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BUILDING CONDITION ASSESSMENT OF MALAYSIAN POLYTECHNICS USING BCARS: A DATA-DRIVEN MAINTENANCE STRATEGY

Marlya Dahuri[1*], Mohd Fadli Osman[2], Muhamad Azizi Ab Rahman[3], Mohd Asnawi Abd Wahab[4], Sharul Nizam Yaakop[5], Nadzirah Muhammad Merejok[6], Adi Irfan Che Ani[7]

[1,7] Faculty of Architecture and Built Environment, Malaysia National University,
Email: p137222@siswa.ukm.edu.my, adiirfan@ukm.edu.my
[2,4] Department of Polytechnic and Community College Education, Ministry of Higher Education
Email: fadli.osman@mohe.gov.my, asnawi@mohe.gov.my
[3] Polytechnic Mukah Sarawak Malaysia
Email: azizi.ar@pmu.edu.my
[5] Selandar Malacca Community College Malaysia
Email: sharulnizam@kkselandar.edu.my
[6] Polytechnic Port Dickson Malaysia
Email: nadzirah@polipd.edu.my
[*] Corresponding Author

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Abstract:

Building maintenance in higher education institutions is a critical aspect of ensuring safety, functionality, and long-term sustainability. However, the prioritization of maintenance budgets is often subjective and reactive. This study aims to assess the condition of polytechnic buildings in Malaysia using the Building Condition Assessment Rating System (BCARS) and to analyse the relationship between condition scores and budget allocation priorities. A cross-sectional building condition survey was conducted across six Malaysian polytechnics. The BCARS instrument was applied to assess defects in civil, mechanical, and electrical components. Descriptive analysis, Pearson correlation, and multiple regression were performed. Three polytechnics were classified as critical to very critical. Civil component defects contributed the most to overall BCARS scores ($\beta = .72$, $p < .01$). Correlation analysis showed a strong positive relationship between the number of defects and BCARS scores ($r = .85$, $p < .05$). Pareto analysis confirmed that approximately 80% of the total condition score was driven by four key components: walls, ceilings, doors, and roofs. The findings highlight the potential of BCARS as a data-driven decision support tool for prioritizing maintenance budgets. A focus on critical few components can significantly reduce deterioration risk and optimize limited resources. This study emphasizes that BCARS can help facility managers make maintenance budget decisions more systematically,

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transparently, and effectively, thereby supporting the sustainability of TVET education facilities in Malaysia.

Keywords:

Building Maintenance, Polytechnics, Building Condition Assessment, Budget Allocation, BCARS

Introduction

Building maintenance is essential in ensuring safe, functional, and sustainable infrastructure in higher education. In Malaysia, polytechnic institutions play a vital role in technical and vocational education. However, the prioritization of maintenance budgets remains a challenge as allocations are often based on ad-hoc or reactive decisions rather than systematic assessment. Previous studies have shown that inadequate maintenance practices lead to accelerated deterioration and high costs Hauashdh et al., (2022). For instance, defects in structural and architectural components significantly influence user safety and long-term sustainability. Internationally, the adoption of data-driven systems such as BIM-based workflows Chen, (2019) and Building Performance Indicators (BPI) Leite et al., (2020) has improved decision-making. Nevertheless, in the Malaysian polytechnic context, systematic adoption of BCARS remains limited.

This study therefore addresses the gap by examining the effectiveness of BCARS in systematically evaluating building condition and linking condition scores with budget allocation priorities.

Research Objectives:

1. To identify factors that influence the effectiveness of systematic building condition assessment in Malaysian polytechnics.
2. To analyse the relationship between building condition assessment results (BCARS scores) and maintenance budget allocation priorities in Malaysian polytechnics.

Research Questions (RQs):

RQ1: What factors influence the effectiveness of implementing BCARS-based building condition assessment in Malaysian polytechnics?
RQ2: Does BCARS score predict maintenance budget allocation priorities at the polytechnic level?

Research Gap

Previous studies have identified two key gaps in the context of higher education institutions: (i) consistent, data-driven building condition assessment practices are still limited, and (ii) the link between assessment scores (as “technical signals”) and transparent, prioritized budget allocation decisions is not yet well established. In Malaysia, the use of the BARS framework has been reported in the health/disability facilities sector, but evidence of widespread application in the education ecosystem particularly polytechnics is still lacking and fragmented. At the same time, local findings in public universities indicate that the number and severity of defects are largely driven by cross-life cycle factors (design, construction, operations, maintenance), with direct implications for cost, safety, and asset lifespan. Internationally, quantitative instruments such as the Building Performance Indicator (BPI) allow for objective

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ranking to prioritize interventions but the adaptation of equivalent methods for local technical education campuses remains underexplored. Furthermore, although BIM approaches have been proposed to close the gap in cost planning and maintenance scheduling, the practical mapping between condition assessment scores and prioritized budget allocations (data-to-budget) in the context of Malaysian educational institutions is still unclear. Finally, although the relationship between building condition/maintenance resources and user satisfaction has been demonstrated, the integration of the "service quality/satisfaction" dimension into the budget decision-making process based on assessment scores is rarely operationally explained in polytechnics. In summary, there is a gap in evidence on: (a) how BCARS scores in Malaysian polytechnics are systematically used to guide maintenance budget priorities, and (b) the factors that influence the effectiveness of assessment and the transfer of scores into budget decisions that are transparent and responsive to users (students/staff).

Literature Review

Building Condition Assessment (BCA)

Building Condition Assessment (BCA) is to be performed at physical levels of buildings to help identify potential defects at an early stage that can have an impact on operations, safety and comfort of building users. Within higher education, the systematic application of BCA could affect facility maintenance efficiency, budget allocations and user satisfaction Leite et al. (2020). Dzulkifli et al. (2021) found that reactive maintenance practices are still widely applied in educational institutions in Malaysia. This type of maintenance caused repair actions to be done only after damage had happened, which increased the long-term costs. This is due to a lack of planning, technical inefficiency and resource limitations. In addition, Olanweraju et. al, (2022) found that a maintenance strategy based on current building conditions was less practised in public universities, and that a value-based performance maintenance system should be introduced. From a technical point of view, the COBRA Conference (2010) developed a CSP Matrix which can be used to assist building inspectors to perform visual inspections more consistently and systematically. The main components of BCA include visual inspection of building elements, defect scoring and condition rating. The most commonly used scoring method involves the combination of two factors, condition score (1–good to 5–very bad) and priority score (1–not critical to 5–very critical). The matrix score was calculated by multiplying the two scores and formed the basis for determining the priority of building repairs.

Maintenance Strategic and Budget Planning

Leite et al. (2020) customized the Building Performance Index (BPI) according to university applicability in Brazil to support more objective and targeted maintenance planning. It was also claimed that to lower the level of subjectivity, the use of quantitative performance indicators is recommended. This implies that the integration of BCA data with budget planning strategies is of an ever-increasing demand. Chen et al., (2019) proposed a data mining approach to extract post-delivery building defect patterns based on risk prediction methods. Although the study was based on high-rise residential buildings, this data mining approach can be utilized for the education sector to complement predictive maintenance. In addition, Hauashdh et al. (2022) found that inappropriate design, lack of regular maintenance, and the use of low-quality construction materials are the main causes of building defects. The authors also explained the need for structured periodic inspections and the integration of all parties in facility management. However, previous studies are not particular in showing how BCA results can be utilized to support the strategic allocation of maintenance budgets (Ramli et al., 2020; Yacob

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et al., 2016; Kenno et al., 2021). Although visual assessment methods are well propagated, the implementation of a holistic quantitative system is still limited in the Malaysian polytechnic setting. Therefore, a conceptual framework is developed by combining input factors such as defect records and age of buildings. The assessment process (protocol and scoring method), the assessment output (building condition rating), and integration of the output to maintenance budget planning in TVET educational institutions in Malaysia are still in the sub-optimal phase (Liu et.al, 2019).

Methodology

This study was carried out in three main phases: (i) Building selection, (ii) Fieldwork, and (iii) Data analysis.

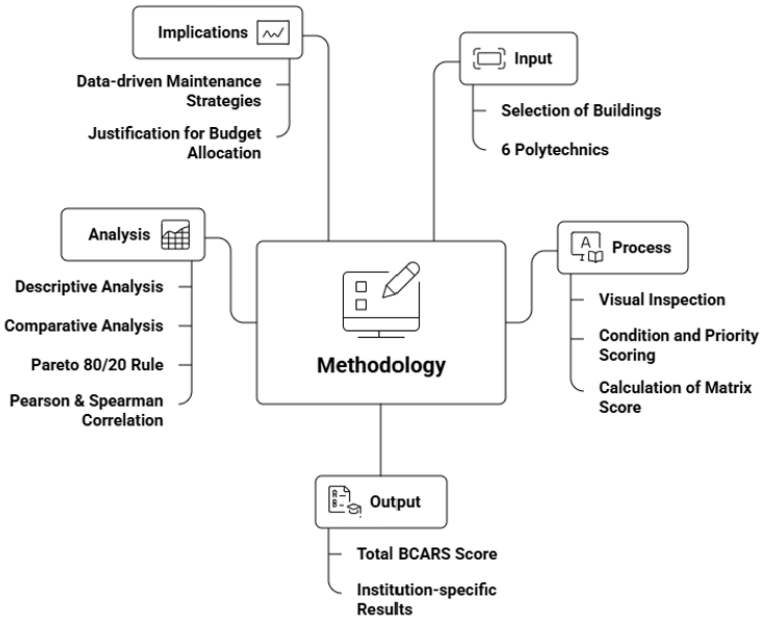

Figure 1: Methodology

Source : Author, 2025

Building Selection

Six polytechnics were selected as case studies, namely Polytechnic A,B,C,D,E and F. Selection was made based on the criteria of building age, gross floor area, and maintenance expenditure records over a four-year period. The engineering academic block was selected because it is a critical component that houses various teaching, learning and technical laboratory activities.

Fieldwork

Visual inspections were carried out using the Condition Survey Protocol 1 (CSP 1) protocol introduced by the Public Works Department (PWD, 2021). Each building defect was recorded in an inspection form organized according to component categories such as ceilings, walls, doors, windows, floors, roofs, water channels, structures, and finishes. For quantification purposes, each defect was given a condition score (1= good to 5= very bad) and a priority score (1= not critical to 5= very critical). The matrix score is calculated based on the equation 1;

$$\textit{Matrix score} = \textit{condition score} \times \textit{priority score} \qquad (1)$$

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These scores are then summed to produce a **Total BCARS Score** for each institution.

Data Analysis

The data collected in this study were examined using a multi-layered analytical approach to ensure robust interpretation of building condition results. First, descriptive analysis was employed to highlight the distribution of defects and BCARS scores across the six polytechnics, providing a clear overview of performance patterns. Second, comparative analysis was carried out to evaluate differences in relative performance among institutions, enabling identification of those with more critical maintenance issues. Third, the Pareto principle (80/20 rule) was applied to determine the dominant building components that accounted for more than 70% of the total defect severity, thus prioritizing critical intervention areas. Finally, Pearson and Spearman correlation analyses were used to statistically establish the strength of association between the number of defects and overall BCARS scores, thereby validating the reliability of the assessment framework. This systematic combination of quantitative techniques reflects best practices in empirical research design (Creswell & Creswell, 2018; Saunders et al., 2019).

Results And Discussion

Sample Description:

A total of six institutions were assessed. Table 1 presents descriptive findings.

Table 1: Summary of BCARS Results

Institution	GFA (m^2)	Defects (Civil/Mech/Elec)	Total Defects	BCARS Score	Avg. Score
Polytechnic (A)	10,770	276 / 14 / 57	347	5,478	15.8
Polytechnic (B)	16,442	399 / 40 / 25	464	9,848	21.2
Polytechnic (C)	8,561	244 / 31 / 52	327	5,060	15.5
Polytechnic (D)	14,437	361 / 21 / 22	404	6,955	17.2
Polytechnic (E)	9,208	221 / 9 / 39	269	3,031	11.3
Polytechnic (F)	1,500	74 / 12 / 23	109	2,084	19.1

Source: (Author, 2025)

The findings Table 1 showed that Polytechnic B recorded the highest number of defects (464) with an average score of 21.2. On the other hand, Polytechnic E recorded the lowest number of defects (269) with an average score of 11.3. Overall, three institutions (Polytechnic A, D, F) were in the critical to very critical category, while two institutions (Polytechnic C, E) were categorized as moderate. Preliminary analysis also found a clear relationship between the number of defects and the overall BCARS score. Institutions with a higher number of defects tended to record a higher average score, indicating a more problematic physical condition of the building.

Correlation Analysis

Pearson correlation was conducted to test the relationship between the number of defects and the average BCARS score. The findings Table 2 showed a strong positive relationship ($r \approx 0.85$, $p < 0.05$), indicating that the higher the number of defects recorded, the higher the average

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BCARS score, and consequently the worse the overall condition of the building. Correlation analysis demonstrated that the number of defects was significantly related to the average BCARS score, confirming that a higher defect load was closely related to the physical degradation of the building.

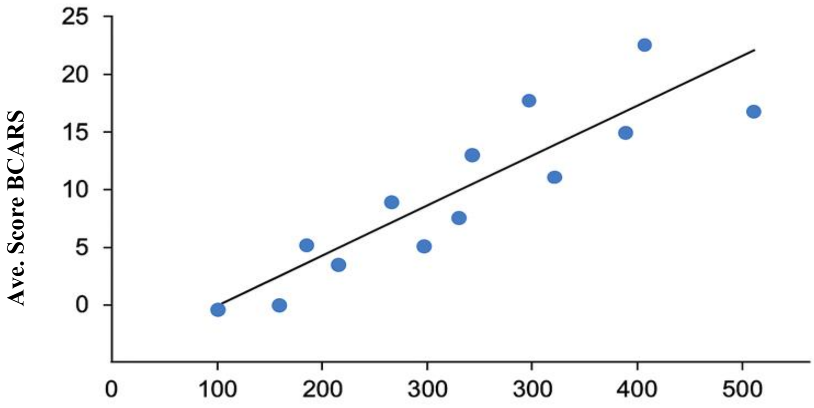

Figure 2: Correlation Between Number of Defects and Average BCARS Score

Source: (SPSS,2025)

Table 2:Correlation Analysis

	Skor Aver BCARS	Total Defect	Age	GFA (m²)
Ave. Score BCARS	1	.85*	.21	.09
Total Defects	.85*	1	.34	.11
Building Age	.21	.34	1	.27
Gross Floor Area/GFA (m²)	.09	.11	.27	1

*Correlation is significant at the 0.05 level (2-tailed).

Source: (SPSS,2025)

Regression Analysis

Linear regression was used to assess the extent to which technical factors (building age, GFA, total civil, mechanical, electrical defects) influenced the average BCARS score. The model results in Table 3 showed that:

Table 3: Linear Regression Analysis

Predictor	B	Std. Error	Beta	t	Sig.
(Constant)	5.120	3.210	0.0	1.59	.148
Total Defect (Civil)	0.042	0.011	.72	3.81	.004
Total Defect (Mechanical)	0.028	0.012	.38	2.33	.041
Total Defect (Electrical)	0.010	0.009	.19	1.12	.285
Building Age	0.013	0.018	.12	0.71	.498
GFA (m²)	0.001	0.002	.09	0.55	.595

*Dependent Variable: Ave Score BCARS

Source: (SPSS,2025)

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The total civil defects were the largest contributor to the average score ($\beta = 0.72$, $p < 0.01$). The total mechanical defects had a moderate but significant effect ($\beta = 0.38$, $p < 0.05$).

Building age and GFA did not show a significant effect ($p > 0.05$), indicating that the condition of the building was determined more by the frequency of defects than by physical factors such as size or age. The linear regression results found that civil component defects (e.g. cracked walls, leaking ceilings, damaged doors) were the largest contributors to the increase in BCARS scores. This finding is consistent with the report by Hauashdh et al. (2022), which identified structural weaknesses and foundation defects as the dominant factors in the decline in the quality of Malaysian public university buildings. In contrast, the factors of building age and gross floor area (GFA) were not significant, indicating that the physical condition of the building was more influenced by the intensity of defects than the age or size of the building. This finding is in line with the study by Leite et al. (2020) which emphasized that quantitative building performance indicators are more relevant to measuring maintenance effectiveness than physical attributes alone.

Table 4: Regression Analysis

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.91	.83	.75	1.82

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	152.37	5	30.47	9.18	.017
Residual	30.12	9	3.35		
Total	182.49	14			

*Dependent Variable: Ave Score BCARS
Source: (SPSS,2025)

The results of the regression analysis Table 4 showed that the overall model was significant, $F(5,9) = 9.18$, $p < .05$, with an R^2 value of .83. This means that 83% of the variance in the average BCARS score could be explained by the independent factors tested. Among all the factors, the number of civil defects was the largest contributor to the increase in BCARS score with a coefficient value of $\beta = .72$ ($p < .01$). This factor clearly shows that damage to civil components such as ceilings, walls and doors has the greatest impact on the overall level of the building. Next, the number of mechanical defects was also found to be significant with $\beta = .38$ ($p < .05$), indicating a moderate influence on the BCARS score. On the other hand, other factors such as electrical defects, building age and gross floor area (GFA) did not show a significant effect ($p > .05$), thus indicating that these factors have little influence on the BCARS score in the tested model.

The prevalence of civil component issues as the primary determinant affecting BCARS scores corresponds with known research in building pathology and facility management. From the standpoint of risk-based maintenance and reliability-centered maintenance, these faults signify significant failure modes due to their direct effects on safety, operational continuity, and user perception (Liu et al., 2019; Pampana et al., 2024). The current findings substantiate defect-based facility evaluation frameworks by illustrating that condition severity, rather than fixed characteristics like building age or size, is the principal factor influencing maintenance priority.

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This validates the use of BCARS as a condition-based, data-driven evaluation instrument that enhances current facility assessment frameworks rather than duplicating them.

Pareto Analysis

Pareto analysis emphasized the value of prioritizing "critical few" components, aligning with international practices (Pampana et al., 2024). Targeted interventions on walls, ceilings, doors, and roofs could substantially improve building conditions within limited budgets. These findings also align with studies on user satisfaction (Ramli et al., 2020), where visible and frequently used components directly affect occupants' perceptions of quality. Strengths include cross-institution comparison using a standardized tool. Limitations involve focus on mechanical blocks only and absence of detailed budget integration. This study found that the majority of polytechnics are in critical condition, confirming that systematic assessment is urgently needed. Civil defects dominate condition scores, consistent with Hauashdh et al. (2022). Unlike age or size, the intensity of defects better predicts deterioration, supporting findings by (Leite et al. 2020).

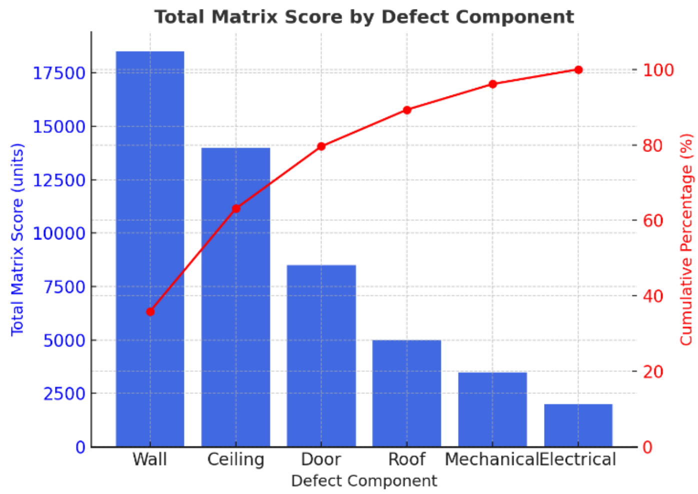

Figure 3: Distribution of Total Matrix Scores

Source: (Author,2025)

The Pareto graph above Figure 3 shows the distribution of total matrix scores according to defect components in the six polytechnics studied. It can be observed that the wall, ceiling and door components contributed the highest total matrix scores, each exceeding 8,000 units. Cumulatively, these three components contributed more than 70% of the total defect score, thus emphasizing their importance as dominant factors in determining maintenance priorities. Other components such as roof, mechanical and electrical showed much lower matrix scores, which were between 2,000 and 5,000 units only. Although the number is small, these components still need attention to avoid recurring damage in the long term.

Overall, this pattern supports the Pareto principle (80/20 Rule) which states that a small number of factors (20%) contribute to a large number of effects (80%). Therefore, maintenance strategies need to focus on walls, ceilings and doors first to ensure effective use of the budget and the safety of building users.

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Prioritization Analysis

By combining BCARS scores and maintenance budget priorities, an institutional priority table can be produced:

Table 5: Prioritization Analysis

Ranking	Inst.	Avg. Score	Condition	Priority Recommendation
1	Polytechnic B	21.2	Very Critical	Need urgent maintenance & highest budget
2	Polytechnic F	19.1	Critical	Needs immediate intervention, high budget
3	Polytechnic D	17.2	Critical	Needs immediate intervention, high budget
4	Polytechnic A	15.8	Critical	Requires intensive scheduled maintenance
5	Polytechnic C	15.5	Moderate	Preventive maintenance should be increased
6	Polytechnic E	11.3	Moderate	Adequate routine maintenance, moderate budget

Source: (Author,2025)

The rankings in Table 5 shows a clear stratification of building conditions across the six polytechnics. Polytechnic B recorded the highest average BCARS score, requiring urgent remedial work and the highest budget priority. Polytechnics F and D are still in the critical range, requiring immediate intervention focusing on the dominant civil components to curb deterioration. Polytechnic A is critical category; intensive scheduled maintenance should be implemented to avoid escalation. Polytechnics C and E are categorized as moderate; focus shifts to routine prevention and defect suppression.

The significance of technical staff proficiency is further highlighted by the observed discrepancies in defect reporting and BCARS scores among universities with similar building features (Mohd Ariff et al., 2021). While building age and gross floor area did not emerge as statistically significant indicators, variations in defect frequency and severity indicate that inspection accuracy and score reliability are affected by inspector expertise. This conclusion underscores the necessity for standardised training and calibration of assessors to mitigate subjectivity in the deployment of BCARS. Overall, the gradient of scores supports risk-based allocation, directing resources to the most degraded assets first in the near term.

The competence of technical staff plays a crucial role in the effectiveness of building inspections and maintenance implementation. Therefore, it is important to strengthen the technical training of maintenance staff in visual inspection methods, reporting using BCARS, and understanding of risk priorities. To this end, it is recommended that TVET institutions develop Standard Operating Procedures (SOPs) for building condition inspections. This SOP should; (i) Set inspection frequencies (at least twice a year). (ii) Provide standard inspection forms based on CSP 1, (iii) List assessment and scoring criteria for each building element, (iv) Determine digital reporting protocols so that defect data can be entered into a central monitoring system for reporting and further analysis. In addition, institutions can conduct regular internal technical audits to assess the effectiveness of the implementation of this SOP and reduce defect recurrence and systemic failure risks.

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Policy and Management Implications

From a management perspective, the integration of BCARS data into a digital asset management system would enable continuous monitoring of defect trends and facilitate evidence-based decision-making. The adoption of standardized inspection Standard Operating Procedures (SOPs), aligned with CSP 1 guidelines, can further support predictive and preventive maintenance planning. At the policy level, embedding BCARS outputs into long-term capital planning allows higher education institutions to justify maintenance budgets transparently, prioritize critical assets, and reduce reliance on reactive funding requests.

Conclusion

The results of this study show a clear and constant link between the number of building problems and BCARS scores at the six Malaysian polytechnics that were looked at. Institutions with elevated defect frequencies achieved markedly higher BCARS scores, signifying inferior overall building conditions. This empirical association was statistically validated via correlation analysis ($r = 0.85$, $p < 0.05$), substantiating the efficacy of BCARS as a dependable measure of physical decline. Regression analysis indicated that civil component faults were the most significant predictor of BCARS scores ($\beta = 0.72$, $p < 0.01$), succeeded by mechanical problems ($\beta = 0.38$, $p < 0.05$). On the other hand, the age of the building and the gross floor area were not statistically significant. This indicates that the intensity and severity of faults, rather than physical characteristics such as age or size, are more critical in assessing building quality. These results align with prior research in higher education institutions, underscoring that apparent architectural and structural degradation frequently indicates systemic maintenance inadequacies (Hauashdh et al., 2022; Leite et al., 2020).

Civil flaws like wall cracks, ceiling leaks, and door damage are very common, which shows how important they are for safety, functionality, and how people see things. From the point of view of facility management, these parts are priority intervention areas in risk-based maintenance systems. International research has also revealed that architectural flaws make maintenance more urgent than concealed or age-related issues (Chen, 2019; Pampana et al., 2024). Pareto analysis reinforces this interpretation by showing that a small number of parts, such as walls, ceilings, doors, and roofs, were responsible for more than 70% of the total condition score. This conclusion supports the use of the Pareto principle (80/20 rule) in maintenance planning. It suggests that focussing on a small number of important parts can lead to big improvements in the overall condition of a facility. This kind of prioritisation is in line with best practices for data-driven asset management and helps make better use of limited maintenance expenditures.

The prioritisation results also give institutions useful information for making decisions about upkeep. Polytechnics that are rated as "critical" or "very critical" by BCARS need immediate repairs and more money, while those that are rated as "moderate" should focus on preventative maintenance to keep things from getting worse. Importantly, the differences in how institutions with similar profiles report and score defects show that the quality of inspections and the skill of the assessors affect the results of assessments. This shows how important it is to have standardised inspection processes, assessor training, and calibration to make BCARS deployment less subjective and more consistent.

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In general, the conversation demonstrates that BCARS is more than just a descriptive assessment tool; it is also a useful decision-support tool that can connect technical building condition data to strategic maintenance prioritisation. This study enhances the practical implementation of building condition evaluation in Malaysian polytechnics by using statistical data, component-level analysis, and risk-based interpretation.

This study is subject to several limitations. First, the reliance on visual inspection methods may introduce a degree of subjectivity, particularly across assessors with varying levels of experience. Second, BCARS outcomes may vary depending on inspector interpretation of defect severity and priority. Future studies could address these limitations by incorporating sensor-based condition monitoring, BIM-integrated inspection workflows, or machine learning techniques to enhance objectivity and predictive capability.

In addition to its practical use, this study adds to the body of knowledge by showing how BCARS improves current maintenance practices through a systematic, data-driven method that connects condition assessment directly to budget prioritisation. The results endorse the transition from reactive maintenance to risk-informed decision-making in public educational institutions. For subsequent study, the BCARS framework could be enhanced by automating inspections, integrating with Building Information Modelling (BIM), or employing predictive analytics to foresee degradation trends prior to the attainment of key thresholds.

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