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Modelling Incidents of Building Collapse Data in Nigeria, Using Poisson and Negative Binomial Regression Models

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Abstract: The rates of building collapse in Nigeria in the past twenty years have assumed a very worrisome dimension as many lives have been lost and huge investments wasted. Several causes have been attributed to natural or man-made phenomena. Survey carried out have shown that the use of substandard building materials, poor workmanship, non-enforcement of building codes or construction regulations, corruption in the building industry etc. have contributed immensely in most of the recorded cases of building failures. This paper is set to examine the application of Poisson and negative binomial regression models to identify the major factors that contributes to building collapse in Nigeria and toascertain the better model suitable for prediction of building collapse or failure in Nigeria, using a secondary data which span from (1995 – 2016). Maximum likelihood estimation procedure was used to estimate the parameter of the selected model. With the number of incidents of building collapse data as the response variable (Y) and 7-explanatory variable (X's), applying the forward selection criteria to the 7-explanatory variables, model 7 is best suitable for forecasting the subject under study. The result of the Poisson regression model showed that there was over dispersion in the incident of building collapse data since the dispersion parameter (3.224) was greater than 1. Hence underestimating the standard error and over estimating the coefficient of the explanatory variable, consequently giving misleading inferences. The result of the assessment criteria for Poisson regression model and Negative binomial regression model revealed that the Negative binomial regression models incident of building collapse data better in Nigeria as considered in this study. Use of quacks (UOQ), Change of Use (COU) and Corruption/greed (C_G) are the major contributors to incident of building collapse in Nigeria, with corruption/greed ranking first. A model suitable for prediction of the incident of building collapse in Nigeria has been developed.

Keywords: Building collapse, building materials, Poisson Regression Model, Negative Binomial Regression Model, Akaike Information Criteria (AIC).

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I. INTRODUCTION

Building collapse, though a common phenomenon all over the world is more rampant and devastating in the developing countries. However, most of the failures were not caused by an earthquake or a terrorist attack, but rather by the poor construction and lack of over-sight Alamu and Gana (2014) added that the menace has cast a slur on the competence of the nation building community of professionals responsible for designing and monitoring construction works at building sites. Experts have also suggested that professional should not bear the blame alone. This is because it has been proved that owners should not bear the blame alone.Owner of building under construction derail from the approved plans relying more on imagination and fantasy. The approving authorities are also known to fail to monitor compliances with approved plans. Some building owners also shun professionals in order to cut cost. Also, the high cost of building materials has led greedy contractors with eyes on profits to patronize substandard materialthese short-cut measures has contributed immensely to the occurrence of failed buildings in the country.

Fademiro (2002) opined that the concentralization of population in cities due to migration created by specific problems of providing adequate building structure. The resultant effect of this is the upsurge of various building projects from various contracting firms of doubtful competencies. Nnaedozie (2005) also added that the development control unit (DCU) is most states play a limited role as they lack the requisite number of staff with expertise to supervise the many developments in progress concurrently across their areas of jurisdiction.

Ede (2010) carried out analysis and evaluation of the death rate involved in the 47 reported cases of building collapse verified between 2000 and 2010and over 300 deaths were recorded for Lagos, Abuja and Port Harcourt which are the three major areas with high rate of casualties.

According to Obiedina (2005), the term failure can be manifested in three forms in the structure, namely: Ultimate limit state, which results in collapse; Serviceability limit state, which has to do with deflections and cracks and finally Durability which has to do with deterioration of the elements. The design of any structure must guard against the structure attaining any of this state. Furthermore, failure can occur in the sub or superstructures or both and can result from: poor design, use of substandard materials and poor-quality control and supervision.

Oloyede, Omoogun and Akinjare (2010) pointed out that different soil types pose varying problems for built foundations and the structural integrity of an entire building. Therefore, to design a foundation it is necessary to calculate the loads on the foundation and determine the nature of the sub-soil its bearing capacity, likely behavior under seasonal and ground water level changes and the possibility of ground movement.

Similarly, the components of the structure should be able to resist deformation under loading conditions. Deformation implies a change a change in size and shape when a body is subjected to stress. This means that the component should possess adequate stiffness. Thus, the stiffness of a beam or column is a measure of its resistance to bending or buckling.

2. A brief reviews/summary of the Causes of building failures or Collapses.

Generally, causes of building collapse can be classified under the following major factors, namely: types and quality of building materials used; mode/method of operation in the building industry and problems emanating from personal/human factor.

(i) *Types and quality of building materials and Equipment*

- The use of substandard building material of different qualities ca be obtained by using its constituent namely
- Poor Concrete mix ratio. Cement water time and coarse aggregates, and mineral addictive in different and right proportion (Gambir, 2005). A mix ratio that does not meet approved standard will have negative effect on the structure.
- Poor construction equipment. Construction plants ranging from small hand plant such as mechanical excavators and tower cranes can be considered for use to maintain the high standards required in any building project. Sad enough, the use of manual labour is still a common practice in most of the of the construction sites in Nigeria.

(ii) Operation Problem.

- Illegal conversion or change of use buildingowners in order to make more money from their property often change the use for which the building was initially approved by the town planning authority, adequate provisions are not often made for subsequent conversion/modification. Structures approved as office complex are illegally turned to a place of worships. The resultant effect is that the structure is eventually overloaded.
- No structural drawing/design available
- Non-enforcement of building codes or construction regulations.
- Hasty construction: Tyler (1981) noted that the growth of strength with age is an important factor in concrete works.

Testing is usually done at 7days and 28days and concrete is regarded as more or less mature at 28 days. Sometimes, the project owner is ill advised on the consequence of loading premature concrete especially when he is in hast to get his project completed
Before the records time.

(iii) *Personal Problem:*

- Poor workmanship and ineffective supervision: Supervision involves the intricate knowledge of workmanship and to ensure adherences to contract documents, especially the drawings. This aspect is often lacking in most construction sites resulting in poor workmanship and subsequent collapse.
- The use of quacks instead of professionals: the activities of unqualified persons in the building industry have done a lot of harm. Building owners in most cases will engage the services of quacks in other to save cost of engaging professionals. A professional in practice is basically responsible for proving solution to problems in the field in the context of scope, functionality, quality and cost, stability, time of production, safety and durability.
- Corruption and greed in the building industry.

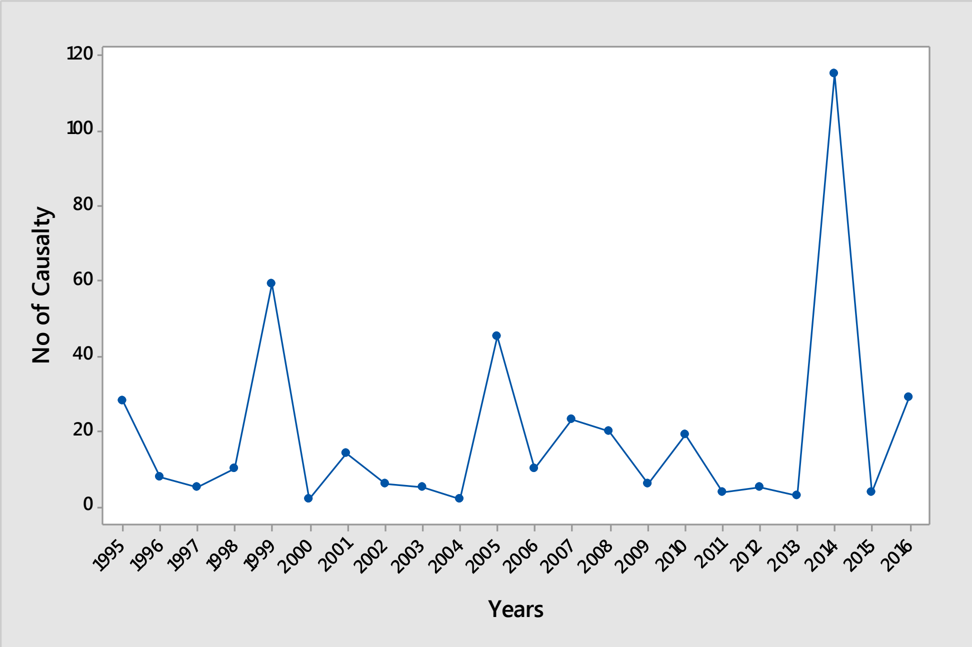

Figure 1: Time series plot of No of Casualty from Collapse Building from (1995 - 2016)

One of the major objective of this study is to provide a model which will be able to predict the major contributors of building collapse in Nigeria, so as to make appropriate recommendation to the various units/department/constructors so as to limit or reduce the number of death recorded from building collapse.

II. METHODS

2.1 Poisson Regression Model

*B*y definition, $Y_{(\text{dependent variable})}$ follows a Poisson distribution with parameter $\lambda > 0$ iff the probability distribution function is given by

$$P(Y = k) = \frac{\exp(-\lambda)\lambda^k}{k!} \qquad (1)$$

For K=0,1,2,… such that $E(Y) = \lambda$ and $Var(Y) = \lambda$

For nindependent random variables $Y_1, Y_2, \ldots, Y_n$

$Y_i \sim P(\mu_i)$, and suppose we want to let the mean and the variance depend on the explanatory variables x_i's

$$g(\mu_i) = \mu_i = x_i'\beta = \eta_i,$$

(2)

We can consider a generalized linear model with log link as: $\log(\mu_i) = x_i'\beta$.

(3)

Where X_i denotes the vector of explanatory variables and β denotes the vector of regression parameters.

2.2 Model Specification

The model for the Poisson regression is given as: $\lambda_i = E(Y_i) = \exp\left(\alpha + \sum_{j=1}^{k} x_j'\beta_j\right)$, (4)

Where α is the intercept, Since the mean is equal to the variance the usual assumption of Homoscedasticity would not be appropriate for a Poisson data.

2.3 Parameter Estimation-Iterative Reweighted Least Squares

Estimation of parameters in Poisson regression relies on maximum likelihood estimation (MLE) method.

The log likelihood function is given as: $\log L(\beta) = \sum\{y_i \log(\mu_i) - \mu_i\}$, (5)

To obtain the maximum likelihood for the parameter β_j we employ the chain rule

$$\frac{\partial l}{\partial \beta_j} = U_j = \sum_{i=1}^{N} \frac{\partial l_i}{\partial \beta_j} = \sum_{i=1}^{N} \left(\frac{\partial l_i}{\partial \theta_i} \cdot \frac{\partial \theta_i}{\partial \mu_j} \cdot \frac{\partial \mu_i}{\partial \beta_i}\right) \qquad (6)$$

Hence the iterative equation would be written as: $b^{(m)} = (X^T W X)^{-1} X^T W$ (7)

Where $w_{ii} = \frac{1}{var\,(Y_i)}$ and $z_i = y_i$

2.4 Negative Binomial Regression (NBR) Model

NBR is a popular generalization of Poisson regression because it loosens the highly restrictive assumption that the variance is equal to the mean made by the Poisson model. The traditional negative binomial regression model, commonly known as NB2, is based on the Poisson-gamma mixture distribution. This model is popular because it models the Poisson heterogeneity with a gamma distribution. This is given as:

$$\lambda = E(y_i) = \exp(\alpha + \sum \beta_i X_i + \sum \gamma_i D_i)$$

(8)

$$P(Y_i = y_i) = \frac{\exp(-\mu_i)\mu_i^{y_i}}{y!}, \quad y_i = 0,1,2,\ldots$$

(9)

$$Y_i \sim NB(\lambda = \exp(X^T\beta), \psi)$$

(10)

Compounding Poisson distribution above and a gamma distribution would give a Negative Binomial distribution

$$\Pr(Y_i = y_i | \mu_i, \alpha) = \frac{\Gamma(y_i + \alpha^{-1})}{\Gamma(y_i + 1)\Gamma(\alpha^{-1})} \left(\frac{1}{1+\alpha\mu_i}\right)^{\alpha^{-1}} \left(\frac{\alpha\mu_i}{1+\alpha\mu_i}\right)^{y_i}$$

(11)

Where $E(Y_i) = \mu_i$ while the variance $Var(Y_i) = \mu_i(1 + \alpha^{-1}\mu_i)$ where $\alpha = v^{-1}$

(12)

- The regression coefficients are estimated using the method of maximum likelihood.
- The significant regression parameters from (11) will be subjected to a test of hypothesis.
- The AIC would reveal the better model between equation (4) and equation (11) then the rank test would be employed to ascertain the levels of contribution of the various factors under consideration to Oil spill in the Niger Delta.

2.5 Model Evaluation

In this research work, we would be applying the techniques below for evaluating the models to also ascertain the better model suitable for modelling Oil spill in the Niger Delta from 1976 – 1996:

Deviance:is a goodness of fit statistic for a model that is often used for statistical hypothesis testing and often used to compare two different models. Larger deviance indicates low performance of the model and less deviance indicates better performance of the model.

$$D = 2(l(y, \phi; y) - l(\hat{\mu}, \phi; y))$$

(13)

Where $l(y, \phi; y)$ is the log-likelihood of the full model and $l(\hat{\mu}, \phi; y)$is the log-likelihood of the current model.

AIC: The Akaike would be used to in selecting the best model that fit our data. The model with the smaller AIC is the best.

$$AIC = -2(likelihood - K) \quad (15)$$

$$BIC = -2In(likelihood) - KIn(n) \quad (16)$$

Where n is sample size and K is number of predictors;

Pearson Residual: It is used to check for model fit of each variable (explanatory variables). It is the discrepancy between our observed and fitted values for each observation.

III. RESULTS AND DISCUSSION

Table 1: Descriptive statistics of the response variable and the explanatory variables

Parameter	Minimum	Maximum	Mean	Std. Deviation
No of Casualty	22	19.18	26.010	676.537
Substandard Materials	22	13.50	18.278	334.071
Poor Concrete Mixture	22	8.73	11.752	138.113
Wrong Construction Method	22	7.73	10.430	108.779
Change of Use	22	4.95	6.492	42.141
Use of Quacks	22	11.45	15.586	242.926
Hasty Construction	22	9.82	13.114	171.965
Corruption/greed	22	6.82	9.069	82.251

Inmodelling the mortality rate data of collapse building in Nigeria, R statistical software version 3.3.3 was used. The Generalized Linear Model (GLM) with **Poisson** as the fundamental distribution for modelling a count data using the Log link function and the Negative Binomial distribution was latter employed to correct the error of **over dispersion** in the count data in situation where the result of the Poisson regression model shows over dispersion.

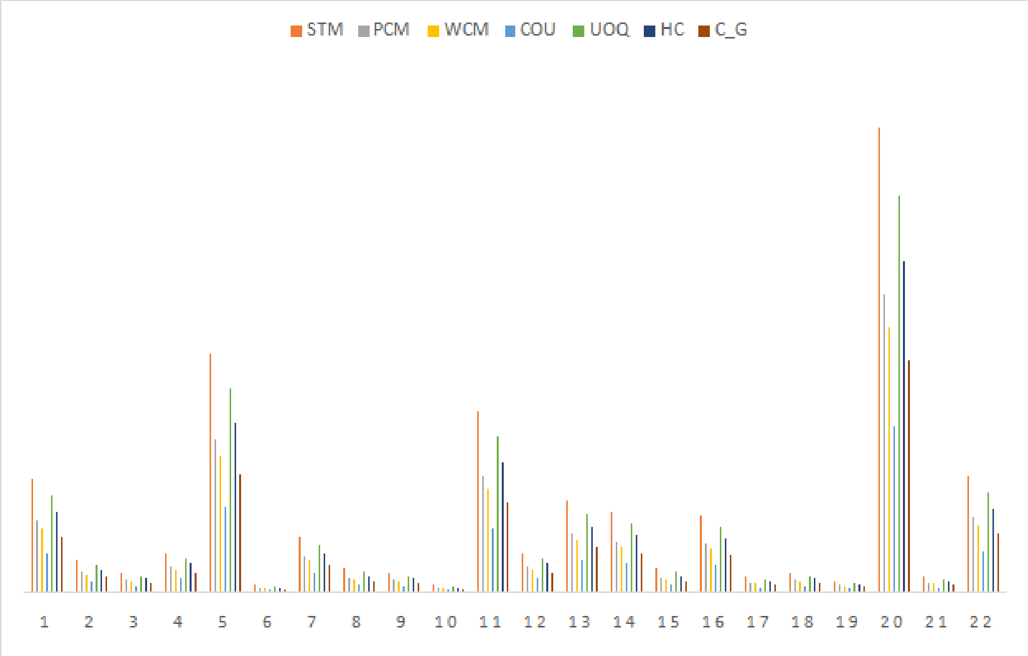

Figure 2: Causes of Collapse Building (1995 - 2016)

3.2 Modelling Incident of Building Collapse Data in Nigeria

Table 2: The Poisson Regression Models for Building Collapse in Nigeria 1995 – 2016 with their AIC's

Models		**AIC**
1.	$\log(\textit{mean of No Killed}) = \alpha_1 + \beta_1 STM$	189.609
2.	$\log(\textit{mean of No Killed}) = \alpha_2 + \beta_1 STM + \beta_2 PCM$	189.982
3.	$\log(\textit{mean of No Killed}) = \alpha_3 + \beta_1 STM + \beta_2 PCM + \beta_3 WCM$	184.820
4.	$\log(\textit{mean of No Killed}) = \alpha_4 + \beta_1 STM + \beta_2 PCM + \beta_3 WCM + \beta_4 COU$	176.181
5.	$\log(\textit{mean of No Killed}) = \alpha_5 + \beta_1 STM + \beta_2 PCM + \beta_3 WCM + \beta_4 COU + \beta_5 UOQ$	168.749
6.	$\log(\textit{mean of No Killed}) = \alpha_6 + \beta_1 STM + \beta_2 PCM + \beta_3 WCM + \beta_4 COU + \beta_5 UOQ + \beta_6 HC$	170.706
7.	$\log(\textit{mean of No Killed}) = \alpha_7 + \beta_1 STM + \beta_2 PCM + \beta_3 WCM + \beta_4 COU + \beta_5 UOQ + \beta_6 HC + \beta_7 CG$	**153.534*****

STM=Substandard Materials, **PCM**=Poor Concrete Mixture, **WCM**=Wrong Construction Method, **COU**=Change of Use, **UOQ**=Use of Quacks, **HC**=Hasty Construction, **CG=Corruption/greed**.

From table 2 above, we see that the best model which fit the Building Collapse data in Nigeria1995 – 2016 is **model 7** because it has the smallest Akaike Information Criterion (AIC). The AIC of model 7 was found to be 153.534 with a null deviance of 504.667 on 21 degree of freedom and a residual deviance of 45.13 on 14 degree of freedom following the chi-square distribution ($\chi^2_{(1)}$).

The parameters and their estimates, the standard errors, the Chi-squares with their associated probability values are presented in table 3 below

Table 3: The Parameter Estimates of the Selected Poisson Regression Model

Parameter	**Estimate**	**Std. Error**	**Z values**	**Pr(>|Z|)**
(Intercept)	2.238	0.1199	18.669	<2e-16
Substandard Materials	-1.161	0.2817	-4.120	3.78e-05
Poor Concrete Mixture	-.440	0.2996	-1.467	0.142389
Wrong Construction Method	1.264	0.4331	2.919	0.003512
Change of Use	-1.546	0.3208	-4.820	1.44e-06
Use of Quacks	1.618	0.4837	3.345	0.000824
Hasty Construction	-.924	0.4213	-2.194	0.028214
Corruption/greed	1.203	0.2836	4.240	2.23e-05

The table 3 presents the parameter estimates of the selected model for the incident of building collapse in Nigeria over 21 years ie from 1995 - 2016. The Akaike information criterion (AIC) of this model was 153.534 with a null deviances of 504.667 on 21 degree of freedom and a residual deviance of1 45.134 on 14 degrees of freedom following the chi-square distribution (χ^2) on one degree of freedom. The dispersion parameter was found to be 3.224 (i.e residual deviance/degree of freedom as seen in table 5) and the Omnibus test flag a P-value equal 0.000 which implies that the model is significant at 5% α -level. However, the assumption of equality of mean and variances in Poisson distribution has been violated since the dispersion parameter is not approximately equal to 1. The dispersion parameter of the above model is 3.224 which is greater than 1, a clear indication of overdispersion in the building collapse data. This further implies that the parameters of the stated model have been over-estimated and the corresponding standard errors have been under estimated consequently giving a misleading inference about the regression parameters. To address this issue, Negative Binomial regression was used to modify the model to nullify the effect of over dispersion in the data and the result is shown in table 3 below.

Table 4: Negative Binomial Regression Model Parameter Estimates

Parameter	Estimate	Std. Error	Z-values	$Pr(>\|Z\|)$
(Intercept)	2.1353	0.1949	10.957	<2e-16
Substandard Materials	-0.9910	0.4291	-2.309	0.0209
Poor Concrete Mixture	-0.4279	0.4378	-0.977	0.3284
Wrong Construction Method	1.1982	0.6637	1.805	0.019
Change of Use	-1.2643	0.5157	-2.452	0.0142
Use of Quacks	1.4096	0.7410	1.902	0.010
Hasty Construction	-0.8899	0.6351	-1.401	0.0473
Corruption/greed	1.0346	0.4397	2.353	0.0022

InterpretationofCoefficients

From table 4 it can be seen that Substandard Materials, Wrong Construction Method, Change of Use, Use of Quacks, Hasty Construction and Corruption/greed were all statistically significant since (p-value < 0.05) while Poor Concrete Mixture was not statistically significant since (p-value < 0.05).

The variables Substandard Materials**(STM)**, Wrong Construction Method**(WCM)**, Change of Use**(COU)**, Use of Quacks**(UOQ)**, Hasty Construction**(HC)** and Corruption/greed**(C_G)** where all statistically significant at 5% α level. This implies that Building Collapse in Nigeriais not as a result of witchcraft,but from this study we see all the above listed factors contributing significantly to building collapse which in turn leads to high number of death recorded. From this study, it can be established that Substandard Materials, Wrong Construction Method, Change of Use, Use of Quacks, Hasty Construction and Corruption/greed are the major contributors to building collapse in Nigeria.

From Table 4 it is observed that the parameter estimates have been reduces and the standard errors have also been increased. The parametric analysis for the comparison between the Poisson and Negative Binomial Regression for goodness of fit of the model is shown in table 5.

Table 5: Assessment Criteria for Poisson and Negative Binomial Regression

Assessment Parameter	Poisson Regression Model	Negative Binomial Regression Model
Null Deviances	504.667	174.196
Degree of Freedom	21	21
Residual Deviance	45.134	23.977
Degree of Freedom	14	14
Log Likelihood	-137.534	-133.63
Dispersion Parameter	3.224	1.715
Akaike's Information Criterion (AIC)	153.534	151.63

From the result presented in table 5, it is clear that the negative binomial regression model is the better model which fits the Building Collapse Data in Nigeria since the dispersion parameter has reduced from 3.224 which was given by the Poisson model to 1.715 in the Negative Binomial model.

The Akaike Information Criteria (AIC) of the Poisson Regression model also reduced from 153.534 to 151.63 in the negative binomial model, we can see more supporting claims from the Null Deviances; Residual Deviance;

Log Likelihood all of which also corroborated our findings that the Negative Binomial Model is the better model to modelling the number of death as a result of building collapse.

3.3 The Model for Predicting Casualty from Building Collapse in Nigeria

For negative binomial regression, the model for the Casualty from Building Collapse data is obtained as:

$$\log(mean\ of\ \ No\ of\ \ Killed) = 2.1353 - 0.9910(STM) - 0.4279(PCM) + 1.1982(WCM) - 1.2643(COU) + 1.4096(UOQ) - 0.8899(HC) + 1.0346(C\_G) + e$$

Table 6: Ranking the Probability Value of the Estimates of Negative Binomial Regression Model

s/n	Parameter	P-values	Ranks
1	**Substandard Materials**	0.0209	**5th**
2	**Wrong Construction Method**	0.0190	**4th**
3	**Change of Use**	0.0142	**3rd**
4	**Use of Quacks**	0.0100	**2nd**
5	**Hasty Construction**	0.0473	**6th**
6	**Corruption/greed**	0.0022	**1st**

From table 6 which ranks the P-values of the better model **(Negative binomial Regression)** to identify which parameter was more significant also which factor contributed more than the other. Corruption/greed was rank in the first position. Implication is that Corruption/greed factor is the most statistically significant factor that contributing to high number of death as a result of building collapse in Nigeria followed by Use of quacks, change of use, wrong construction method, substandard materials and hasty construction while poor concrete was not a significant contributor in the subject matter in this study.

IV. CONCLUSION

Negative binomial regression model is the better model suitable for modeling incident of building collapse in Nigeria as considered in this study. Substandard Materials **(STM)**, Wrong Construction Method **(WCM)**, Change of Use **(COU)**, Use of Quacks **(UOQ)**, Hasty Construction **(HC)** and Corruption/greed **(C_G)**are the major factors that contribute to the high number of death as a result of building collapse in Nigeria. The model which can be used to forecast future number of casualty from building collapse keeping the factors considered in this study constant is shown below:

$$\begin{bmatrix} \log(mean\ of\ \ No\ of\ \ Killed) = 2.1353 - 0.9910(STM) \text{-} 0.4279(PCM) + 1.1982(WCM) - 1.2643(COU) \\ +1.4096(UOQ) - 0.8899(HC) + 1.0346(C\_G) + e \end{bmatrix}$$

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