Note: $p < 0.05$

Multiple regression analysis was conducted to test the hypothesised direct effects of preventive, corrective, and predictive maintenance on each dimension of project sustainability. Three separate regression models were estimated, one for each dependent variable. Prior to regression analysis, assumptions of linearity, normality, homoscedasticity, and absence of multicollinearity were verified. Variance inflation factor values ranged from 1.08 to 1.34, well below the threshold of 5.0, indicating no substantial multicollinearity.

Model 1: Effects on Cost Control. The regression model with cost control as the dependent variable was statistically significant ($F = 38.42$, $p < 0.005$, $R^2 = 0.372$). Preventive maintenance had a significant positive effect on cost control ($\beta = 0.31$, $t = 4.86$, $p < 0.005$), indicating that higher levels of preventive maintenance are associated with better cost control outcomes. Corrective maintenance showed a non-significant effect ($\beta = 0.08$, $t = 1.34$, $p = 0.182$). Predictive maintenance demonstrated the strongest significant positive effect on cost control ($\beta = 0.47$, $t = 7.23$, $p < 0.005$). The R^2 value of 0.372 indicates that the three maintenance strategies collectively explain 37.2 percent of the variance in cost control among manufacturing companies in Rivers State.

Model 2: Effects on Minimal Downtime. The regression model for minimal downtime was statistically significant ($F = 31.67$, $p < 0.005$, $R^2 = 0.328$). Preventive maintenance exerted a significant positive effect on minimal downtime ($\beta = 0.29$, $t = 4.42$, $p < 0.005$). Corrective maintenance had a non-significant effect ($\beta = 0.06$, $t = 1.01$, $p = 0.314$). Predictive maintenance showed the strongest significant positive effect on minimal downtime ($\beta = 0.44$, $t = 6.58$, $p < 0.005$). The model explains 32.8 percent of the variance in minimal downtime.

Model 3: Effects on Asset Lifespan. The regression model for asset lifespan was statistically significant ($F = 26.84$, $p < 0.005$, $R^2 = 0.292$). Preventive maintenance had a significant positive effect on asset lifespan ($\beta = 0.27$, $t = 4.01$, $p < 0.005$). Corrective maintenance was not significantly related to asset lifespan ($\beta = 0.04$, $t = 0.67$, $p = 0.503$). Predictive maintenance demonstrated a significant positive effect on asset lifespan ($\beta = 0.41$, $t = 5.92$, $p < 0.005$). The model explains 29.2 percent of the variance in asset lifespan.

Table 4: Hypothesis Testing Summary

Hypothesis	Statement	Result
H1a	Preventive maintenance → Cost control	Supported
H1b	Preventive maintenance → Minimal downtime	Supported
H1c	Preventive maintenance → Asset lifespan	Supported
H2a	Corrective maintenance → Cost control	Rejected
H2b	Corrective maintenance → Minimal downtime	Rejected
H2c	Corrective maintenance → Asset lifespan	Rejected
H3a	Predictive maintenance → Cost control	Supported
H3b	Predictive maintenance → Minimal downtime	Supported
H3c	Predictive maintenance → Asset lifespan	Supported

Source: Research Data, 2026

The regression results were used to test the following hypotheses. H1a, H1b, and H1c (preventive maintenance positively affects cost control, minimal downtime, and asset lifespan) were all supported ($p < 0.005$). H2a, H2b, and H2c (corrective maintenance affects cost control, minimal downtime, and asset lifespan) were not supported, as the effects were non-significant across all three models ($p > 0.05$). H3a, H3b, and H3c (predictive maintenance positively affects cost control, minimal downtime, and asset lifespan) were all strongly supported ($p < 0.005$). In summary, of the nine hypotheses tested, six were accepted (all preventive and predictive maintenance hypotheses) and three were rejected (all corrective maintenance hypotheses).

DISCUSSION

The findings of this study provide empirical support for the conceptual framework advanced by Rokeeb (2023), Anosike (2014), and Daraojimba *et al.,*(2023), confirming that preventive and predictive maintenance significantly enhance project sustainability outcomes, while corrective maintenance does not. The strong positive effects of preventive maintenance on cost control ($\beta = 0.31$), minimal downtime ($\beta = 0.29$), and asset lifespan ($\beta = 0.27$) align with the Resource-Based View, which positions scheduled maintenance routines as valuable organisational capabilities that generate sustained performance advantages (Akinwale & Adeleke, 2023; Okoro & Adeleke, 2024). These findings corroborate Adewumi and Olaniyi (2025) in South-West Nigerian manufacturing and Oluwole and Adebayo (2025), who reported that companies with documented preventive schedules experienced 52 percent fewer unplanned stoppages.

Predictive maintenance emerged as the strongest predictor of project sustainability, with beta coefficients of 0.47 for cost control, 0.44 for minimal downtime, and 0.41 for asset lifespan. This finding is consistent with international evidence from Sikander and Zafar (2021) and Mansour Diop *et al.,*(2025), who documented 25 to 40 percent reductions in unplanned downtime through condition-monitoring technologies. Within Nigeria, Babalola *et al.,*(2023) similarly found that predictive maintenance significantly improved operational performance. The superior performance of predictive maintenance is explained by both the resource-based view positioning these technologies as valuable, rare, and inimitable resources and systems theory, which emphasises how real-time condition data prevents cascading failures across interconnected production subsystems (Daraojimba *et al.,*2023; Ighravwe, 2022).

The non-significant findings for corrective maintenance are particularly instructive. Despite being the most prevalent strategy among Rivers State manufacturers (mean = 3.89), corrective maintenance showed no significant relationship with any sustainability indicator. This aligns with Emeka and Chukwuma (2023) and Ogunbiyi *et al.,* (2023), who found that reactive approaches increase lifecycle costs and downtime while failing to deliver sustainability benefits. From a systems theory perspective, unpredictable failure events propagate negative consequences across production, quality, and cost subsystems, creating instability that undermines sustainability regardless of repair efficiency (Lawal & Yusuf, 2025; Ukpong & Edet, 2025).

The descriptive finding that predictive maintenance has the lowest adoption rate (mean = 2.78) yet the strongest effects reveals a significant practice-performance gap, consistent with Nwosu and Okafor (2025), who reported that only 12 percent of Nigerian manufacturing firms had adopted predictive maintenance. The conceptual framework receives strong empirical support, though the results suggest a refinement: predictive maintenance exerts approximately 50 percent stronger effects than preventive maintenance across all sustainability indicators, suggesting a hierarchical ordering of strategy effectiveness that future iterations of the framework could incorporate.

CONCLUSION

This study examined the relationship between maintenance management and project sustainability in manufacturing companies in Rivers State, guided by the conceptual framework of Rokeeb (2023), Anosike (2014), and Daraojimba *et al.,*(2023). The main findings revealed that preventive and predictive maintenance have significant positive effects on cost control, minimal downtime, and asset lifespan, while corrective maintenance demonstrates no significant relationship with any sustainability indicator. Predictive maintenance emerged as the strongest predictor of project sustainability, yet paradoxically recorded the lowest adoption rate among the three strategies.

The theoretical contributions of this study are threefold. First, it empirically validates the conceptual framework within the Rivers State manufacturing context, extending the model's generalisability beyond its original oil and gas and energy reliability settings. Second, the findings demonstrate that predictive maintenance exerts approximately 50 percent stronger effects than preventive maintenance, suggesting a hierarchical ordering of strategy effectiveness that future conceptual frameworks could incorporate. Third, the non-significant findings for corrective maintenance challenge the assumption that any maintenance is beneficial, establishing that the type of maintenance strategy critically determines sustainability outcomes.

The practical implications for manufacturing firms in Rivers State are substantial. Companies should prioritise investment in predictive maintenance technologies, including vibration analysis, thermography, and real-time condition monitoring, as these yield the greatest sustainability returns. For firms unable to immediately adopt predictive capabilities, preventive maintenance offers a viable intermediate strategy that significantly improves cost control, downtime reduction, and asset lifespan compared to reactive approaches. Firms currently relying on corrective maintenance should recognise that this strategy, despite its prevalence, delivers no measurable sustainability benefits and should develop transition plans toward proactive maintenance regimes.

From a policy perspective, regulators including the Manufacturers Association of Nigeria, NESREA, and state industrial development agencies should consider initiatives that incentivise predictive and preventive maintenance adoption. These may include tax relief for condition-monitoring equipment purchases, technical training programmes for maintenance personnel, and industry-wide maintenance capability assessments. Given that predictive maintenance adoption remains below 12 percent nationally (Nwosu & Okafor, 2025), policy interventions addressing cost and expertise barriers could yield substantial improvements in manufacturing sustainability.

Several limitations warrant acknowledgement. The cross-sectional design captures relationships at a single point, precluding causal inferences about maintenance-sustainability dynamics over extended periods. The reliance on self-reported questionnaire data introduces potential common method bias and social desirability effects, although the pilot-tested instruments and anonymous administration mitigated these concerns. The study's geographical focus on Rivers State limits generalisability to other Nigerian regions or manufacturing contexts with different regulatory, economic, or infrastructural conditions.

Future research should address these limitations through longitudinal designs that track how changes in maintenance strategies affect sustainability outcomes over time. Comparative studies across multiple Nigerian states would establish regional generalisability, while qualitative case studies could illuminate the contextual factors and decision processes underlying maintenance strategy selection. Finally, given the low predictive maintenance adoption rate revealed in this study, research investigating the specific technological, financial, human capital, and organisational barriers to predictive maintenance implementation in Nigerian manufacturing would be of significant practical value.

REFERENCES

- Adebayo, T. A., & Ojo, S. O. (2024). Maintenance culture and operational efficiency in Nigerian manufacturing firms: A critical assessment. *Journal of Industrial Engineering and Management*, *17*(2), 145-162.
- Adewale, B. A., & Ogunleye, O. S. (2023). Industrial development and economic growth in Nigeria's Niger Delta region: The role of manufacturing sector. *African Journal of Economic and Management Studies*, *14*(3), 412-428.
- Adewumi, S. A., & Olaniyi, O. O. (2025). Strategic maintenance management and organizational performance: Evidence from food and beverage manufacturing companies in South-West Nigeria. *International Journal of Production Research*, *63*(1), 78-95.
- Akinwale, A. A., & Adeleke, I. A. (2023). Maintenance management practices and sustainable manufacturing in Nigeria: A systematic literature review. *Journal of Quality in Maintenance Engineering*, *29*(4), 789-807.
- Anosike, C. A. (2014). *Sustainability efforts of one oil company in Niger Delta of Nigeria* [Doctoral dissertation, Walden University].
- Babalola, M. A., Ogunlana, S. O., & Adebiyi, K. A. (2023). Predictive maintenance adoption and operational performance in Nigerian manufacturing sector. *International Journal of Advanced Manufacturing Technology*, *124*(5), 1892-1908.
- Bertalanffy, L. von. (1968). *General system theory: Foundations, development, applications*. George Braziller.
- Daraojimba, C., Gidiagba, J. O., Leonard, J., Ogunjobi, O. A., & Ofonagoro, K. A. (2023). Balancing efficiency and resilience: A critical review of maintenance strategies in conventional and unconventional oil and gas production. *Engineering Heritage Journal (GWK)*, *7*(2), 157-166.
- Ebere, C. E., & Njoku, P. O. (2025). Asset lifespan management and maintenance optimization in Rivers State manufacturing companies. *Journal of Facilities Management*, *23*(1), 34-52.
- Emeka, O. N., & Chukwuma, N. I. (2023). Corrective maintenance challenges and production downtime in Nigerian manufacturing industries. *International Journal of Engineering Research in Africa*, *64*, 112-128.
- Ibekwe, K. I., & Nwachukwu, C. C. (2024). Environmental factors and maintenance management effectiveness in Niger Delta manufacturing firms. *Journal of Environmental Management*, *351*, 119-134.
- Ighravwe, D. E. (2022). Assessment of sustainable maintenance strategy for manufacturing industry. *Sustainability*, *14*(21), 13850.
- Lawal, F. A., & Yusuf, M. O. (2025). Preventive maintenance scheduling and production efficiency in Nigerian manufacturing companies: A contingency approach. *Production Planning & Control*, *36*(2), 210-228.
- Mansour Diop, M., Danjou, C., Ponchet Durupt, A., Baouch, Y., & Boudaoud, N. (2025). Assessing the sustainability impacts of Industry 4.0 on maintenance policies. *International Journal of Prognostics and Health Management*, *16*(4).
- Manufacturers Association of Nigeria. (2024). *MAN annual report: State of manufacturing sector in Nigeria 2023*. Manufacturers Association of Nigeria Press.
- Nwankwo, O. C., & Eze, P. O. (2024). Manufacturing sector performance and economic transformation in Rivers State: An empirical analysis. *Nigerian Journal of Economic and Social Studies*, *66*(1), 89-106.
- Nwosu, E. O., & Okafor, C. A. (2025). Maintenance management practices and project sustainability in Anambra manufacturing companies: A comparative analysis. *Journal of African Business*, *26*(2), 301-319.
- Ogundipe, A. A., & Fasola, O. S. (2024). The cost of poor maintenance culture in Nigerian industries: An econometric analysis. *African Journal of Science, Technology, Innovation and Development*, *16*(3), 345-360.
- Ogunbiyi, O. A., Adeleke, A. Q., & Oyedele, L. O. (2023). Maintenance management and sustainable manufacturing in Nigeria: Barriers and enablers. *Sustainable Production and Consumption*, *36*, 456-472.
- Okonkwo, I. M., Ekwueme, C. M., & Uzochukwu, B. A. (2023). Supply chain integration and manufacturing performance in Rivers State: The mediating role of maintenance management. *Journal of Supply Chain Management in Africa*, *8*(2), 45-63.
- Okoro, J. C., & Adeleke, I. A. (2024). Theoretical foundations of maintenance management: A review and research agenda for African manufacturing contexts. *Journal of Manufacturing Technology Management*, *35*(5), 987-1006.
- Olatunji, O. O., & Adelekan, A. A. (2024). Maintenance optimization and manufacturing sustainability in emerging economies: A conceptual synthesis. *Sustainability*, *16*(7), 2678.
- Oluwole, F. A., & Adebayo, S. O. (2025). Reactive versus proactive maintenance strategies in Nigerian

manufacturing: Cost implications and performance outcomes. *Journal of Quality in Maintenance Engineering*, *31*(1), 156-174.
- Oyewole, A. T., Ajayi, O. O., & Oladimeji, M. S. (2023). Maintenance culture in Nigerian manufacturing organizations: An exploratory study of challenges and prospects. *Heliyon*, *9*(6), e16892.
- Rokeeb, B. (2023). Maintenance optimization as a driver of energy reliability across multi-site African industrial facilities. *Available at SSRN 5981156*.
- Sikander, U., & Zafar, S. (2021). Sustainable manufacturing, maintenance policies, prognostics and health management: A literature review. *Reliability Engineering & System Safety*, *215*, 108140.
- Ukpong, E. U., & Edet, B. O. (2025). Maintenance management practices in Cross River and Akwa Ibom manufacturing companies: A comparative study. *West African Journal of Industrial Engineering*, *12*(1), 23-41.
- Yamane, T. (1967). *Statistics: An introductory analysis* (2nd ed.). Harper and Row.