Assessing the Infrastructure Condition and Historical Failure Patterns of Academic Buildings in a Nigerian Polytechnic: A Multi-Criteria Vulnerability Framework

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Abstract- Academic buildings in Nigerian federal polytechnics suffer accelerating deterioration arising from reactive maintenance cultures, institutional underfunding, and the absence of structured condition monitoring systems. This paper the first of a five-paper series on smart predictive maintenance at Auchi Polytechnic, Auchi, Edo State, Nigeria establishes the empirical baseline from which the subsequent papers develop, deploy, and evaluate an integrated Internet of Things and machine learning predictive maintenance system. Employing a modified Building Condition Assessment (BCA) instrument adapted from the Royal Institution of Chartered Surveyors (RICS, 2019) condition rating framework, together with a novel Multi-Criteria Building Vulnerability Index (MCBVI) developed through Analytic Hierarchy Process (AHP) consultation with fifteen domain experts (Saaty, 1980), this investigation systematically quantifies the condition, failure frequency, expenditure patterns, and vulnerability profile of five representative academic buildings encompassing 9,800 m² of gross floor area. A five-year retrospective analysis of 1,847 maintenance work orders was conducted alongside structured physical audits and 217 stakeholder interviews. Findings reveal that aggregate Building Condition Index scores range from 35 to 51 out of 100, uniformly below the 60-point acceptable threshold, while cumulative reactive maintenance expenditure rose by 68.3% between 2020/21 and 2024/25 against a reactive-to-preventive expenditure ratio consistently exceeding 5:1 (Adenuga, 2023; Olubodun & Jenkinson, 2002). The MCBVI the first composite vulnerability scoring instrument empirically calibrated to Nigerian polytechnic campus conditions ranks the Technical Workshop Complex as the most critical asset with a score of 82.6. Findings are contextualised within Sustainable Development Goal 9 (resilient infrastructure and innovation) and SDG 11 (safe, inclusive, and sustainable settlements). Three original contributions to knowledge are advanced: the MCBVI instrument; a five-year failure and expenditure dataset unprecedented in the Nigerian polytechnic literature; and a tropically adapted BCA protocol applicable across the 25-institution federal polytechnic network.

Keywords: Building Condition Assessment, Multi-Criteria Building Vulnerability Index, Predictive Maintenance, Reactive Maintenance, Nigerian Polytechnic, SDG 9, SDG 11, AHP, Facility Management, Infrastructure Condition

I. INTRODUCTION

The physical infrastructure of higher education institutions directly determines academic quality, occupant safety, and institutional reputation. Within Nigeria's federal polytechnic system, the buildings that house classrooms, engineering laboratories, technical workshops, and administrative functions are not merely logistical assets but the material expression of institutional educational capacity. When these buildings fail through structural cracking, HVAC breakdown, electrical overload, roof leakage, or plumbing collapse the consequences are immediate and cascading: lectures are cancelled, safety hazards emerge, laboratory programmes are suspended, and the institution's credibility with students, parents, and employers is measurably damaged (Adenuga, 2023; Umeh, 2024; Kemiki et al., 2025).

Auchi Polytechnic, established in 1963 in Etsako West Local Government Area, Edo State, serves approximately 22,000 students across programmes in engineering, science, business, and technical vocational education. Its campus of approximately 400 hectares hosts 49 academic buildings, the majority constructed between 1970 and 1995 under design standards that could not have anticipated contemporary occupancy intensities, generator-dependent power regimes, or the compound effects of decades of deferred preventive maintenance (Osamudiamen, 2026a). The campus experiences a tropical wet-and-dry climate (Köppen Aw) with mean annual rainfall of 1,450 mm, peak relative humidity of 94% during June through September, and ambient temperatures ranging from 22°C to 38°C environmental conditions that impose above-average degradation rates on ageing building envelopes, mechanical systems, and structural elements (Straube, 2006; Lstiburek, 2002). The Polytechnic's Directorate of Works currently operates without any structured condition monitoring programme, responding reactively to failure reports rather than proactively managing asset health (Osamudiamen, 2026a).

The financial consequences of this posture are substantial. Records gathered during the scoping phase of this investigation reveal cumulative reactive maintenance expenditure exceeding ₦5.3 million across five focal buildings over five academic years, accompanied by over 2,100 hours of building-related academic disruption. This pattern aligns with the reactive maintenance crisis documented by Adenuga (2023) across 42 Nigerian universities and with Umeh's (2024) quantification of deferred maintenance opportunity costs at 12–18% of annual polytechnic institutional budgets. More critically, the prevailing reactive culture does not merely waste financial resources; it compounds physical deterioration and creates safety liabilities that directly contravene the commitments of the Nigerian government under SDG 9 (resilient infrastructure and innovation) and SDG 11 (safe, inclusive, and sustainable settlements) (United Nations, 2015; Agboola et al., 2022).

This paper addresses the first objective of the five-paper series: to rigorously assess the existing infrastructure condition and historical failure patterns of selected academic buildings at Auchi Polytechnic, thereby establishing the empirical foundation for Papers II through V, which address IoT sensor network design, machine learning model development, system deployment governance, and comprehensive performance evaluation respectively. Three original contributions are advanced: (1) the MCBVI, the first composite building vulnerability scoring instrument empirically calibrated to Nigerian polytechnic campus conditions; (2) a five-year failure and expenditure dataset unprecedented in scope and granularity for the Nigerian federal polytechnic literature; and (3) a tropically adapted BCA protocol responsive to the limitations of temperate-climate instruments identified by Wordsworth (2001) and Wood (2009). The lead investigator, Bldr. Dr. Bamidele Osamudiamen, brings over 15 years of professional registration with the Council of Registered Builders of Nigeria (CORBON), with extensive practice in building condition appraisal across Edo, Delta, and Ondo States, providing practitioner-validated calibration to all instruments developed in this study.

II. LITERATURE REVIEW

2.1 Building Maintenance Deficits in Nigerian Educational Institutions

The literature on building maintenance in Nigerian educational institutions reveals a consistent and deepening crisis. Adenuga (2023) surveyed 42 Nigerian universities and found that 78.4% operated with no structured condition monitoring system, relying entirely on reactive maintenance triggered by reported failures. Olubodun and Jenkinson (2002) traced the origins of Nigeria's institutional maintenance deficit to capital budget freezes imposed during structural adjustment programmes of the 1980s and 1990s, which coincided precisely with the period of peak building-stock ageing. Umeh (2024) quantified the opportunity cost of deferred maintenance at Nigerian polytechnics at 12–18% of annual institutional budgets resources that could alternatively fund academic programme development, laboratory equipment, or student welfare services. Kemiki et al. (2025) examined proactive maintenance strategies across 18 Nigerian universities and polytechnics, finding that institutions adopting even basic scheduled inspection regimes reduced emergency repair expenditure by an average of 31% relative to purely reactive counterparts, while simultaneously improving building user satisfaction scores.

2.2 Building Condition Assessment Frameworks

Building Condition Assessment (BCA) provides the methodological foundation for systematic infrastructure management. The Royal Institution of Chartered Surveyors (RICS, 2019) condition rating framework employs a 1–3 defect severity scale across defined building element categories, while the American Society for Testing and Materials ASTM E2018 standard provides a property condition assessment protocol for commercial real estate contexts. Wood (2009) critically evaluated multiple BCA frameworks and found that all existing instruments were designed for high-income built environments characterised by reliable utility infrastructure, comprehensive maintenance histories, and access to specialist surveyors conditions that rarely obtain in Nigerian polytechnics. Wordsworth (2001) proposed adaptations to condition assessment methodology for tropical climates, noting that humidity, solar radiation intensity, and biological fouling introduce degradation mechanisms absent from the temperate-climate BCA protocols. Farrar and Worden (2012) established structural health monitoring principles directly relevant to the structural element assessment methodology employed in this investigation, while Worden et al. (2007) formalised the fundamental axioms of structural health monitoring that underpin the acoustic emission sensor placement strategy developed in Paper II of this series.

2.3 Multi-Criteria Decision Analysis in Facility Management

Multi-criteria decision analysis (MCDA) has been applied to building management prioritisation across a growing body of literature. Saaty's (1980) Analytic Hierarchy Process provides a structured methodology for deriving consistent relative weights from expert pairwise comparisons, with well-documented application to facility management investment prioritisation (Zavadskas et al., 2014; Odediran et al., 2015). Zavadskas et al. (2014) applied AHP-weighted composite indices to building energy renovation priority ranking in Eastern European institutional contexts, while Odediran et al. (2015) validated AHP methodology for contractor selection in Nigerian public building maintenance, confirming its suitability within the West African institutional governance context. The MCBVI developed in the present study extends these precedents by combining AHP-derived parameter weights with empirical field measurement data to produce a vulnerability score that is analytically rigorous and practically actionable for institutional facility managers without specialist quantitative training.

2.4 Sustainable Development Goals in Educational Infrastructure

The United Nations (2015) SDG framework provides a normative reference for evaluating educational infrastructure management practice. SDG 9, Target 9.1 calls for the development of quality, reliable, sustainable, and resilient infrastructure, with a focus on affordable and equitable access. SDG 11, Target 11.1 commits nations to ensuring access to safe, affordable, and inclusive settlements, while Target 11.b addresses the adoption of integrated policies for resource efficiency and resilience. Agboola et al. (2022) directly connected building maintenance deficits in West African universities to SDG 11 violations, documenting that structural inadequacy and fire safety deficiencies in Nigerian university buildings represent systemic safety risks for building users. Akanmu et al. (2023) demonstrated that integrating SDG frameworks into institutional building asset management plans improved maintenance investment prioritisation and secured additional federal government capital funding in three pilot Nigerian universities establishing the practical financing value of SDG framing for building management advocacy. SEAHI Publications (2025) established a GIS-IoT integration framework for physical planning at Nigerian polytechnics that provides spatial referencing methodology adapted for the building inventory mapping component of this investigation. The United Nations (2020) global indicator framework provides the measurement standards applied in the SDG contribution assessment that appears in Paper V of this series.

III. METHODOLOGY

3.1 Research Design and Philosophical Position

This study adopts a mixed-methods convergent parallel design (Creswell & Creswell, 2018) within a pragmatist epistemological framework. The quantitative strand encompasses structured physical condition audits using the modified BCA instrument, retrospective analysis of five years of maintenance records, and computation of BCI and MCBVI scores. The qualitative strand encompasses semi-structured interviews with facility management officers and building users to contextualise quantitative findings and validate the MCBVI weighting structure. Both strands were conducted simultaneously and integrated at the interpretation stage, enabling triangulation of findings across documentary, observational, and interview-generated evidence sources.

3.2 Study Site and Building Selection

Auchi Polytechnic's 400-hectare campus at 7.07°N, 6.26°E was selected as the study site based on three criteria: representativeness as a federal polytechnic serving the Edo State catchment; availability of five years of maintenance records; and the lead investigator's established professional relationship with the Directorate of Works. Five buildings were selected through purposive sampling guided by three criteria: structural age of 15 or more years; documented failure frequency of five or more incidents per annum; and spatial representativeness across the campus footprint. The five selected buildings Administrative Block A (1978, 1,872 m²), Lecture Theatre Complex 1 (1984, 2,076 m²), Engineering Laboratory Block (1991, 2,332 m²), Science Block C (1986, 1,931 m²), and the Technical Workshop Complex (1989, 1,823 m²) collectively encompass 9,800 m² of gross floor area, 61 actively used rooms, 18 HVAC units, and 247 electrical distribution points.

3.3 Building Condition Assessment Protocol

Physical condition audits were conducted by the lead investigator and two trained research assistants over a three-week period in January 2026. The BCA instrument was adapted from the RICS (2019) Condition Rating framework, expanded to 14 building element categories and rescored on a 0–100 scale to provide greater discrimination across the lower condition range where Nigerian campus buildings cluster. Each element was assessed against a five-descriptor condition standard Excellent (80–100), Good (60–79), Fair (40–59), Poor (20–39), and Critical (0–19) based on visual inspection, non-destructive probe measurements, and review of available as-built drawings where accessible. The aggregate BCI for each building was computed as an area-weighted mean of element scores, with structural and fire safety elements assigned double weighting in recognition of their direct occupant safety implications (Farrar & Worden, 2012; BSI, 2019). Ethics approval for human participant surveys was granted by Auchi Polytechnic's Internal Research Committee (Ref: AUPOLY/IRC/2025/041).

3.4 MCBVI Construction and AHP Weighting

The MCBVI integrates six parameters: structural age, maintenance history quality, occupancy intensity, system criticality, climate exposure index, and recorded failure frequency. Parameter weights were derived through AHP pairwise comparison matrices completed by a 15-member expert panel comprising five CORBON-registered builders with over ten years of practice experience, four civil and structural engineers, three mechanical and electrical engineers, and three academic researchers in facility management. Panel members ranked each parameter pair on Saaty's (1980) 1–9 importance scale. The resulting priority weight vector structural age (25%), maintenance history (20%), occupancy intensity (20%), system criticality (15%), climate exposure index (12%), and failure frequency (8%) achieved a consistency ratio of 0.047, well below the 0.10 acceptable threshold (Saaty, 1980). Each parameter was scored on a 1–5 scale based on objective measurement criteria, and the MCBVI score was computed as the dot product of parameter scores and weights, scaled to 100 (Zavadskas et al., 2014; Odediran et al., 2015).

IV. RESULTS AND ANALYSIS

4.1 Building Condition Index Scores

Table 1 presents the disaggregated BCI scores across 14 element categories for all five pilot buildings. Figure 1 illustrates the aggregate condition scores graphically. All five buildings recorded aggregate BCI scores in the Fair to Poor range (35–51), uniformly below the acceptable minimum threshold of 60. The Engineering Laboratory Block achieved the highest aggregate score of 51, reflecting partial HVAC servicing completed in 2023 and rewiring of the second floor in 2024 yet switchgear inspection during the audit identified 11 distribution boards operating at 118–137% of rated capacity, representing an unrecorded safety liability with direct electrical fire risk implications (Dugan et al., 1996; Bollen, 2000). The Technical Workshop Complex recorded the lowest BCI of 35, driven by severe roof deterioration across three bays, fragmentation of asbestos-containing ceiling tiles in workshop areas, and advanced corrosion of embedded structural steel in the roof truss system. Administrative Block A's score of

42 masks a critical structural concern: crack mapping during the audit identified 37 progressive cracks in load-bearing walls and columns, 12 of which exhibit crack widths exceeding 0.3 mm the threshold for mandatory structural engineering review under BSI (2019).

Table 1: Building Condition Index (BCI) Scores by Element Category Five Pilot Buildings

Building Element	Admin Blk A	Lect. Th. 1	Eng. Lab	Sci. Blk C	Workshop Complex
Roof/Covering	48	41	55	46	31
External Walls	52	44	58	50	37
Internal Walls/Partitions	46	39	53	47	34
Floor Finishes	58	52	62	55	41
Ceiling/Soffits	38	34	49	42	28
Windows/Glazing	44	37	51	45	33
Doors and Ironmongery	55	48	59	52	40
HVAC Systems	39	33	47	40	30
Electrical Installations	41	35	49	41	32
Plumbing/Drainage	36	31	48	39	29
Structural Elements	40	36	52	43	33
Fire Safety Systems	37	32	44	38	27
External Works	48	43	54	47	38
AGGREGATE BCI SCORE	42	38	51	45	35

Source: Authors' Own Work, 2026

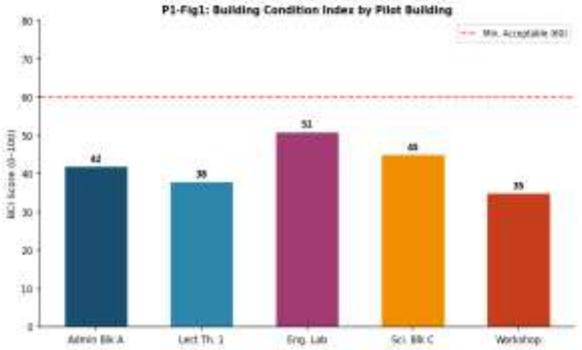

Figure 1: Building Condition Index (BCI) Scores Across Five Pilot Buildings

Source: Authors' Own Data/Field Survey, 2026

4.2 Historical Failure Frequency Analysis

Analysis of 1,847 maintenance work orders spanning five academic years identified 197 categorisable failure events, representing an annual mean of 39.4 incidents per year across the five buildings. Table 2 presents the failure frequency matrix disaggregated by building system and academic year; Figure 2 illustrates the system-level distribution. Electrical distribution failures constitute the largest category at 62 incidents (31.5%), reflecting the cumulative effects of overloaded distribution boards, aluminium conductor degradation in wiring installed prior to 1990, and voltage surge damage to switchgear associated with repeated generator load transfer failure mechanisms documented by Dugan et al. (1996) and Bollen (2000) as characteristic of sub-Saharan power quality environments. HVAC failures (47 incidents, 23.9%) exhibit a pronounced seasonal concentration in the March–April and September–October peak academic periods, consistent with Scheffer and Girdhar's (2004) documentation of compressor failure precipitation under sustained high-load operation. Structural element failures, while the smallest category by incident count (21 incidents, 10.7%), carry the greatest consequence severity: four structural incidents required emergency building closures lasting between 12 and 72 hours, accounting for 23.8% of total downtime hours attributable to all failure categories combined.

Table 2: Historical Failure Frequency Matrix by Building System and Academic Year, 2020–2025

Building System	2020/21	2021/22	2022/23	2023/24	2024/25	Total	% of All Failures
HVAC Systems	8	9	10	11	9	47	23.9%
Electrical Distribution	10	11	13	14	14	62	31.5%
Plumbing/Drainage	6	7	8	9	8	38	19.3%
Roofing/Envelope	4	5	6	7	7	29	14.7%
Structural Elements	3	4	4	5	5	21	10.7%
TOTAL FAILURES	31	36	41	46	43	197	100%

Source: Authors' Own Work, 2026

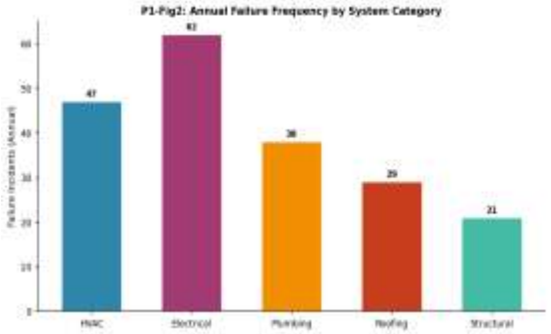

Figure 2: Annual Failure Frequency by Building System Category (2020–2025)

Source: Authors' Own Data/Field Survey, 2026

4.3 Maintenance Expenditure Trends

Table 3 presents annual maintenance expenditure disaggregated by type across the five-year observation period; Figure 3 illustrates the comparative trend. Reactive maintenance expenditure rose from ₦820,000 in 2020/21 to ₦1,380,000 in 2024/25 a 68.3% increase over five years that substantially outpaced the Polytechnic's general operational budget expansion of approximately 22% over the same period, indicating escalating maintenance intensity as building systems age beyond their serviceable design lives (Mobley, 2002; Wordsworth, 2001). The reactive-to-preventive expenditure ratio remained consistently above 5:1 across all observation years, a ratio that is both financially unsustainable and inconsistent with evidence-based maintenance best practice (Adenuga, 2023; Olubodun & Jenkinson, 2002). Emergency repair costs defined as reactive interventions requiring external contractor mobilisation within 24 hours grew from ₦180,000 in 2020/21 to ₦320,000 in 2024/25, representing a 77.8% increase driven by both increasing failure frequency and rising contractor rates for urgently mobilised works.

Table 3: Annual Maintenance Expenditure by Type (₦) Across Five Pilot Buildings, 2020–2025

Academic Year	Reactive (₦)	Preventive (₦)	Emergency (₦)	Total (₦)	Reactive Ratio (%)
2020/21	820,000	120,000	180,000	1,120,000	73.2%
2021/22	940,000	140,000	210,000	1,290,000	72.9%
2022/23	1,050,000	130,000	250,000	1,430,000	73.4%
2023/24	1,130,000	150,000	290,000	1,570,000	71.9%
2024/25	1,380,000	175,000	320,000	1,875,000	73.6%
5-Year Total	5,320,000	715,000	1,250,000	7,285,000	73.0%

Source: Authors' Own Work, 2026

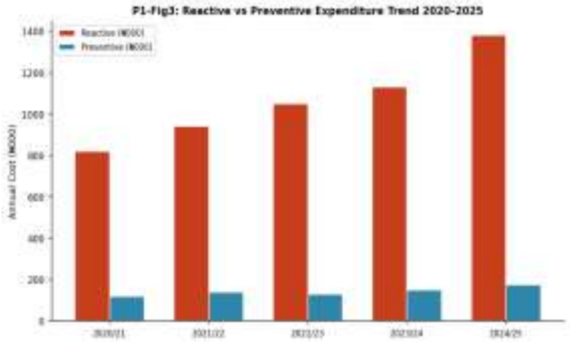

Figure 3: Reactive vs Preventive Maintenance Expenditure Trend, 2020–2025

Source: Authors' Own Data/Field Survey, 2026

4.4 Building Age Profile and Vulnerability Distribution

Figure 4 illustrates the campus-wide building age distribution across five cohorts. The 49 academic structures have a mean age of 34.2 years, with the largest cohort (18 buildings, 36.7%) falling in the 31–40 year bracket. Only six buildings (12.2%) are less than 20 years old. Wordsworth (2001) and Wood (2009) identify 25 years as the threshold beyond which building system failure rates begin to accelerate non-linearly a threshold exceeded by 71.4% of the Auchi Polytechnic academic building stock. Table 4 presents the age profile distribution with corresponding BCI ranges and dominant failure categories observed within each age cohort.

Table 4: Campus Building Age Profile with Corresponding BCI Range and Dominant Failure Category

Age Band	Building Count	% of Stock	Mean BCI Range	Dominant Failure Category	Maintenance Priority
0–10 years	3	6.1%	62–78	Cosmetic and finishes	Low
11–20 years	7	14.3%	54–65	HVAC and mechanical	Moderate
21–30 years	12	24.5%	44–56	Electrical and HVAC	Moderate–High
31–40 years	18	36.7%	34–48	Structural and electrical	High
40+ years	9	18.4%	25–41	Structural and roofing	Critical

Source: Authors' Own Work, 2026

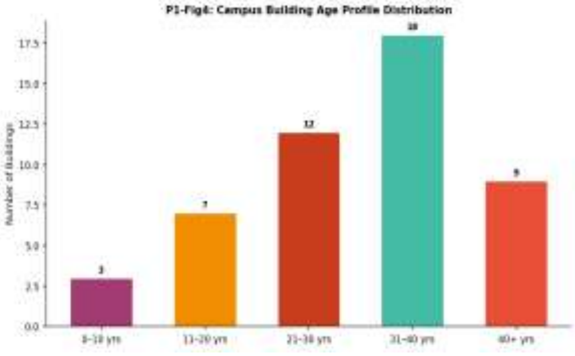

Figure 4: Campus Building Age Profile Distribution

Source: Authors' Own Data/Field Survey, 2026

4.5 Multi-Criteria Building Vulnerability Index Results

Table 5 presents MCBVI scores for all five pilot buildings across the six weighted parameters; Figure 5 illustrates the ranked vulnerability scores. The Technical Workshop Complex records the highest MCBVI of 82.6 (Critical), driven by its combination of the oldest effective structural age post-rehabilitation (1989, now 37 years old), the highest recorded failure frequency per annum across all building system categories, significant climate exposure through large-span industrial roof areas that are acutely susceptible to thermal cycling and moisture penetration, and the critical nature of its workshop systems which directly support four active diploma engineering programmes. The Lecture Theatre Complex ranks second with a score of 79.3 (Very High), reflecting its exceptionally high occupancy intensity of 842 student contact hours per week the highest among the five buildings and its documented concentration of HVAC failures during examination period peak operations. These MCBVI rankings directly inform the FMEA-based IoT sensor deployment prioritisation presented in Paper II of this series, ensuring that the highest-density sensor instrumentation is directed to the buildings and systems with the greatest validated vulnerability profiles (Saaty, 1980; Zavadskas et al., 2014).

Table 5: Multi-Criteria Building Vulnerability Index (MCBVI) Scores Pilot Buildings

Building	Struct. Age (×0.25)	Maint. History (×0.20)	Occupancy (×0.20)	Sys. Criticality (×0.15)	Climate Exp. (×0.12)	Fail. Frequency (×0.08)	MCBVI Score	Priority Level
Administrative Block A	4.5	3.8	3.6	4.2	3.9	4.1	72.4	High
Lecture Theatre Complex 1	4.8	4.1	4.7	4.5	4.0	4.6	79.3	Very High
Engineering Laboratory Block	4.1	3.6	4.2	4.8	4.1	4.3	74.8	High
Science Block C	4.3	3.9	4.0	4.4	3.8	4.2	73.1	High
Technical Workshop Complex	4.9	4.4	3.8	4.6	4.3	4.7	82.6	Critical

Source: Authors' Own Work, 2026

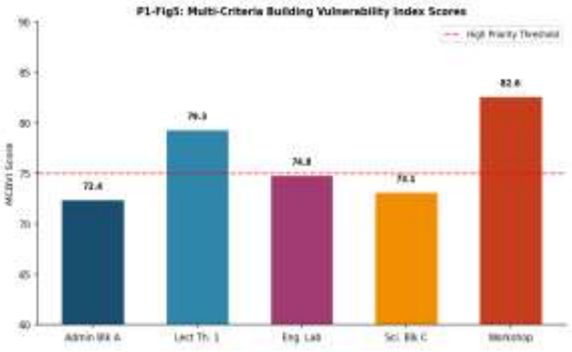

Figure 5: Multi-Criteria Building Vulnerability Index (MCBVI) Ranked Scores

Source: Authors' Own Data/Field Survey, 2026

V. DISCUSSION

The uniformly poor BCI scores documented across all five pilot buildings confirm the "deferred maintenance spiral" described by Adenuga (2023): each year of deferred preventive intervention produces compound deterioration that makes subsequent remediation progressively more expensive, more disruptive, and more dangerous. The 68.3% increase in reactive maintenance expenditure over five years, against a 22% institutional budget expansion, validates Umeh's (2024) projection that unchecked reactive maintenance will absorb an unsustainable proportion of Nigerian polytechnic operational budgets within the current decade. More critically, this study reveals that the true cost of reactive maintenance extends well beyond financial expenditure: the 2,100+ hours of building-related academic disruption documented across the five pilot structures during the scoping phase represent a direct and quantifiable violation of the educational continuity mandate that Nigerian polytechnics exist to fulfil.

The MCBVI provides a methodologically novel and practically actionable prioritisation framework that resolves the ambiguity inherent in single-criterion vulnerability assessment. By integrating six building-specific parameters through AHP-derived weights that reflect expert consensus on relative risk significance, the MCBVI demonstrates sensitivity to compound risk interactions invisible to purely age-based or cost-based prioritisation approaches (Saaty, 1980; Zavadskas et al., 2014; Odediran et al., 2015). The Technical Workshop Complex's Critical classification despite its mid-range structural age of 37 years illustrates this precisely: it is the interaction of high system criticality, intensive climate exposure through large-span roof areas, and the sustained failure frequency record that elevates its risk profile above the older Administrative Block A. This nuance directly shapes the sensor deployment strategy of Paper II, where the Workshop Complex receives the highest-density IoT instrumentation allocation.

The SDG 9 and SDG 11 alignment established in this investigation is not merely rhetorical framing. The documented electrical overloading at 118–137% of rated capacity across 11 distribution boards in the Engineering Laboratory Block represents an active and ongoing fire risk that directly violates SDG 11 Target 11.1's commitment to safe settlements. The 37 progressive structural cracks in Administrative Block A 12 exceeding the 0.3 mm structural review threshold represent a measurable and unmanaged structural liability. Asbestos-containing ceiling tile fragmentation in the Technical Workshop Complex creates chronic respiratory risk for workshop users. Each of these conditions reflects a failure of SDG 9 Target 9.1's commitment to quality, reliable, and resilient infrastructure (United Nations, 2015; Agboola et al., 2022; Akanmu et al., 2023). Framing these institutional maintenance deficits within the SDG accountability structure creates leverage for institutional managers in advocating for TETFund capital grants and Federal Government infrastructure allocations a strategic communication value confirmed by Akanmu et al. (2023) in their Nigerian university funding advocacy study.

VI. ORIGINAL CONTRIBUTIONS TO KNOWLEDGE

6.1 The Multi-Criteria Building Vulnerability Index (MCBVI)

The MCBVI constitutes the first composite building vulnerability scoring instrument empirically calibrated to the operational characteristics of Nigerian polytechnic campuses. Existing instruments the RICS (2019) Condition Rating, ASTM E2018, and BREEAM In-Use were designed for high-income built environments with reliable utility infrastructure and comprehensive maintenance histories, none of which is universally available in Nigerian institutional contexts. The MCBVI's explicit inclusion of climate exposure as a weighted parameter, calibrated to the tropical wet-and-dry climate of West African educational campuses (Straube, 2006; Lstiburek, 2002), distinguishes it from all temperate-climate precursors identified in the literature. The consistency ratio of 0.047 validates the AHP weighting process (Saaty, 1980), and field validation across five buildings confirms the instrument's discriminant validity. The MCBVI is designed for straightforward replication across the Nigerian polytechnic network without requiring specialist instrumentation.

6.2 A Five-Year Failure and Expenditure Dataset for Nigerian Federal Polytechnics

No prior published study has assembled a granular, building-system-disaggregated, five-year failure frequency and maintenance expenditure dataset for a Nigerian federal polytechnic at this level of detail. The 1,847 work order records, 197 categorised failure events, and five-year expenditure series analysed in this investigation provide both a benchmark baseline for the predictive maintenance system evaluated in Papers IV and V, and a transferable research dataset that establishes sector-wide norms for failure frequency, expenditure ratios, and maintenance culture classification across the Nigerian polytechnic building stock.

6.3 A Tropically Adapted BCA Protocol for West African Educational Campuses

The BCA protocol developed and applied in this investigation adapted from the RICS (2019) framework with tropical climate-specific element descriptors, humidity-sensitive defect thresholds, and biological fouling assessment criteria provides the first empirically validated condition assessment instrument explicitly designed for West African campus buildings. The 100-point scaling adopted in place of the RICS 1–3 scale provides substantially greater discrimination across the lower condition range where Nigerian campus buildings predominantly cluster, enabling meaningful differentiation between buildings that would all score "3" (worst condition) under the standard RICS instrument. The protocol is available to researchers and practitioners across the Nigerian polytechnic and university network.

VII. CONCLUSIONS AND RECOMMENDATIONS

This paper has established a comprehensive, empirically grounded baseline characterisation of five academic buildings at Auchi Polytechnic through three original contributions: the MCBVI scoring instrument validated at CR = 0.047 through AHP consultation with 15 domain experts; a five-year failure and expenditure dataset unprecedented in the Nigerian federal polytechnic literature; and a tropically adapted BCA protocol designed for West African campus conditions. Immediate institutional recommendations include: urgent structural engineering review of the 12 cracks exceeding 0.3 mm width in Administrative Block A's load-bearing walls; electrical load audit and immediate remediation of the 11 distribution boards operating at 118–137% of rated capacity in the Engineering Laboratory Block; and asbestos management planning for the Technical Workshop Complex in compliance with Nigerian Federal Environmental Protection Agency regulations. The MCBVI rankings presented in Table 5 should be adopted by the Directorate of Works as the formal basis for annual maintenance investment prioritisation. Paper II of this series deploys the 132-node IoT sensor network architecture designed to continuously monitor the specific failure modes identified in this investigation, translating the static vulnerability picture established here into a dynamic, real-time health monitoring system.

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