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Technical Factor Analysis that Impacts Building Maintenance in the Retention Phase

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ABSTRACT: Building maintenance during the retention phase (Defects Liability Period) was a critical stage in construction projects because defects frequently emerged after handover and could cause delays, cost overruns, and disputes between owners and contractors. In Indonesia, although a retention fund mechanism was applied, maintenance performance during this phase often remained suboptimal. This study aimed to identify and quantify the influence of technical factors on building maintenance success in high-rise projects during the retention phase in Surabaya. Data were collected through a structured questionnaire using a five-point Likert scale from 31 project staff members with relevant professional experience, selected using purposive sampling. The analysis was conducted using Partial Least Squares–Structural Equation Modeling (PLS-SEM) to evaluate both the measurement and structural models, supported by supplementary regression analysis. The results showed that technical factors had a strong and significant effect on building maintenance success, with material availability emerging as the most influential technical factor, while schedule planning was the most dominant success criterion. The high R^2 and effect size values indicated that technical factors played a substantial practical role in determining maintenance performance during the retention phase. These findings highlighted the importance of effective material logistics, systematic maintenance planning, and strict quality control. Overall, the study demonstrated that improved technical management practices significantly enhanced maintenance performance. From a practical perspective, contractors were encouraged to establish stockpiles of essential materials and adopt digital tools for maintenance planning to ensure timely execution, smooth operations, and effective cost control during the retention phase.

KEYWORDS: Building maintenance; retention phase; technical factors; SEM-PLS.

1. Introduction

Building maintenance management was a crucial issue because it was directly related to the safety of all occupants and users within a structure and ensured that the service life of a building could reach its designed lifespan [1, 2]. Proper maintenance activities involved systematic inspection, repair, and replacement of structural components, infrastructure, and building facilities to maintain operational performance and functionality [3, 4]. In the context of facility management, successful building maintenance was commonly evaluated using several key performance criteria, including cost, time, quality, health and safety, and environmental impact [5, 6].

In the Indonesian construction industry, the Defects Liability Period (DLP), or retention phase, was widely recognized as a critical stage due to the high frequency of defect rectification works and the associated financial risks borne by contractors [7, 8]. Several studies reported that many high-rise building projects experienced recurrent defects, particularly in architectural finishes, mechanical–electrical systems, and building services, which often led to schedule delays, additional costs, and disputes between owners and contractors [9, 10, 11]. Although a retention fund mechanism was applied as a contractual safeguard, its existence did not automatically guarantee effective maintenance performance [12]. In Indonesia, regulations usually set the retention fund at 5% of the contract value; however, contractors continued to face significant challenges in achieving effective maintenance during this period.

From a facility management perspective, technical factors played a decisive role in determining maintenance effectiveness and long-term building durability. Recent facility management studies consistently emphasized the importance of digital tools, such as computerized maintenance management systems and Building Information Modeling (BIM), as well as maintenance-oriented design, reliable material supply chains, and continuous quality control, rather than relying solely on reactive maintenance approaches. In this study, technical factors were defined as technological resources, design attributes, materials, and procedural practices that shaped the execution of building maintenance activities.

Based on this background, the study conceptualized technical factors as a latent construct represented by seven key elements: software technology utilization (X1), building design (X2), maintenance frequency (X3), material availability (X4), material quality (X5), maintenance planning (X6), and work quality control (X7). Previous studies identified these elements as significant determinants of maintenance practices and outcomes across various building types. These factors were expected to influence building maintenance success, which was measured using five indicators: cost planning (Y1), schedule planning (Y2), work quality (Y3), safety and security (Y4), and environmental impact (Y5). Previous research on building maintenance performance indicated that outcomes were influenced by a combination of technical, human, financial, organizational, and user-related factors. However, many empirical studies demonstrated that technical factors often exerted the strongest influence, as they directly affected on-site feasibility, efficiency, and quality. Factors such as material availability, quality control, and systematic planning were found to significantly influence costs, schedules, and service performance.

Accordingly, this study examined the effect of technical factors on building maintenance success during the retention phase of high-rise projects in Surabaya. Structural Equation Modeling–Partial Least Squares (SEM–PLS) was employed due to its suitability for predictive and exploratory research and its ability to analyze complex relationships among latent variables using relatively small sample sizes. SEM–PLS was particularly effective for theory testing and simultaneous evaluation of variable relationships. To clearly illustrate the theoretical relationships, a conceptual framework was developed to depict the influence of the retention phase on technical factors and their subsequent impact on maintenance success in terms of cost, schedule, quality, safety, and environmental performance. The framework is presented in Figure 1.

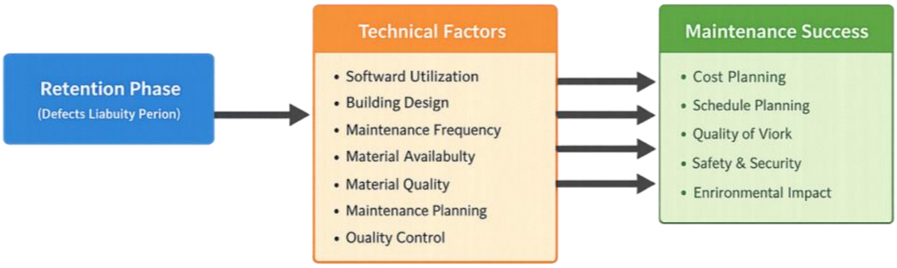

Figure 1. Conceptual framework of building maintenance during the retention phase.

2. Materials and Methods

2.1. Research design.

Figure 2 illustrated the PLS-SEM structural model results. The arrows represented the causal relationships between constructs, while the numerical values indicated the standardized path coefficients, which measured the strength of the influence between variables. The t-values shown in parentheses were obtained through bootstrapping and were used to assess statistical significance; a path was considered significant when the t-value exceeded 1.96 ($p < 0.05$). The R^2 value of 0.790 for the Maintenance Success construct indicated that Technical Factors explained 79% of the variance in maintenance success. Among the indicators, material availability (X4) emerged as the strongest contributor to Technical Factors ($\beta = 0.860$; $t = 7.69$), while schedule planning (Y2) was identified as the most influential component of Maintenance Success ($\beta = 0.726$; $t = 6.58$).

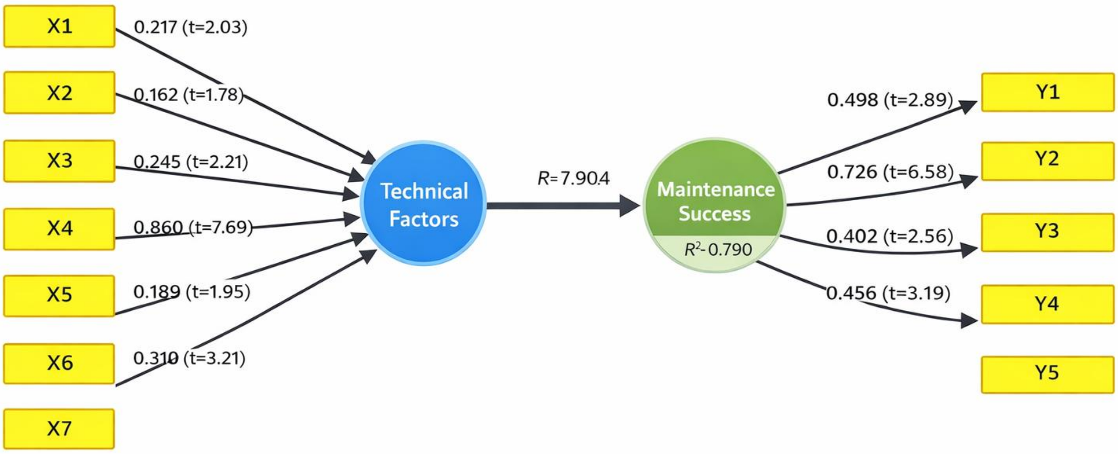

Figure 2. Path diagram model.

2.2. Variable and indicator development.

The indicators for Technical Factors (X1–X7) and Building Maintenance Success Criteria (Y1–Y5) were derived from an extensive review of previous studies (Table 1) [26, 27]. Each indicator represented a key aspect frequently reported in the building maintenance and facility management literature, such as software utilization, design quality, material availability, and quality control [26, 28]. These indicators were formulated as reflective measures of their respective latent constructs [25, 27].

Table 1. Technical factors and building maintenance success criteria.

Category	Factor / Criteria	Indicator	References
Technical Factors	Use of Software Technology	X1	[8–12]
	Building Design	X2	[8, 12–17]
	Frequency of Building Maintenance	X3	[11, 18]
	Availability of Required Materials	X4	[15, 19]
	Quality of Materials Used	X5	[13–15, 20–23]
	Maintenance Implementation Planning	X6	[8, 13, 24, 25]
	Implementation of Work Quality Control	X7	[19, 25, 26]
Building Maintenance Success Criteria	Cost Planning	Y1	[3, 8, 27–29]
	Schedule Planning	Y2	[8, 27]
	Quality of Work	Y3	[8]
	Safety and Security	Y4	[27–29]
	Environmental Impact	Y5	[8, 28, 29]

2.3. Questionnaire design and content validity.

A structured questionnaire was developed using a five-point Likert scale ranging from 1 (Very Uninfluential) to 5 (Very Influential) [29]. To ensure content validity, the initial questionnaire draft was reviewed by two academic experts in construction management and one senior practitioner involved in high-rise building projects [26]. Minor revisions were made to improve the clarity and consistency of technical terminology. A small pilot test involving five practitioners was also conducted to ensure that the questions were clearly understood and interpreted consistently by respondents [30].

2.4. Sampling and respondent profile.

The study employed purposive sampling targeting project staff involved in high-rise building projects in Surabaya who had at least two years of professional experience [23, 26]. A total of 31 valid responses were collected, representing positions such as Project Manager, Project Engineer, QHSE staff, Quantity Surveyor, Supervisor, Drafter, Procurement staff, and Finance staff [27].

2.5. Justification of sample size and use of PLS-SEM.

Although the sample size (N = 31) was relatively small, PLS-SEM was considered appropriate for exploratory and predictive research with limited samples [24, 25]. Following the "10-times rule," the minimum sample size should be at least ten times the maximum number of structural paths directed at a latent construct [25]. In this study, the maximum number of paths directed at the endogenous construct (Building Maintenance Success Criteria) was one, which implied a minimum requirement of 10 samples. Therefore, the sample size of 31 exceeded this minimum threshold [24]. Moreover, considering the limited number of high-rise projects in Surabaya during the data collection period and the targeted professional profile of respondents, the sample was deemed representative of the relevant project staff population [26, 27].

2.6. Data collection procedure.

The questionnaire was distributed directly to respondents involved in ongoing or recently completed high-rise building projects in Surabaya [23]. Respondents were informed about the purpose of the study and were assured of the confidentiality of their responses in accordance with common research ethics practices [29]. All returned questionnaires were checked for completeness before being included in the analysis [30].

2.7 Data analysis techniques.

Data analysis was conducted using SmartPLS 3.0 following established procedures for PLS-SEM analysis [24, 25]. The analysis followed two main stages: (1) evaluation of the measurement model, including reliability, convergent validity, and discriminant validity; and (2) evaluation of the structural model, including path coefficients, R^2, f^2, and Q^2 [25, 30]. Additional regression analysis using SPSS was performed to examine the influence of each technical factor (X1–X7) on each building maintenance success criterion (Y1–Y5) [29].

2.8. Hypothesis.

H1: Technical Factors (X) had a positive and significant effect on Building Maintenance Success Criteria (Y) during the retention phase. In addition, to provide more detailed insights, the effects of individual technical factors (X1–X7) on each success criterion (Y1–Y5) were examined through supplementary regression analysis.

3. Results and Discussion

3.1. Classical assumption test.

A normality test was conducted to examine whether the data followed a normal distribution. A substantial dataset that is not normally distributed may yield less accurate conclusions [32]. The normality test employed the critical value criterion for the skewness and kurtosis ratios, set at ±2.58. Data were considered normally distributed when the critical ratios fell within this absolute value range [33]. As shown in Table2, the critical ratio values for both skewness and kurtosis for all variables were within the range of ±2.58. These results confirmed that the data satisfied the normality assumption. A multicollinearity test was also performed to detect strong linear relationships among the predictor variables in the regression model [34]. This test used the Variance Inflation Factor (VIF), with values required to be less than 10 [35]. The VIF value obtained was 1.000. This result confirmed that the predictor variables did not exhibit high linear relationships, indicating that they could be treated as independent variables and that each contributed uniquely to the model.

Table 1. Normality test result.

Name	Kurtosis	cr	Skewness	cr
X1	0.217	-1.753	-1.122	-0.707
X2	2.382	-0.389	-1.646	-1.037
X3	-0.537	-2.228	-0.243	-0.153
X4	-0.845	-2.422	-0.711	-0.448
X5	0.288	-1.708	-1.092	-0.688
X6	-1.093	-2.578	-0.339	-0.214
X7	0.977	-1.274	-1.38	-0.869
Y1	0.036	-1.482	-1.185	-0.593
Y2	-0.486	-1.743	-1.009	-0.505
Y3	0.757	-1.122	-1.266	-0.633
Y4	0.22	-1.390	-1.075	-0.538
Y5	2.078	-0.461	-1.368	-0.684

The heteroscedasticity test was conducted to identify any inconsistency or non-constant variance in the residuals of the regression model [36]. Using the Breusch–Pagan method, a variable was considered free from heteroscedasticity when the p-value exceeded 5% (0.05) [37]. As shown in Table 3, the p-value obtained was 0.093 (9.3%). This result indicated that the variable did not exhibit heteroscedasticity, suggesting that the residual variance was homogeneous. The linearity test was performed to confirm the nature of the relationship between variables [38], with a minimum p-value requirement of 0.05 [39]. The test yielded a p-value of 0.331. Based on this result, the relationship between the variables was concluded to be linear.

Table 3. Heteroscedasticity and linearity test results.

Test Type	Relationship / Variable	Test Statistic	df	p-value
Breusch–Pagan (Heteroscedasticity)	Regression Model	2.825	1	0.093
Linearity Test	Technical Factors → Success Criteria	—	—	0.331

3.2. Measurement model analysis.

Reliability was assessed using Cronbach's alpha (α) and Composite Reliability (CR), with both required to exceed 0.7 [1, 2]. As shown in Table 7, both Technical Factors and Success Criteria met this threshold, confirming that the constructs were reliable and suitable for subsequent validity testing.

Table 3. Reliability test result.

	Cronbach's Alpha	Composite Reliability	AVE
Technical Factors	0.852	0.860	0.536
Success Criteria	0.837	0.838	0.609

Convergent validity was assessed using factor loadings and Average Variance Extracted (AVE). An indicator was considered valid if the factor loading exceeded 0.5 [1, 2] and the AVE exceeded 0.5 [1, 2]. As shown in Table 4, the highest factor loading for Technical Factors was 0.860 (X4: Availability of Required Materials), while for Success Criteria, Schedule Planning (Y2) had the highest loading at 0.831. Discriminant validity is confirmed when each indicator's cross-loading with its latent variable is greater than its cross-loading with other latent variables [41]. Table 9 confirms that all indicators pass the discriminant validity test.

Table 4. Convergent validity and cross-loading results.

Indicator	Factor Loading (Convergent Validity)	Cross-Loading: Technical Factors	Cross-Loading: Success Criteria
X1	0.718	0.718	0.596
X2	0.832	0.832	0.639
X3	0.751	0.751	0.429
X4	0.860	0.860	0.680
X5	0.599	0.599	0.477
X6	0.672	0.672	0.602
X7	0.654	0.654	0.572
Y1	0.680	0.625	0.680
Y2	0.831	0.629	0.831
Y3	0.829	0.635	0.829
Y4	0.786	0.642	0.786
Y5	0.766	0.585	0.766

3.3. Structural model analysis.

The structural model results indicated a strong influence of Technical Factors (X) on Building Maintenance Success Criteria (Y). The path coefficient from Technical Factors to Success Criteria was 0.801, reflecting a substantial positive effect. The coefficient of determination (R^2) for Success Criteria was 0.642, with an adjusted R^2 of 0.629, indicating that Technical Factors explained 62.9% of the variance in Success Criteria. The effect size (f^2) of Technical Factors on Success Criteria was 1.790, representing a very large influence. Finally, the predictive relevance (Q^2) of the model was 0.344, demonstrating high predictive ability and confirming that the model had strong explanatory and predictive power (Table 5).

Table 5. Structural model results: path coefficient, r^2, effect size, and predictive relevance.

Relationship	Path Coefficient	R^2	Adjusted R^2	f^2	Q^2
Technical Factors (X) → Success Criteria (Y)	0.801	0.642	0.629	1.790	0.344

3.4. Regression test analysis.

Regression tests using SPSS yielded coefficients showing the influence of each technical factor (X1–X7) on all success criteria (Y1–Y5). Table 6 shows that all technical factors have positive coefficients, indicating a direct positive effect. The null hypothesis (H_0) is accepted, confirming that technical factors positively impact building maintenance success.

Table 6. Regression test results.

Predictor / Parameter	Y1 (Cost Planning)	Y2 (Schedule Planning)	Y3 (Quality of Work)	Y4 (Safety & Security)	Y5 (Environmental Impact)
Intercept	1.172	0.860	1.963	1.455	0.995
X1 (Software Tech)	0.221	0.184	0.138	0.080	0.182
X2 (Building Design)	0.090	0.240	0.056	0.051	0.026
X3 (Maintenance Freq)	0.355	0.250	0.350	0.108	0.225
X4 (Material Avail.)	0.108	0.444	0.030	0.013	0.628
X5 (Material Qual.)	0.182	0.063	0.128	0.029	0.071
X6 (Maintenance Plan)	0.064	0.306	0.334	0.319	0.324
X7 (Work Quality Ctrl)	0.557	0.149	0.334	0.180	0.008

3.5. Discussion.

Results showed that material availability (X4) had the highest factor loading at 0.860, highlighting the critical role of logistics during the retention phase. Once handover occurred, suppliers and subcontractors often withdrew, making it difficult to procure specialty items such as architectural finishes or custom components. Delays in material availability disrupted schedules (Y2, loading 0.831), aligning with previous studies that identified materials as a major bottleneck in post-handover maintenance. Furthermore, the substantial effect size (f^2 = 1.790) demonstrated that Technical Factors were not only statistically significant but also practically meaningful. In practice, enhancing material planning tools, maintaining comprehensive design documentation, and enforcing rigorous quality control could substantially improve maintenance performance during the retention phase.

Examining the regression results in detail, X7 (Quality Control) had a strong coefficient of 0.557 on Y1 (Cost Planning), indicating that effective oversight reduced costs by preventing repeated repairs and rework. Similarly, X4 (Material Availability) influenced Y2 (Schedule Planning) at 0.444 and Y5 (Environmental Impact) at 0.628, showing that timely material supply helped maintain schedules and reduced waste from additional shipments or purchases. While software utilization (X1) and design quality (X2) had lower coefficients than material-related and planning factors, they still contributed positively. This suggests that digital tools and well-prepared design documentation acted as enabling factors, supporting more efficient planning, coordination, and decision-making during maintenance, in line with modern facility management principles.

3.6. Limitations and future research.

This study had several limitations. First, the sample size was relatively small and focused exclusively on high-rise projects in Surabaya, which limits generalizability to other locations or building types. Second, the study relied on respondents' perceptions, which may have introduced personal bias. Although respondents represented a range of roles from project managers to drafters, their perspectives were not analyzed separately. Third, the study focused solely on technical factors, while maintenance performance is also influenced by organizational, human, and contractual factors. Future research should expand geographically, increase sample sizes, and incorporate additional variables such as human resources, organizational capacity, and contractual incentives or penalties to develop a more comprehensive model of retention-phase maintenance.

4. Conclusions

This study confirmed that technical factors had a strong and positive influence on building maintenance success during the retention phase of high-rise projects in Surabaya. Among these factors, the availability of required materials emerged as the most critical, while schedule planning was the most influential success criterion. The high R^2 and effect size values indicate that technical factors have substantial practical importance in determining maintenance outcomes. Practically, contractors should establish a "retention inventory" of key materials before handover to ensure maintenance activities proceed without delays. Owners and project teams should adopt digital planning tools to coordinate schedules, documentation, and workflows effectively during the retention period. Additionally, strict quality control is essential, as it minimizes rework and reduces costs over time. While this study provides insights into high-rise projects in Surabaya from a technical perspective, future research with larger and more diverse samples, incorporating human and organizational factors, could provide a more comprehensive understanding of retention-phase maintenance performance.

Author Contributions

The authors contributed equally to the development and finalization of this manuscript. Achmad Nur Ramadhani (First Author) was responsible for the conceptualization of the research, drafting the methodology, data curation, formal analysis, investigation (data collection), software application, and writing—original draft preparation. I Nyoman Dita Pahang Putra (Second Author and Corresponding Author) was responsible for supervision, validation of the results, provision of resources, project administration, and writing—review and editing of the final manuscript.

Data Availability Statement

The raw data supporting the conclusions of this article was made available by the authors, without undue reservation, to any qualified researcher. Requests for data access, including the raw questionnaire responses and statistical analysis outputs, should be directed to the corresponding author, I Nyoman Dita Pahang Putra.

Competing Interest

The authors declare that they have no known financial, professional, or personal conflicts of interest that could have influenced the work reported in this study.

References

[1] Kristiana, W.; Nuswantoro, W.; Yulfrida, D. A. (2017). Manajemen perawatan dan pemeliharaan bangunan gedung pada Kantor Sekretariat Daerah Provinsi Kalimantan Tengah. *Jurnal Teknika: Jurnal Teoritis dan Terapan Bidang Keteknikan*, *1*(1), 20–25. https://doi.org/10.52868/jt.v1i1.1369.

[2] Yusella, P.; Fitriani, H.; Arifin, D. Z.; Toyfur, M. F. (2024). Manajemen pemeliharaan gedung sekolah pasca masa pandemi Covid-19 SMP Negeri Kota Palembang. *Syntax Literate: Jurnal Ilmiah Indonesia*, *9*(3), 1855–1866. https://doi.org/10.36418/syntax-literate.v7i9.14285.

[3] Benitez, P.; Rocha, E.; Varum, H.; Rodrigues, F. (2020). A dynamic multi-criteria decision-making model for the maintenance planning of reinforced concrete structures. *Journal of Building Engineering*, *27*, 100971. https://doi.org/10.1016/j.jobe.2019.100971.

[4] Plebankiewicz, E.; Malara, J. (2020). Analysis of defects in residential buildings reported during the warranty period. *Applied Sciences*, *10*(17), 6123. https://doi.org/10.3390/app10176123.

[5] Waridin, J.; Ilat, V.; Gamaliel, H. (2024). Analisis pelaksanaan konstruksi dalam pengerjaan (KDP) pada pekerjaan konstruksi Dinas Pekerjaan Umum dan Penataan Ruang Daerah Provinsi Sulawesi Utara. *Riset Akuntansi dan Manajemen Pragmatis*, *2*(2), 183–207. https://doi.org/10.58784/ramp.206.

[6] Peraturan Presiden Republik Indonesia Nomor 16 Tahun 2018 tentang Pengadaan Barang/Jasa Pemerintah. (2018). 38–39. https://jdih.lkpp.go.id/regulation/peraturan-presiden/peraturan-presiden-nomor-16-tahun-2018.

[7] Altaie, M. R. (2023). Factors affecting building maintenance practices. *Journal of Engineering*, *29*(12), 153–172. https://doi.org/10.31026/j.eng.2023.12.10.

[8] Hauashdh, A.; Jailani, J.; Rahman, I. A. (2021). Structural equation model for assessing factors affecting building maintenance success. *Journal of Building Engineering*, *44*, 102680. https://doi.org/10.1016/j.jobe.2021.102680.

[9] Akanmu, A. A.; Olayiwola, J.; Olatunji, O. A. (2020). Automated checking of building component accessibility for maintenance. *Automation in Construction*, *114*, 103196. https://doi.org/10.1016/j.autcon.2020.103196.

[10] Hussein, T. A.; Oztas, A. (2020). Effect of using building maintenance information management system in maintenance process in Ministry of Education. *Kurdistan Journal of Applied Research*, *5*(2), 24–35. https://doi.org/10.24017/science.2020.2.3.

[11] Ohaedeghasi, C. I.; Ezeokoli, F. O.; Agu, N. N.; Okolie, K. C.; Ugochukwu, S. C. (2021). Prospects for improving building maintenance management in Nigerian public universities: A case study of

Nnamdi Azikiwe University. *Journal of Engineering Research and Reports*, *21*(4), 53–59. https://doi.org/10.9734/JERR/2021/v21i417458.
[12] Sarbini, N. N.; Ibrahim, I. S.; Abidin, N. I.; Yahaya, F. M.; Azizan, N. Z. N. (2021). Review on maintenance issues toward building maintenance management best practices. *Journal of Building Engineering*, *44*, 102985. https://doi.org/10.1016/j.jobe.2021.102985.
[13] Breesam, H. K.; Jawad, Z. A. (2021). Factors affecting maintenance procedures for public buildings. *IOP Conference Series: Materials Science and Engineering*, *1090*, 012120. https://doi.org/10.1088/1757-899X/1090/1/012120.
[14] Dahal, R. C.; Dahal, K. R. (2020). A review on problems of the public building maintenance works with special reference to Nepal. *American Journal of Construction and Building Materials*, *4*(2), 39. https://doi.org/10.11648/j.ajcbm.20200402.12.
[15] Ebekozien, A. (2021). Maintenance practices in Nigeria's public health-care buildings: A systematic review of issues and feasible solutions. *Journal of Facilities Management*, *19*(1), 32–52. https://doi.org/10.1108/JFM-08-2020-0052.
[16] Islam, R.; Nazifa, T. H.; Mohammed, S. F.; Zishan, M. A.; Yusof, Z. M.; Mong, S. G. (2021). Impacts of design deficiencies on maintenance cost of high-rise residential buildings and mitigation measures. *Journal of Building Engineering*, *39*, 102215. https://doi.org/10.1016/j.jobe.2021.102215.
[17] Odeyemi, S.; Adeniyi, O.; Amoo, A. (2019). Assessment on building maintenance in Nigerian universities: A case study of University of Ilorin. *Nigerian Journal of Technology*, *38*(3), 566–572. https://doi.org/10.4314/njt.v38i3.4.
[18] Au-Yong, C. P.; Ali, A. S.; Chua, S. J. L. (2019). A literature review of routine maintenance in high-rise residential buildings: A theoretical framework and directions for future research. *Journal of Facilities Management*, *17*(1), 2–17. https://doi.org/10.1108/JFM-10-2017-0051.
[19] Olanrewaju, A. L.; Wong, W. F.; Yahya, N. N.-H. N.; Im, L. P. (2019). Proposed research methodology for establishing the critical success factors for maintenance management of hospital buildings. *AIP Conference Proceedings*, *2114*, 020001. https://doi.org/10.1063/1.5126571.
[20] Chima, O. A.; Ifeanyichukwu, N. E.; Nnamdi, A. T.; Chukwuemeka, I. G.; Precious-Favour, N. O. (2021). Evaluation of the practice of building survey for maintenance of public building in South-East Nigeria. *Journal of Engineering Research and Reports*, *20*(3), 108–122. https://doi.org/10.9734/jerr/2021/v20i317288.
[21] Fotovatfard, A.; Heravi, G. (2021). Identifying key performance indicators for healthcare facilities maintenance. *Journal of Building Engineering*, *42*, 102838. https://doi.org/10.1016/j.jobe.2021.102838.
[22] Ogunbayo, B.; Aigbavboa, C.; Thwala, D. (2022). Occupants' maintenance requests in higher educational institution (HEI) residential buildings. *AIP Conference Proceedings*, *2437*, 020020. https://doi.org/10.1063/5.0092302.
[23] Zolkafli, U. K.; Zakaria, N.; Mohammad Mazlan, A.; Ali, A. S. (2019). Maintenance work for heritage buildings in Malaysia: Owners' perspectives. *International Journal of Building Pathology and Adaptation*, *31*(1), 186–195. https://doi.org/10.1108/IJBPA-07-2018-0062.
[24] Che-Ghani, N. Z.; Myeda, N. E.; Ali, A. S. (2016). Operations and maintenance cost for stratified buildings: A critical review. *MATEC Web of Conferences*, *66*, 00041. https://doi.org/10.1051/matecconf/20166600041.
[25] Dakhil, A.; Qasim, I.; Chinan, J. (2017). Barriers for implementation the proactive building maintenance in Iraq: Basra City as case study. *Kufa Journal of Engineering*, *8*(1), 26–36. https://doi.org/10.30572/2018/KJE/811188.
[26] Waziri, B. S. (2016). Design and construction defects influencing residential building maintenance in Nigeria. *Jordan Journal of Civil Engineering*, *10*(3), 360–369. https://doi.org/10.14525/JJCE.10.3.3605.

[27] Besiktepe, D.; Ozbek, M. E.; Atadero, R. A. (2020). Identification of the criteria for building maintenance decisions in facility management: First step to developing a multi-criteria decision-making approach. *Buildings*, *10*(9), 166. https://doi.org/10.3390/buildings10090166.

[28] Ighravwe, D. E.; Oke, S. A. (2019). A multi-criteria decision-making framework for selecting a suitable maintenance strategy for public buildings using sustainability criteria. *Journal of Building Engineering*, *24*, 100753. https://doi.org/10.1016/j.jobe.2019.100753.

[29] Kheradranjbar, M.; Mohammadi, M.; Rafiee, S. (2022). Appropriate building repair and maintenance strategies using multi-criteria decision-making analysis: A Delphi study. *Acta Structilia*, *29*(1), 86–111. https://doi.org/10.18820/24150487/as29i1.4.

[30] Hair, J. F., Jr.; Hult, G. T. M.; Ringle, C. M.; Sarstedt, M.; Danks, N. P.; Ray, S. (2021). *Partial least squares structural equation modeling (PLS-SEM) using R: A workbook*. Springer Nature. https://doi.org/10.1007/978-3-030-80519-7.

[31] Simanjuntak, S. C.; Panjaitan, M.; Napitupulu, J. (2020). Pengaruh bauran promosi dan loyalitas pelanggan dalam meningkatkan volume penjualan pada PT Telkom Kota Medan. *Jurnal Ilmiah Methonomi*, *6*(Suplemen), 85–91. https://doi.org/10.46880/methonomi.Vol6NoSuplemen.pp85-91.

[32] Usmadi, U. (2020). Pengujian persyaratan analisis (uji homogenitas dan uji normalitas). *Inovasi Pendidikan*, *7*(1). https://doi.org/10.31869/ip.v7i1.2281.

[33] Pratiwi, A. C.; Dwiyanto, B. M. (2021). Pengaruh perceived value terhadap purchase intention digital music streaming services dengan satisfaction sebagai variabel intervening (studi pada aplikasi Joox dan Spotify). *Indicators: Journal of Economic and Business*, *3*(1), 98–108. https://doi.org/10.47729/indicators.v3i1.103.

[34] Hidayah, B.; Nawawi, K.; Gustiawati, S. (2022). Pengaruh motivasi kerja dan lingkungan kerja Islami terhadap kinerja karyawan pada Bank Syariah Indonesia KCP Bogor Pomad. *El-Mal: Jurnal Kajian Ekonomi dan Bisnis Islam*, *3*(1), 96–114. https://doi.org/10.47467/elmal.v3i1.639.

[35] Puspa, S. D.; Riyono, J.; Puspitasari, F. (2021). Analisis faktor-faktor yang mempengaruhi pemahaman konsep matematis mahasiswa dalam pembelajaran jarak jauh pada masa pandemi Covid-19. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *5*(1), 302–320. https://doi.org/10.31004/cendekia.v5i1.533.

[36] Purba, D. S.; Tarigan, W. J.; Sinaga, M.; Tarigan, V. (2021). Pelatihan penggunaan software SPSS dalam pengolahan regresi linear berganda untuk mahasiswa Fakultas Ekonomi Universitas Simalungun di masa pandemi Covid-19. *Jurnal Karya Abdi Masyarakat*, *5*(2), 202–208. https://doi.org/10.22437/jkam.v5i2.15257.

[37] Ilori, O. O.; Tanimowo, F. O. (2022). Heteroscedasticity detection in cross-sectional diabetes pedigree function: A comparison of Breusch–Pagan–Godfrey, Harvey, and Glejser tests. *International Journal of Scientific Management Research*, *5*, 150–163. https://doi.org/10.37502/IJSMR.2022.51211.

[38] Sitanggang, H. L.; Sidabutar, R. (2023). The influence of the cooperative learning model type numbered heads together (NHT) on the mathematical creative thinking ability of students in class VIII of Trisakti Private Junior High School, Pematang Siantar. *EduMatika: Jurnal MIPA*, *3*(3), 52–56. https://doi.org/10.56495/emju.v3i3.392.

[39] Irwandi, D.; Masykur, R.; Suherman, S. (2021). Korelasi kecanduan Mobile Legends terhadap prestasi belajar mahasiswa. *Jurnal Lebesgue: Jurnal Ilmiah Pendidikan Matematika, Matematika dan Statistika*, *2*(3), 292–299. https://doi.org/10.46306/lb.v2i3.

[40] Yurinanda, S.; Rozi, S.; Sarmada, S. (2023). Analisis model kepuasan civitas akademika terhadap pelayanan perpustakaan di Fakultas Sains dan Teknologi Universitas Jambi dengan metode structural equation modeling (SEM). *Jurnal Lebesgue: Jurnal Ilmiah Pendidikan Matematika, Matematika dan Statistika*, *4*(3), 1532–1542. https://doi.org/10.46306/lb.v4i3.434.

[41] Muthia, A.; Setiawan, T. H.; Sastro, G. (2021). Analisis tingkat penerimaan program beberes sendiri pada restoran KFC menggunakan metode structural equation modelling–partial least square (SEM-PLS). *Jurnal Lebesgue: Jurnal Ilmiah Pendidikan Matematika, Matematika dan Statistika*, *2*(1), 22–33. https://doi.org/10.46306/lb.v2i1.51.
[42] Alshehri, A.; Motawa, I.; Ogunlana, S. (2015). The common problems facing the building maintenance departments. *International Journal of Innovation, Management and Technology*, *6*(3), 234. https://doi.org/10.7763/IJIMT.2015.V6.608.
[43] Al-Emran, M.; Mezhuyev, V.; Kamaludin, A. (2019). PLS-SEM in information systems research: A comprehensive methodological reference. *Proceedings of the International Conference on Advanced Intelligent Systems and Informatics 2018*, 644–653. https://doi.org/10.1007/978-3-319-99010-1_59.
[44] Huang, C.-H. (2021). Using PLS-SEM model to explore the influencing factors of learning satisfaction in blended learning. *Education Sciences*, *11*(5), 249. https://doi.org/10.3390/educsci11050249.
[45] Sarstedt, M.; Ringle, C. M.; Hair, J. F. (2022). Partial least squares structural equation modeling. In Homburg, C.; Klarmann, M.; Vomberg, A. (Eds.), *Handbook of Market Research* (pp. 587–632). Springer International Publishing. https://doi.org/10.1007/978-3-319-57413-4_15.