TIMBOU-AFRICA PUBLICATION INTERNATIONAL JOURNAL FEBRUARY, 2025 EDITIONS.

INTERNATIONAL JOURNAL OF BUILT ENVIRONMENT AND EARTH SCIENCE

VOL. 7 NO. 4 E-ISSN 3027-1606 P-ISSN 3027-0049

MATHEMATICAL MODELS FOR MONITORING PHYSICAL CONDITION OF RESIDENTIAL BUILDINGS FOR SUSTAINABLE MAINTENANCE IN TAMBARI HOUSING ESTATE, BAUCHI STATE, NIGERIA

ISAH A. S.[1]; & GARBA U.[2.]

[1]Department of Civil Engineering, Federal Polytechnic Bali, Taraba State, Nigeria. [2]Department of Works, Federal University Kashere, Gombe State, Nigeria.

DOI: https://doi.org/10.70382/tijbees.v07i4.026

ABSTRACT

This research aimed to developed a predictive mathematical model for sustainable residential building maintenance and assessed the level of physical condition of residential buildings in Tambari Housing Estate (Bauchi state). A case study design approach was adopted for this research to develop models for sustainable residential building maintenance and

Introduction

According to Waziri & Vanduhe, (2019) Maintenance of building is the most vital means of sustaining the life span of building so as to achieve the purpose for which the building was built, despite all olds. Olaifa *etal*., (2025) further described maintenance as the combination of any actions carried out to retain an item in or restore it to an acceptable condition.

Odediran *et al*., (2019) stated that maintenance management is concerned with the planning and control of construction resources to ensure that necessary repairs and renewal are carried out with maximum efficiency and economy. Effective

the population consists sof the personnel and some selected buildings of the Estate. The survey method using structured questionnaire was adopted throughout the research work. Thus, sixty (60) questionnaires were distributed and total o forty-eight (48) questionnaires were collected back and used for the analysis. Data collected were analyzed using descriptive statistics and regression analysis. Tables were used to display the percentage and frequency of distribution. Multiple regression model was used to establish relationship between the dependent variable (physical condition of buildings) and other predictor variables. Statistical Package for Social Science (SPSS) software, version 17, was used to further analyze the data using mean and standard deviation. The result findings based on the responses of the respondents shows that the physical condition of their buildings is very poor and need attention for the sustainability of the residential buildings. It also shows that the level of maintenance of residential buildings is very poor and the developed model is appropriate for monitoring and quick evaluation of residential building maintenance.

Keywords: Maintenance, Building Maintenance, Mathematical Model, Maintenance Management, Multiple Regression

maintenance of building requires careful analysis of defect and the most appropriate way of affecting measures based on applicable technical knowledge so as to avoid wastage of material, labour and finance. Almost all necessitate of life need to be maintained in order to get maximum satisfaction from them. The building as one of the necessities needs to be maintained as well. Maintenance of buildings brings about improved utilization of buildings ensuring the safety standard.

A well operated system of maintenance for buildings and equipment has the effects of being a very effective disaster mitigation measures in terms of cost and facilities usage. It ensures the most economical way of keeping the building and equipment in the best of form for normal use, given the original design and material. Moreover, maintenance can also be explained as the continuous protective care of fabrics, contents and setting of places can be categorized according to why and when it happens, as corrective maintenance, which is necessary to bring a building to an accepted standard. Planned maintenance work is prevented failures, which recure predictable within the life of a building such as cleaning gutters or painting. Emergency corrective maintenance deals with the work that must be initiated immediately for health, safety, security reason or that may result in rapid deterioration of the structure or fabrics if not undertaken (for example, roof repairs after storm damage or repairing broken glasses), (Osuagwu *etal*., 2020).

However, for residential building maintenance predictive model can be used for monitoring and quick evaluation of buildings. This could be done through assessment of few specific components of building, analyze the data with the model and use it to predict the status of the building.

Furthermore, sustainability of residential building can be described as a residential building in which optimum performance can be achieved throughout its life span (Haruna 2023).

The deterioration of building element is highly dependent upon the method of construction, type of material used, element of weather i.e environmental condition and purpose for which the building was originally been build. The residential buildings in Tambari Housing Estate lack adequate maintenance attention due to lack of maintenance management and tools for assessing the level of maintenance of such buildings. Therefore, there is a need to establish tools that can monitor the level of maintenance of residential buildings using appropriate analysis. Gahlot (2018) describes three main problems in maintenance management which are general problems, they are: Bad management, deficiency in building design and lack of finance.

This study would not only contribute to knowledge and theory, but also contribute to good maintenance practice in residential buildings in Tambari Housing Estate (Bauchi State).

It will also provide an insight in appreciating the factors effecting the decision to carry out the maintenance since the existing building in the

E-ISSN 3027-1606
P-ISSN 3027-0049

Estate lack adequate maintenance attention, where most of the buildings are very poor. Thus, the paper will proffer solution to the problems.
According to Oyefeko (2019), Maintenance is defined as work undertaken in other to keep or restore every facility (i.e every part of the site, building and content) to an acceptable standard and cost.
Maintenance therefore is all the necessary work done to preserve a building with its furnishes and fittings, so that it continues to provide the same or almost the same facilities, amenities, and serves as it did when it was first built. It includes the expenditure necessary to maintain the rental values of the property.

TYPES OF MAINTENANCE

BS 3811(1984) classified building maintenance as presented in figure 1:

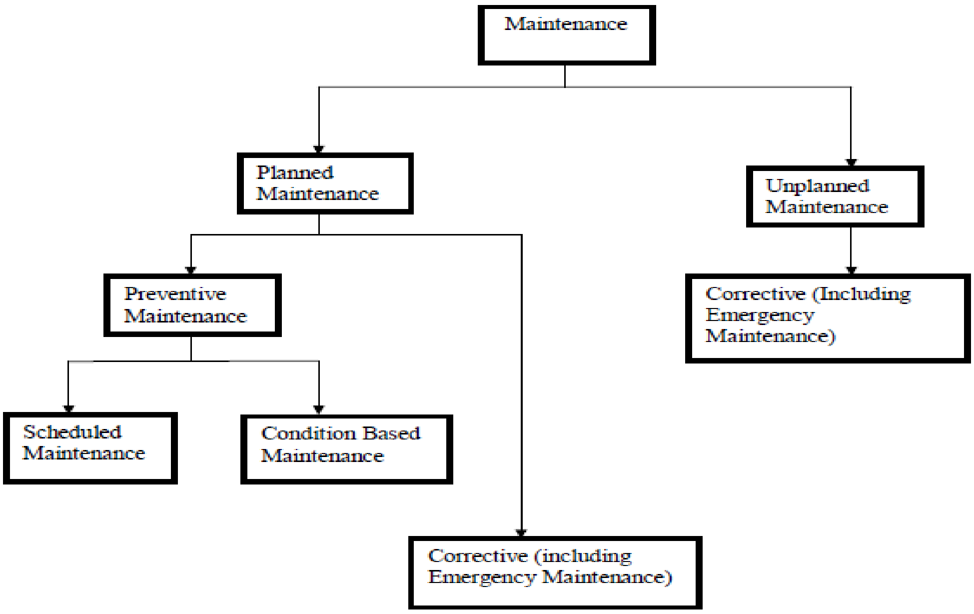


Figure 1: Types of Maintenance
Source: adopted from BS 3811:1984 (as cited Nik-Elyna (2018)

i. Planned Maintenance: The maintenance organized and carried out with forethought, control and use of records to a predetermined plan.
ii. Unplanned Maintenance: The plan carried out to no predetermined plan it referred to work necessitated by unforeseen breakdown or

damages. For example, the ripping off of a building, through the action of a storm, and its remedial action constitute unforeseen damages. It can also be termed unexpected and unavoidable maintenance.

iii. Preventive Maintenance: The maintenance carried out at predetermined intervals or corresponding to prescribed criteria and intended to reduce the probability of failure or the performance degradation of an item

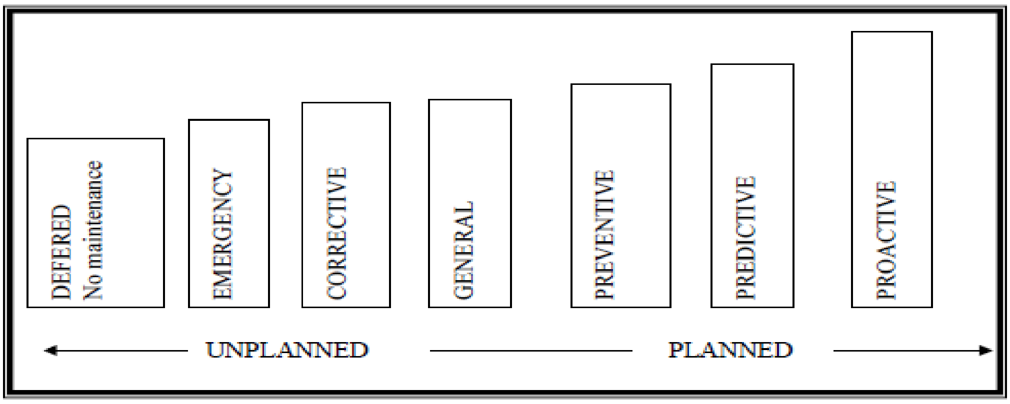
iv. Corrective Maintenance: The maintenance carried out after a failure has occurred and intended to restore an item to a state in which it can perform its required function.

v. Emergency Maintenance: The maintenance which is necessary to put in hand immediately to avoid serious consequences. This is referred to as day-to-day maintenance, resulting from such incidents as gale leaks and gate damage.

vi. Condition – Based Maintenance: The preventive maintenance initiated as a result of knowledge of the Condition of an item from routine of continuous monitoring.

vii. Scheduled Maintenance: The preventive maintenance carried out to a predetermined interval of time, number of operations, mileage etc.

viii. Running Maintenance: Maintenance which can be carried out whilst an item is in service.



Source: (Gahlot, 2018)

Figure 2: Continuum of Building Maintenance

TIJBEES E-ISSN 3027-1606
P-ISSN 3027-0049

Maintenance work has also been categorized according to Olanrewaju (2018) as 'Predictable' and 'Avoidable'.

Predictable maintenance is regular periodic work that may be necessary to retain the performance characteristics of a product, as that required to replace or repair the product after it has achieved a useful lifespan.

Avoidable Maintenance is the work required to identify failures caused by poor design, incorrect installation or the use of faulty materials.

COMPONENTS OF MAINTENANCE

Maintenance involves a considerable amount of work which has been categorized into three components namely; Servicing, Rectification and replacement (Oyefeko 2019).

i. Servicing: Servicing is essentially a clearing operation undertaken at regular intervals of varying frequency and is sometimes termed day-to-day maintenance. Daily sweeping of floors, monthly washing and cleaning of windows and regular painting for decoration and protection every four years are some examples of servicing.

ii. Rectification: Rectification work usually occurs fairly early in the life of a building; but it can also occur sometime within the lifespan of the building. It arises from shortcoming in design, inherent fault in or unsuitability of component, damage of goods in transit or installation and incorrect assembly. Rectification represents a fruitful point at which to reduce the cost of maintenance, because it is available. All that is necessary at any rate in theory is to ensure that some components and materials are suitable for their purpose and are correctly installed.

iii. Replacement: Replacement occurs at all costs in buildings. It is inevitable because service condition cause materials to decay at different rate. Much replacement work stems not so much from physical breakdown of the material or element as from deterioration of appearance.

E-ISSN 3027-1606
P-ISSN 3027-0049

OBJECTIVES OF THE STUDY

i. The aim of this project is to develop mathematical model for monitoring physical condition of residential buildings for sustainable maintenance.
ii. To assess the level of physical condition of residential buildings in Tambari Housing Estate.
iii. To develop regression models for monitoring the level of maintenance of such buildings.

METHODOLOGY

A case study design approach was adopted for this research to develop models for sustainable residential building maintenance with reference to Tambari Housing Estate. The population consists of the personnel and buildings of selected Tambari Housing Estate.

The survey method using structured questionnaire was adopted throughout the research work. Thus, sixty (60) questionnaires were distributed and total of (48) questionnaires were collected back and used for the analysis. Data collected were analysed using descriptive statistics and regression analysis. Tables were used to display the percentage and frequency of distribution. Multiple regression model was used to establish relationship between the dependent variable (physical condition of buildings) and other predictor variables.

RESULTS AND DISCUSSION

Table 1: Academic Qualification of Respondents

Academic qualification	frequency	percentage
First Degree	18	37.50%
HND	17	35.42%
NCE	3	6.25%
Diploma	10	20.83%
TOTAL	48	100%

Source: (Field Survey 2025)

E-ISSN 3027-1606
P-ISSN 3027-0049

Table 1 shows the respondents academic qualification. The responses shows that 37.50% of respondents are degree holders, 35.42% are HND holders, 6.25% are NCE holders and 20.83% are Diploma holders

MULTIPLE REGRESSION MODELS

Data collected were subjected to multiple regression analysis to establish relationship between the dependent variable (physical condition of buildings) and other 20 predictor variables (post occupancy evaluation, POE variables for buildings condition) and also to detect the strongest variables among the twenty (20) predictor variables. The variables are presented in Table 2.

Table 2: Specification of Variable

S/NO	Variable Number	Code	Name
1	V01	AGERSD	Age of Respondent
2	V02	RESEDU	Respdnt. Highest Qual.
3	V03	RESOCC	Respondent occupation
4	V04	TNOFOC	Number of female occupant
5	V05	TNOOCC	Total number of occupant
6	V06	AGEBLD	Age of building
7	V07	NMRBDR	Number of bed room
8	V08	NMRTLT	Number of toilet
9	V09	NMRSTR	Number of store
10	V10	NMRMLE	Number of male occupant
11	V11	ROFCND	Roof condition
12	V12	TTFCND	Toilet facilities condition
13	V13	DOWCND	Doors and window condition
14	V14	EXWCND	Exterior wall condition
15	V15	INWCND	Interior wall condition
16	V16	ELFCND	Electric fittings condition
17	V17	DWRCND	Discharge of waste condition
18	V18	FLOCND	Floor condition

E-ISSN 3027-1606
P-ISSN 3027-0049

19	V19	CELCND	Ceiling condition
20	V20	FSHCND	Finishes condition

Source: (Research design 2025)

Multiple regression models were again used to establish relationships between dependent variables (physical condition of building). The multiple regression method was adopted so as to detect the strongest variables among the twenty predictor variables and to get the equation of best regression that can describe the relationship and be used for prediction. The variables of the model are presented in Table 3.

Table 3: Model Variables

S/No	CODE	PARTICULARS
1	ROFCND	Roof condition
2	FSHCND	Finishes condition
3	TLFCND	Toilet facilities condition
4	DOWCND	Doors and window condition
5	EXWCND	Exterior wall condition
6	INWCND	Interior wall condition
7	ELFCND	Electric fittings condition
8	DWRCND	Disch. of waste water condtn
9	FLOCND	Floor condition
10	CELCND	Ceiling condition

Source: (Research design 2025)

The model equation is,

$\hat{Y}=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7+\beta_8X_8+\beta_9X_9+\beta_{10}X_{10}$

Where:

Y = Physical condition of building (dependent variable, PHYCON)

X_1 = Finishes condition (FSHCND)

X_2= Roof condition (ROFCND)

E-ISSN 3027-1606
P-ISSN 3027-0049

X_3= Toilet facilities condition (TLFCND)

X_4 =Doors and windows condition (DOWCND)

X_5 = Exterior wall condition (EXWCND)

X_6 = Interior wall condition (INWCND)

X_7 = Electric fittings condition (ELFCND)

X_8 = Discharge of waste water condition (DWRCND)

X_9 = Floor condition (FLOCND)

X_{10} = Ceiling condition (CELCND)

Table 4: Model Summary of Physical Condition and other (10) Predictor Variables

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.716[a]	.512	.381	11.01821	.512	3.888	10	37	.001

a. Predictors: (Constant), X10, X8, X1, X7, X5, X2, X4, X6, X3, X9

Table 5: Regression Model's Coefficient and the Corresponding Beta values

S/No	Regression Model Coefficients Particulars	Values	Beta Values
	Constant β_0	71.038	
1	β_1	-2.868	-0.126
2	β_2	1.816	0.088
3	β_3	-9.181	-0.420
4	β_4	2.390	0.090
5	β_5	-1.451	-0.055
6	β_6	3.029	0.130
7	β_7	-1.848	-0.090
8	β_8	2.553	0.102
9	β_9	-9.296	-0.491
10	β_{10}	-0.590	-0.029

Source: Using SPSS Program, (statistics analysis version 17.0)

E-ISSN 3027-1606
P-ISSN 3027-0049

Table 5 shows the emerging model equation's regression coefficient estimates. Therefore, the model can be written as:

$\hat{Y}$=71.038+ $(-2.868X_1) + (1.816X_2) + (-9.181X_3) + (2.390X_4) +$
$(-1.451X_5) + (3.029X_6) + (-1.848X_7) + (2.553X_8) + (-9.296X_9) + (-0.590X_{10})$

Where X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9 and X_{10} are independent variables presented in Table 6 with their respective mean values

Table 6: Mean of Model's Variables.

S/No	CODE	PARTICULARS	MEAN VALUES
	Y	Physical condition of building (dependent variable, PHYCON)	24.5000
1	X_1	Finishes condition (FSHCND)	2.7917
2	X_2	Roof condition (ROFCND)	2.5625
3	X_3	Toilet facilities condition (TLFCND)	3.1250
4	X_4	Doors and windows condition (DOWCND)	2.9792
5	X_5	Exterior wall condition (EXWCND)	3.3750
6	X_6	Interior wall condition (INWCND)	3.0208
7	X_7	Electric fittings condition (ELFCND)	3.0417
8	X_8	Discharge of waste water condition (DWRCND)	3.3333
9	X_9	Floor condition (FLOCND)	2.9167
10	X_{10}	Ceiling condition (CELCND)	2.7917

Substituting the mean values of each variable in the model, the model estimate becomes

$\hat{Y}$=71.038 - 2.868(2.7917) + 1.816(2.5625) - 9.181(3.1250) + 2.390(2.9792) - 1.451(3.3750) + 3.029(3.0208) - 1.848(3.0417) + 2.553(3.3333) - 9.296(2.9167) - 0.590(2.7917)

$\hat{Y}$=71.038 - 8.001 + 4.654 – 28.691 + 7.120 – 4.897 + 9.150 – 5.621 + 8.510 – 27.114 – 1.647

$\hat{Y}$=24.501

Therefore, model estimate, $\hat{Y}$=24.501 while actual observation, Y= 24.5000

Where error term is given as:

$E^2=(Y-\hat{Y})^2$

TIJBEES E-ISSN 3027-1606 P-ISSN 3027-0049

$E^2 = (24.5000-24.501)^2$

$E=0.001$

This means that the error term is 0.001, which explain the physical condition of building in Tambari Housing estate is very poor for human habitation. Therefore 10 maintenance factors are significant to physical condition of building in the estate. These factors are listed as follows:

i. Finishes condition
ii. Roof condition
iii. Toilet facilities condition
iv. Doors and windows condition
v. Exterior wall condition
vi. Interior wall condition
vii. Electric fittings condition
viii. Discharge of waste water condition
ix. Floor condition
x. Ceiling condition

The quantitative regression equation is:

$\hat{Y}$=71.038 - 8.001 FSHCND + 4.654 ROFCND – 28.691 TLFCND + 7.120 DOWCND – 4.897 EXWCND + 9.150 INWCND – 5.621 ELFCND + 8.510 DWRCND – 27.114 FLOCND – 1.647 CELCND

Where:

Y=physical condition of building (dependent maintenance factor- PHYCON), While others (physical condition of buildings predictor) are the following:

i. (FSHCND) Finishes condition
ii. (ROFCND) Roofs condition
iii. (TLFCND) Toilet facilities condition
iv. (DOWCND) Doors and windows condition
v. (EXWCND) Exterior walls condition
vi. (INWCND) Interior walls condition
vii. (ELFCND) Electric fittings condition

TIJBEES E-ISSN 3027-1606
P-ISSN 3027-0049

viii. (DWRCND) Discharge of waste waters condition
ix. (FLOCND) Floors condition
x. (CELCND Ceilings condition

All the above 10 listed building maintenance factors of physical condition of buildings gives the assessment of physical condition of buildings in the Tambari Housing Estate.

FINDINGS OF THE STUDY

The result findings based on the responses of the respondents shows that the physical condition of their buildings is very poor and need attention for the sustainability of the residential buildings. It also shows that the level of maintenance of residential buildings is very poor and the developed model is appropriate for monitoring and quick evaluation of residential building maintenance.

CONCLUSION

The research assessed the level of physical condition of residential buildings in Tambari Housing Estate (Bauchi state) and developed a predictive mathematical model for sustainable residential building maintenance in the estate. Thus, the research has shown that the physical condition of residential buildings in Tambari Housing Estate can be assessed using the regression model below:

$\hat{Y}$=71.038 - 8.001 FSHCND + 4.654 ROFCND – 28.691 TLFCND + 7.120 DOWCND – 4.897 EXWCND + 9.150 INWCND – 5.621 ELFCND + 8.510 DWRCND – 27.114 FLOCND – 1.647 CELCND.

From the result findings of this research it shows that the physical condition of residential buildings in Tambari Housing Estate is very poor based on the building condition index. Thus, model can be used for quick assessment of physical condition of residential buildings.

RECOMMENDATION

The following recommendations were drawn:

TIJBEES E-ISSN 3027-1606
P-ISSN 3027-0049

i. It is recommended that for effective maintenance practice in Tambari Housing Estate, the Estate and maintenance managers should oversee periodic inspections of buildings' conditions and create an inventory of buildings' components and equipment.

ii. The estate managers should also plan building inspection, since proper planning of inspection is a sure way to reduce cost of maintenance since doing so can provide insight into future maintenance needs and avoid unnecessary costs.

iii. The physical condition assessment model developed, should be adopted and used for quick assessment of residential buildings in the estate.

REFERENCE

Gahlot, P. S. (2018). Building Repair and Maintenance Management (3rd edition). New Delhi: CBS publishers

Haruna, P. B., Zubairu, S., Olagunju, R. E., & Akande, O. K. (2023). Liveability Considerations: Towards Designing Sustainable Public Housing in Niger State, *Nigeria. Journal of Contemporary Urban Affairs,* 7(2), 262–278. https://doi.org/10.25034/ijcua.2023.v7n2-16

Nik-Elyna, M. N. M. (2018). Performance measurement of office buildings maintenance management. University Malaya

Odediran, S. J. (2019). Maintenance of Residential Buildings: Users' Practices in Nigeria. Department of Quantity Surveying, Obafemi Awolowo University, Ile-Ife, Nigeria

Olaifa, A. S., Ali, M. A. A., Olaifa, E. O., Oladimeji, R. M. & Akpala, K. C. (2025). Principals' Facilities Maintenance Measures and Administrative Effectiveness in Private Secondary Schools in Kwara State, Nigeria. *Chalim Journal of Teaching and Learning*, 4(2), 101–118. https://doi.org/10.31538/cjotl.v4i2.1745

Olanrewaju, S. B. O. & Anifowose, O. S. (2018). The challenges of building maintenance in Nigeria: A case study of Ekiti State. European Journal of Educational and Development Psychology 3(2), 30-39.

Osuagwu, A. C., Okolie Kelvin C., Nkeleme E. I. Okoye U. C. Onwuka E. (2020). Current Issues Associated with Public Building Maintenance in South-East Nigeria. *International Journal of Innovative Science, Engineering & Technology*, Vol. 8 Issue 2, February 2021 ISSN (Online) 2348 – 7968

Oyefeko, S. T. (2019). The Role of Maintenance Culture in Buildings in the Economic Development of Nigeria, NIOB journal vol.1 no. 2. Pp. 72 – 76.

Waziri, B. S. & Vanduhe, B. A. (2019). Evaluation of factors affecting residential building maintenance in Nigeria: User's perspective. Civil and Environmental Research 3(8), 56- 57.