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Perceived Influence of Building Design on Maintenance of Tetfund Sponsored Buildings in Tertiary Institutions in Benue State

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The maintenance of buildings has consistently presented significant challenges, with tertiary institutions being no exception, as their facilities frequently require repairs. This study aimed to explore the potential for reducing maintenance issues by emphasizing considerations during the design phase of buildings. The objective was to identify the perceived architectural, structural engineering, electrical engineering and mechanical engineering design deficiencies that influence maintenance of buildings. A cross-sectional survey design was employed for the study. Utilizing the census sampling technique, all tertiary institutions with buildings sponsored by the Tertiary Education Trust Fund (TETFUND) were included. Data were gathered from 99 staff members working in the Physical Planning and Maintenance Departments of nine Institutions through a structured questionnaire. Findings revealed that within the category of architectural design deficiencies, issues related to drainage system design (M = 4.01, SD =0.90) were particularly prominent. In terms of structural engineering design, inadequate detailing of beams and columns (M=3.93, SD=0.85) was identified as a major contributor to maintenance challenges. Furthermore, within the domain of electrical engineering design, insufficient load calculations (M= 4.06, SD = 0.84) were found to significantly impact building maintenance. Additionally, the failure to consider climatic factors in building orientation (M =3.86, SD = 0.87) was highlighted as a critical mechanical engineering design deficiency influencing long-term maintenance outcomes. Based on the findings, design deficiencies were perceived to influence maintenance of buildings. It was therefore recommended that feedback from maintenance personnel be incorporated during design stages in order to create systems that are both functional and maintainable.
Keywords: Building design, building maintenance, design deficiencies, perception, tertiary institution

Introduction

Educational institutions are established to promote teaching, learning, and research, but these goals cannot be effectively achieved without adequate buildings (Ohaedeghasi *et al*., 2021). The functionality of a structure is measured by how well it supports intended activities, and deterioration in building components requires timely maintenance to preserve comfort and safety (Hatem & Zahraa, 2021). However, many educational buildings in Nigeria are in poor condition due to prolonged neglect, despite their crucial role in national development. Numerous studies (Chima, 2021; Ebenechi *et al*., 2021; Islam *et al*., 2021) indicated that building defects can be minimized through better consideration during design and construction stages. Design flaws are a significant contributor to maintenance issues. Ikedionu *et al*. (2019) emphasized that poor design decisions place long-term burdens on buildings, while Ohaedeghasi *et al*. (2021) identified the design phase as the most critical for technical performance. Emoh and Ndulue (2021) highlighted issues such as inappropriate material selection, building orientation, environmental factors, and lack of maintainability in designs.

To address infrastructural needs in higher institutions, the Nigerian government established the Tertiary Education Trust Fund (TETFUND) through the Education Tax Act of 1993 and operationalized it in 2011. TETFUND supports federal and state tertiary institutions by funding physical infrastructure, instructional materials, research, staff development, and other essential educational components. The fund is managed by a Board of Trustees, ensuring accountability, transparency, and adherence to project specifications. Despite these efforts, field observations revealed defects in TETFUND-sponsored buildings, including sagging ceilings, rising dampness, mould, and structural cracks. Prior research (Chima, 2021; Ebenechi et al., 2021; Islam *et al*., 2021; Awasho & Alemu, 2023) attributed these issues to design deficiencies. This prompted the present study, which aimed to assess how architectural, structural, electrical, and mechanical design flaws influence building maintenance in TETFUND-sponsored projects within tertiary institutions in Benue State as there seems to be a dearth of literature particularly concerning TETFUND sponsored buildings.

Building Design

Building design significantly affects a structure's performance and maintenance (Islam *et al*., 2021). Merritt and Ricketts (2001) defined building design as a detailed process that ensures safety, health, and user needs, spanning from feasibility studies to post-construction services. Design professionals; architects, engineers, and technologists, are responsible for executing this process (Saleh *et al*., 2019). Errors in design, especially due to lack of coordination or detail, can lead to long-term maintenance problems (Waziri, 2016; Ikedionu *et al*., 2019). Common design deficiencies include poor material selection, environmental neglect, and overlook of maintainability (Emoh & Ndulue, 2021). Design deficiencies fall into three main categories: architectural, structural, and mechanical/electrical/plumbing (Islam *et al*., 2021), with architectural issues having the greatest maintenance impact. Architectural design flaws include poor ventilation, incomplete drawings, sharp wall edges, improper drainage systems, inaccessible maintenance areas, and incompatible external finishes (Aras *et al*., 2016; Dahal & Dahal, 2020; Jimoh, 2016; Islam *et al*., 2021; Okandu *et al*., 2021). Structural design, which ensures that a building meets safety and performance standards can suffer from poor joint detailing, inadequate concrete cover, improper element placement, and failure to consider soil and load conditions (Aras *et al*., 2016; Jimoh, 2016; Islam *et al*., 2021). Mechanical and electrical (ME) engineering services covering HVAC, lighting, and power, also face design issues such as undersized cabling, power failure risks, poor HVAC sizing, reduced lift capacity, and inaccessible equipment (Sharma & Dixit, 2023; Islam *et al*., 2021).

Maintenance

Maintenance involves technical, administrative, and management activities aimed at preserving or restoring a building's functionality (Dahal & Dahal, 2020; Hatem & Zahraa, 2021; Awasho & Alemu, 2023). Its main goals include retaining the performance and economic value of building systems and structures (Saleh *et al*., 2019). Saleh *et al*. (2019) categorized maintenance into four types: Preventive maintenance: Scheduled checks to prevent breakdowns, Statutory maintenance: Compliance-based upkeep (e.g., fire systems, lifts), Corrective maintenance: Repairs of faulty components, Backlog maintenance: Delayed work needed to prevent deterioration. Common defects caused by design deficiencies include leaks, peeling paint, cracks, moisture, damaged roofs, electrical faults, termite damage, mold, and decayed wood (Dahal & Dahal, 2020). Poor maintenance can result in early building decay, reduced usability, inadequate service delivery, lower safety and comfort, increased repair costs, and decreased building value (Matse *et al*., 2022).

Building Design and Maintenance

Several studies highlighted the critical relationship between building design and maintenance outcomes. A study by Ikedionu *et al*. (2019) used questionnaires and interviews to assess the effects of poor design on construction and maintenance. Key issues identified included improper structural design, lack of detail, noncompliance with specifications, and use of expired materials. These flaws were grouped into subsurface, construction, material, and design-related categories. The study emphasized the need for better awareness among contractors regarding durable materials and the importance of maintenance considerations during the design stage.

Okandu *et al*. (2021) conducted a case study on multi-story buildings, finding that neglecting maintenance during design led to inefficiencies in building services. Their conclusions reinforced Ikedionu et al.'s (2019) findings, affirming the vital role of design in building longevity.

Hatem and Zahraa (2021), in a study on government buildings, found that both technical and administrative issues including design flaws, poor workmanship, delayed jobs, and inadequate safety measures affect maintenance practices. Their findings align with global research emphasizing design's long-term impact on maintenance. Islam *et al*. (2021) examined high-rise residential buildings and identified 42 design flaws linked to higher maintenance costs, poor material choices, and structural risks. The study proposed strategies to mitigate design-related maintenance problems and recommended proactive design planning and case study validation.

Basically, these studies consistently underscore that poor building design leads to increased defects, inefficiencies, and long-term maintenance burdens, highlighting the importance of incorporating maintainability during the design phase (Ikedionu *et al*., 2019; Okandu *et al*., 2021; Aras *et al*., 2016; Hatem & Zahraa, 2021; Islam *et al*., 2021).The table below shows the categories of design deficiencies that are perceived to influence maintenance of buildings.

Table 1: List of Design Deficiencies

Architectural Design Deficiencies	Reference
Inadequate working drawing and specification	Islam *et al.*, 2021; Dahal & Dahal, 2020; Khan *et al.*, 2021
Lack of ventilation design	Islam *et al.*, 2021
Ignorance of performance of materials	Islam *et al.*, 2021; Khan *et al.*, 2021; Dahal & Dahal, 2020
Non-availability of specific building materials in the market	Islam *et a*l., 2021
Inadequate space, size and location of duct work	Islam *et al*., 2021
Specifying incompatible exterior finishes with the weather	Islam *et al*., 2021s; Aras *et al*., 2016; Jimoh, 2016
Designing walls with sharp edges	Islam *et al*., 2021
Inappropriate allocation of spaces in building such as toilets	Islam *et al*., 2021
Poor drainage system design	Islam *et al*., 2021; Okandu *et al*., 2021
Specifying finishes that needs complete replacement	Islam *et al*., 2021; Jimoh, 2016
Ignorance of maintenance access when designing	Olayinka, 2020; Aras *et al.*, 2016
Ignorance of availability of maintenance tools during design stage	Aras *et al*., 2016
Structural Design Deficiencies	
Poor joint design and detailing	(Islam *et al.*, 2021; Aras *et al.*, 2016)
Lack of attention to design details of structural elements such as beams, columns and walls	Islam *et al.*, 2021
Incorrect locating conduits and piping at critical structure location	Aras *et al*., 2016
Insufficient provision for thermal movement	Aras *et al*., 2016; Jimoh, 2016
Insufficient structural design in such parts as the foundation	Islam *et al*., 2021; Aras *et al*., 2016; Jimoh, 2016
Ignoring variation in soil conditions	Jimoh, 2016
Inadequate concrete cover on the reinforcement	Islam *et al*., 2021; Jimoh, 2016
Ignoring load impact on structure stability	Jimoh, 2016
Exceeding allowable deflection	Jimoh, 2016
Mechanical Engineering Design Deficiencies	
Total power fail from one error	Islam *et al*., 2021
Ignoring climatic effects on building shape and orientation	Islam *et al*., 2021
Uncommon design and technology	Islam *et al*., 2021
Lower capacity of passenger lift	Islam *et al*., 2021
Electrical Engineering Design Deficiencies	
Inadequate size and low resistance cabling	Islam *et al*., 2021
Inappropriate selection and specification of materials (pipe, rebar)	Islam *et al*., 2021
Inadequacy of the HVAC system for a comfortable temperature	Islam *et al*., 2021
Inaccessibility to chillers and condensers for maintenance	Islam *et al*., 2021
Insufficient number and distribution of switch and plug points	Islam *et al*., 2021

Research Methodology

The research adopted a cross-sectional approach. Moreover, the survey design easily generated data for analysis (Islam *et al*., 2021). The research focused on the maintenance and physical planning departments of nine tertiary institutions in Benue State with TETFUND sponsored buildings. The selected institutions (Joseph Saawuan Tarkaa University, Federal University of Health Science, Rev. Fr. Moses Orshio Adasu University, Benue State Polytechnic, Nigerian Army College of Environmental and Science Technology, College of Education, Katsina-Ala, College of Education, Oju, and Federal College Odugbo) were chosen based on their involvement in the design and post-construction phases of the buildings. The total population of the staff was 99, providing a robust sample size for the study. The study used a structured questionnaire as data collection instrument, which was reliable and accurate for research purposes. They are a long-standing reliable means of gathering data though their validity and reliability are dependent on them being well designed with non-biased questions (Holmes, 2023) hence, its use in this research. A questionnaire was used to assess design deficiencies in four categories: architectural, structural, electrical, and mechanical engineering. A Likert scale was used with five parameters assigned to the questions. The data collection process took three months, with the researcher reviewing the questionnaire's completeness to ensure accuracy. Ethical considerations were taken into account, and consent was obtained before giving out the questionnaire. Out of 99 questionnaires, only 71 were returned and filled correctly, resulting in a response rate of 71.7%, which is considered excellent in survey-based research (Nulty 2008). The research used mean and standard deviation to answer questions; with items with mean response scores of 3.0 considered agreed and those with scores less than 3.0 considered disagreed, using the Statistical Package for the Social Sciences version 20 for descriptive statistics.

Results and Discussion

Demographic characteristics of the respondents

Table 2 showed that the 71 respondents were drawn from nine tertiary institutions in Benue State, with the highest representation from Federal Polytechnic, Wannune (16.9%) and the least from Federal University of Health Sciences, Otukpo (4.2%). In terms of profession, most fell under "others" (42.3%) and administrators (21.1%), while civil and electrical engineers formed notable proportions. The majority of respondents were highly qualified, with MSc holders (49.3%) and BSc holders (32.4%) dominating, while only a few had OND, HND, or PhDs. Respondents also had substantial work experience, with most having over 11 years in service (52.2%), indicating a seasoned and knowledgeable sample. Overall, the data reflects a diverse group of professionals across institutions, qualifications, and experiences, thereby enhancing the reliability of the study findings.

Table 2: Demographic Characteristics of the Respondents

	Respondents	Freq.	Percentage
Institution	Federal University of Health Sciences, Otukpo	3	4.2
	Joseph Swuan Tarkaa University, Makurdi	11	15.5
	Benue State University, Makurdi	9	12.7
	Nigerian Army College of Environmental Science and Technology, Makurdi	9	12.7
	Federal Polytechnic, Wannune	12	16.9
	Benue Polytechnic, Ogbokolo	4	5.6
	Federal College of Education, Odugbo	5	7.0
	College of Education, Kastina Ala	11	15.5
	College of Education, Oju	7	9.9
	Total	71	100.0
Profession	Architect	3	4.2
	Building Technician	5	7.0
	Civil Engineer	9	12.7
	Electrical Engineer	8	11.3
	Mechanical Engineer	1	1.4
	Administrator	15	21.1
	Others	30	42.3
	Total	71	100.0
Qualification	OND	3	4.2
	HND	6	8.5
	BSc	23	32.4
	MSc	35	49.3
	PhD	4	5.6
	Total	71	100.0
Working Experience	<1 year	4	5.6
	1-5 years	16	22.5
	6-10 years	14	19.7
	11-15 years	18	25.4
	>15 years	19	26.8

Table 3 analysed architectural design deficiencies, focusing on their influence on maintenance. The cluster mean for all deficiencies is 3.50, indicating consensus on their existence and impact. The most pressing architectural deficiency was the "Poor drainage design system," with a high mean indicating a strong concern for drainage issues. The low standard deviation (0.90) suggests consensus on this issue. In support of these findings, studies by, Akinradewo *et al*. (2020), Islam *et al*. (2021) and Ikedionu *et al*. (2019) highlighted the importance of architectural design decisions in long-term performance. This study, involving tertiary institution physical planning and maintenance staff, highlighted the real-world significance of these issues. The current study used descriptive statistics and Likert-scale questionnaires, similar to Khalid *et al*. (2019)'s study on building design in institutional settings. The study suggested a universal nature of design-related issues, but Ugwu *et al*. (2018) argued that user behaviour and management practices influenced maintenance problems more than initial design, contradicting the current study's focus on design phase decisions.

Table 3: Architectural design deficiencies that influence maintenance of buildings

S/N	Architectural Design Deficiency	Mean	Std. Deviation	Remark
1	Inadequate working drawing details and specifications	3.70	0.98	Agree
2	Lack of ventilation design	3.28	1.09	Agree
3	Ignorance of performance of materials	3.94	0.84	Agree
4	Unavailability of specific building materials in the market	3.03	1.07	Agree
5	Inadequate space, size and location of duct work	2.97	1.08	Disagree
6	Specifying incompatible exterior finishes with the weather	3.37	0.99	Agree
7	Poor drainage design system	4.01	0.90	Agree
8	Designing walls with sharp edges	3.13	0.83	Agree
9	Inappropriate allocation of spaces in building such as toilets	3.44	0.97	Agree
10	Specifying finishes that needs complete replacement	3.73	0.96	Agree
11	Ignorance of maintenance access when designing	3.76	0.99	Agree
12	Ignorance of availability of maintenance tools during design stage	3.66	0.96	Agree
	Cluster Mean	**3.50**		

The report in Table 4 analysed structural engineering design deficiencies focusing on their impact on maintenance of TETFund-sponsored buildings. Survey responses revealed a consensus on common deficiencies, with a cluster mean of 3.70, indicating frequent or significant impacts in practice. Correspondingly, Assakkaf and Ayyub (2017) emphasized similar problems, including insufficient joint detailing and structural element design flaws that lead to premature failures and safety risks. Also, in the current study, ignoring variation in soil conditions has a mean of 3.85. This emphasizes the importance of geotechnical analysis in ensuring structural stability overlooking it can lead to major foundational issues. It further emphasizes the extent to which the design team can be held accountable such that adequate attention should be given to preliminaries of construction as soil testing (Chukwujama *et al*., 2019). Sullivan and Tien (2017) advocated for "design-for-maintenance" practices to enhance long-term building performance and reduce lifecycle costs.

Table 4: **Structural Engineering design deficiencies that influence maintenance buildings**

S/N	Structural Engineering Design Deficiency	Mean	Std. Deviation	Remark
1	Poor joint design and detailing	3.79	0.94	Agree
2	Lack of attention to design details of structural elements such as beams, columns and walls	3.93	0.85	Agree
3	Incorrect locating conduits and piping at critical structure location	3.51	1.026	Agree
4	Insufficient provision for thermal movement	3.77	0.741	Agree
5	Insufficient structural design in such parts as the foundation	3.55	0.968	Agree
6	Ignoring variation in soil conditions	3.85	0.936	Agree
7	Inadequate concrete cover on the reinforcement	3.73	0.894	Agree
8	Ignoring load impact on structure stability	3.61	1.021	Agree
9	Exceeding allowable deflection	3.54	0.923	Agree
	Cluster mean	**3.70**		

Table 5 presented an analysis of various electrical engineering design deficiencies, based on data provided by survey respondents. The objective was to identify the perceived influence of structural engineering design deficiencies on TETFund sponsored buildings in tertiary institutions in Benue State. The data reflects a strong agreement across all listed items, with a cluster mean of 3.82. The most pressing issue was improper load calculations, with the highest mean score of 4.06. This reflects a critical design shortfall that can lead to overload, inefficiencies, and potential safety hazards. Ensuring accurate load estimation is fundamental for both the performance and safety of electrical systems. Afolabi *et al*. (2020) opined that improper load calculations tend to result to overloads, frequent tripping and rapid equipment deterioration. These are a huge part of the most recurrent electrical maintenance issues. Another concern was the insufficient number and poor distribution of switch and plug points, with a mean of 3.89. This affects user convenience and often leads to unsafe improvisations, such as the use of multiple extension cords. Nwankwo and Alade (2018) noted that outlets that are poorly distributed result in inefficient space utilization, and constant use of such outlets. This results to rapid degradation hence, frequent need for the maintenance team to carry out replacements. Other notable issues include inadequate circuit distribution, inappropriate selection of materials (e.g., pipes, rebar), and poor placement of electrical outlets and switches. While these may not always lead to immediate hazards, they contribute significantly to inefficiencies and maintenance difficulties (Umeh & Obiorah, 2021).

Table 5: **Electrical Engineering design deficiencies that influence maintenance of buildings**

S/N	Electrical Engineering Design Deficiency	Mean	Std. Deviation	Remark
1	Inadequate size and low resistance cabling	3.92	0.82	Agree
2	improper load calculations	4.06	0.84	Agree
3	inadequate circuit distribution	3.76	0.81	Agree
4	Poor Placement of Electrical Outlets and Switches	3.72	1.00	Agree
5	Insufficient or Improper Fire Safety Provisions	3.85	0.89	Agree
6	Inappropriate selection and specification of materials (pipe, rebar)	3.74	0.70	Agree
7	Inaccessibility to chillers and condensers for maintenance	3.62	0.85	Agree
8	Insufficient number and distribution of switch and plug points	3.89	0.87	Agree
	Cluster mean	**3.82**		

Table 6 presented an assessment of mechanical engineering design, deficiencies based on feedback from industry professionals. The objective was to highlight critical areas where design improvements are necessary to combat the occurrence of maintenance issues. The data revealed a cluster mean of 3.63, indicating overall agreement among respondents that the listed issues are important and prevalent. All five deficiencies received a mean score above 3.25, reflecting broad recognition of mechanical design challenges within the building industry. The most prominent deficiency, with a mean score of 3.86, was ignoring climatic effects on building shape and orientation. This suggests that environmental responsiveness is often overlooked, which can result in reduced HVAC efficiency and poor indoor environmental quality. Climate-sensitive design is essential to optimizing energy performance and user comfort. The findings align with Adebayo *et al*. (2018) as the research suggested that a design that is conscious of the climate of the location of the building is less prone to defects during occupancy stage.

Table 6: **Mechanical Engineering design deficiencies that influence maintenance of buildings**

S/N	Mechanical Engineering l Design Deficiency	Mean	Std. Deviation	Remark
1	Total power fail from one error	3.68	0.94	Agree
2	Ignoring climatic effects on building shape and orientation	3.86	0.87	Agree
3	Uncommon design and technology	3.67	0.81	Agree
4	Lower capacity of passenger lift	3.25	1.07	Agree
5	Inadequacy of the HVAC- heating, ventilation, and air conditioning system for a comfortable temperature	3.69	0.97	Agree
	Cluster mean	**3.63**		

Conclusion

The findings of the study revealed that architectural, structural, electrical, and mechanical engineering design deficiencies significantly influence building maintenance. The most influential deficiencies were poor drainage design systems, insufficient joint detailing, improper load calculations, and ignoring climatic effects on building shape and orientation. The study recommends prioritizing effective drainage system design, including proper grading, downspouts, and surface water management, to mitigate water-related deterioration. Feedback from maintenance personnel should also be incorporated during design stages to create functional and maintainable systems. The study also suggests assessing the adequacy of training provided to architects and engineers on maintenance-conscious design during their academic and professional development. The results of this study, once published, will hold significant practical value for building professionals, clients and educational stakeholders.

References

Afolabi, A. O., Ojelabi, R. A., & Fagbenle, O. I. (2020). Evaluation of electrical system planning in Nigerian residential buildings. *International Journal of Building Pathology,* 10(2), 130–140.

Akinradewo, O. A., Ogunoh, E. O., & Fadeyi, M. (2020). Design-related issues influencing building performance in tropical environments. *Journal of Construction in Developing Countries*, 25(2), 49–65.

Aras, N., Salim, A., Salleh, N. M., & Zahari, N. F. (2016). Design failure affecting maintenance management on public higher education institutions in Malaysia. *MATEC Web of Conferences,* 66, 00122

Assakkaf, I., & Ayyub, B. M. (2017). Reliability-based structural design. *Naval Engineers Journal*, 114(2) 89-111

Awasho, T. T., & Alemu, S. K. (2023). Assessment of public building defects and maintenance practices: Cases in Mettu Town, *Ethiopia. Heliyon*, 9(4), e15052.

Chima, O. A. (2021). Current issues associated with public building maintenance in South-East Nigeria. *International Journal of Innovative Science, Engineering & Technology*, 8(2), 225–241.

Chukwujama, S. O., Umeuduji, J. E., & Ogunoh, M. A. (2019). Assessment of causes of foundation failure in buildings. *International Journal of Civil Engineering and Technology,* 10(2), 344–352.

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), 39–50.

Ebenechi, I. Y., Unamba, E. M., & Junaidu, A. (2021). Assessment of maintenance practice of financial institutions in buildings in some Northern parts of Nigeria. *Taraba Journal of Engineering and Technology,* 2(8), 13–17.

Emoh, F. I., & Ndulue, L. A. (2021). Strategies for maintenance management of hostel buildings in Nigeria. *British Journal of Environmental Sciences*, 9(3), 10–25.

Hatem, B., & Zahraa, J. (2021). Factors affecting maintenance procedures for public buildings. *IOP Conference Series: Materials Science and Engineering*, 1090(1), 012127.

Ikedionu, J. C., Okolie, K. C., & Ezeokoli, F. O. (2019). Effect of faulty design on construction and maintenance of buildings in Asaba, Delta State, Nigeria. *Advances in Research*, 20(6), 1–10.

Islam, R., Nazifa, T., Mohammed, S., Zishan, M., Yusof, Z., & Mong, S. (2021). Impacts of design deficiencies on maintenance cost of high-rise residential buildings and mitigation measures. *Journal of Building Engineering,* 39, 102270.

Jimoh, T. A. (2016). Effect of faulty design and construction on building. *Procedia Engineering*, 24, 110–118.

Khalid, E., Abdullah, S., Hanafi, M., Said, S., & Hasim, M. (2019). The consideration of building maintenance at design stage in public buildings: The current scenario in Malaysia. *Journal of Construction in Developing Countries*, 24(1), 109–123.

Khan, S., Hussain, A., & Saquib, M. (2021). Causes of defects in buildings and their relationship with life cycle: Design, construction and post occupancy stage. *International Congress on the Phenomenological Aspects of Civil Engineering.*

Matse, N., Mashwama, N. X., Thwala, D., & Aigbavboa, C. (2022). A theoretical assessment of the impacts of poor maintenance of public infrastructure. *IOP Conference Series: Materials Science and Engineering,* 1218(1), 012018.

Merritt, F. S., & Ricketts, J. T. (2001). *Building design and construction handbook* (6th ed.). McGraw-Hill.

Nwankwo, U., & Alade, O. (2018). User-centered electrical design for residential buildings. *Nigerian Journal of Engineering and Applied Sciences*, 6(3), 66–72.

Ohaedeghasi, C. I., Ezeokoli, F. O., & Agu, N. N. (2021). Threats to effective building maintenance management in Nigerian public universities: A case study of Nnamdi Azikiwe

University, Awka. *International Journal of Advances in Engineering and Management,* 2(8), 89–93

Okandu, C., Akani, C., & Brisibe, W. (2021). Maintainability, design processes and building services: A case study of selected buildings in the Rivers State University. *Journal of Environmental Design and Construction Management,* 7(4), 18–28.

Olayinka, O. A. (2020). Assessment of defect in building services equipment in tertiary institutions across Lagos megacity, Nigeria. *Nigerian Journal of Environmental Sciences and Technology,* 5(4).

Saleh, R. M., & Al-Swidi, A. (2019). The adoption of green building practices in construction projects in Qatar: A preliminary study. Management of Environmental Quality: *International Journal of environmental sciences,* 30(6), 1238–1255.

Sharma, M. L., & Dixit, A. (2023). Mechanical, electrical, plumbing and fire fighting (MEP) works contracts. *International Journal of Scientific Research in Engineering and Management,* 5(6), 1–13.

Shoar, S., Nejat, A., & Eslami, M. (2022). Assessment of the causes and effects of design deficiencies for large-scale construction projects. *Journal of Engineering, Design and Technology*, 20(2), 313–331.

Sullivan, K. T., & Tien, S. C. (2017). Maintaining design integrity through lifecycle management. *Journal of Facilities Management*, 15(3), 271–287.

Tayeh, B., Maqsoom, A., Issa, Y., Aisheh, A., Almanassra, M., & Salahuddin, H. (2020). Factors affecting defects occurrence in the construction stage of residential buildings in Gaza Strip. *SN Applied Sciences*, 2, 1–12.

Ugwu, C., Okafor, C. N., Sam-Amobi, C., Andy, N. N., Okere, C. E., & Anih, E. (2020). A conceptual shift in architectural designs in Nigeria towards climate change mitigation. *International Journal of Architecture and Urban Development*, 11(1), 1408–1417.

Umeh, C. E., & Obiorah, K. J. (2021). Fire safety implementation in electrical designs: An urban perspective. *Journal of Environmental Design and Safety*, 14(1), 21–30.

Waziri, B. S. (2016). Design and construction defects influencing residential building maintenance in Nigeria. *Jordan Journal of Civil Engineering*, 10(3), 313–323.

Zhou, Q., Lu Y., & Liu, Y. (2018). Enhancing construction document quality through digital coordination tools. *Automation in Construction*, 96, 122–130