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Modelling Maintenance Cost of Roads: Anambra State Situation

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Abstract
This study dealt with the Anambra State situation of modelling maintenance cost of roads. The objective of this study was to design generalized nonlinear models for estimating maintenance cost of roads using economic factors and asphalt quantity parameters. The source of data for this study was secondary source of data collection obtained from the records department of Consolidated Construction Company Uli Asphalt Plant Anambra State, Nigeria. Also, economic data were extracted from the Central Bank of Nigeria Statistical Bulletin 2013. The result of generalized nonlinear model for estimating maintenance cost of roads using economic factors found a Pearson Chi-squared value of 3.776235e-11 and an Akakike Information Criterion value of -212.64. Also, the result of generalized nonlinear model for estimating maintenance cost of roads using economic factors and asphalt quantity parameters found a Pearson Chi-squared value of 1.332268e-14 and an Akakike Information Criterion (AIC) value of -292.44. The result of the correlation analysis used for determining the efficiency of the models in estimating maintenance cost of roads in Anambra State revealed a positive perfect correlation with even correlation coefficient measure of 1.00. In addition, it was found that model (2) which comprise of the economic and quantity parameters best describe the process of maintenance cost of roads in Anambra State than model (1) since it has a lower AIC measure of -292.44.

Keywords: Generalized nonlinear model, Economic factor, maintenance cost of roads, Akakike Information Criterion,

Notations: *Quantity of binder produced (Qbp), Imports of Articles of Stone, Plaster, Cement (IASPCA), Sectoral Contribution to Real GDP (SCRGDP), Market Capitalization of Quoted Company for Construction (MCQCC), Market Capitalization of Quoted Companies for Machinery (MCQCM), Composition of Gross fixed Capital Formation at Current Purchase Value Machinery and Equipment (CGFCFCPME), GDP at Constant Basic Price for Building and Construction (GDPCBPBC), GDP at Current Basic Price for Building at Construction (GDPBPBC), Total Length of Roads (LR), Mean Relative Rain fall (MRR), Mean Efficiency (MeF).*

1. Introduction

Road maintenance involves activities programmed to preserve the road infrastructure. This means that during the design life of the road, conscious efforts must be made to arrest the various deteriorations that takes place on it. Road infrastructure is composed of the carriage way, the pedestrian facilities where applicable, drainage system, culverts (Box or Ring types), bridges and flyovers, street light installations, traffic signs and traffic islands [1]. The purpose for this course of action is to ensure that the road provides an acceptable level of service to the users for substantial period of its service life. In order to ensure proper planning preparatory to actual budgeting for maintenance, there is need to categorize the options available for maintenance activities such as routine maintenance, recurrent maintenance, periodic maintenance and urgent or special maintenance works [2]. Ref [1] proposed the under-listed alternative sources of funding to enable the local, states and federal governments cope with the road maintenance funding. Apart from the usual annual vehicle license obtained for every Category of vehicles, an acceptable annual levy could be charged for various categories of vehicles. Stake holders meetings at Community levels of all local governments could be

organized to explain the advantages of the levy on improved road conditions. Annual levy of N1000 - N5000 depending on vehicle type and axle Load could be charged. Other areas that could be used are parking fees and fines for illegal Parking, road worthiness testing, hackney permit, licensing of public Service vehicles and services. The imposition of fuel levy could generate quick fund. This should be done tactically In the light of the presently unstable high cost of Petrol and other petroleum products. Such levy should be proportionally disbursed to the 3-tiers of government for properly monitored road maintenance programmed. Private sector initiative and community participation on road infrastructure maintenance should be encouraged and done to mutually acceptable specifications and standard.

Ref [3] noted that funding of road infrastructure projects remains a major constraint in the delivery of efficient and improved road networks across the country. Until recently, the funding of road projects has been through the budgetary provisions and executed by traditional method of direct contract award. This method has proven to be inadequate and most often unimplemented thereby creating a funding gap for execution of road projects. On an average, the annual funding requirement is estimated at NGN500b against an average budgetary allocation of NGN120bn with a deficit of NGN380bn. In 2012, out of the NGN143bn budgetary allocation for road infrastructure development only NGN110bn was released with deficit of NGN33bn unimplemented [4]. The deficit is evident to have negative consequences on the development of road infrastructure thereby undermining national economic growth and causing loss of lives and properties across the country. Against this background, reports have further shown that Nigeria has the second highest road traffic accident fatalities among 193 countries in the world. It was observed that Nigeria records 152 deaths for every 100,000 people, making road accidents the third highest killer in the country. It was further revealed that eighty per cent of injuries in Nigeria are traffic accident related. In the first half of 2012, the Federal Road Safety Commission put statistics for accidents at 1,936 fatalities and substantial part of it is attributable to the poor state of our roads. In Nigeria, with the urgent need for investment in road infrastructure improvements, a need that greatly exceeds available financing, the Federal Government of Nigeria (FGN) has identified Road or Highway Bonds as an emerging option and a way forward for enhancing Highway Financing. The Bonds which will be issued in form of FGN bonds will assume similar characteristics as such. The road bonds will become debt securities (liabilities) of the Federal Government of Nigeria issued under the authority of Debt Management Office (DMO) and listed on the Nigerian Stock Exchange (NSE). The FGN is mandated to pay the bondholder the principal and agreed interest as they fall due.

The World Bank report on infrastructural development carried out by the African Infrastructure Country Diagnostic [5], provided an overview of the status of public expenditure, investment needs and sector performance as some infrastructure sectors that included, energy, information and communication techniques, irrigation, transport, water and sanitation covering twenty four nations including Nigeria. The report states that" any plan for scaling up infrastructure in Africa must rest on a thorough evaluation of how fiscal resources are allocated and financed because the public sector retains the lion's share of infrastructure financing with private participation remaining limited". Provision of physical infrastructure particularly road is vital to economic growth of nations itching to take

advantages of global connections. However, the issue of government expenditure is an important arm of public financing. Expenditures will be illusion without the source of revenue to the government. Revenue generation through taxing system constitutes the most important source of earnings by government. Adequate cooperation from all the sectors in the economy in terms of taxes will enhance government's desire to expand on every facet of the economy. Roads and other infrastructure therefore are very essential to rural and urban welfare of residents of any nation and a pivotal key critical for the acceleration of the economy. Road transportation is considered the most patronized among other modes of transportation especially in developing nations like Nigeria because of its large coverage and ability to provide door to door services. It was estimated that road transportation carries about 95% of the national passenger and freight services and provides the only access to rural communities where majority of the economically active population lives [6]. A part from savings in the cost of preservation of national, investment on roads, substantial reduction in vehicle operating cost and other road user's benefits, other economic benefits of road maintenance that enhances national development are as follows: (a) Employment creation (b) Agricultural production (c) Industrial development (d) Man power development (e) Research and development.

2. Methodology

2.1 Generalized nonlinear Model

The nonlinear regression model is a form of regression analysis in which observational data are modelled by a function which is a nonlinear combination of the model parameters and depends on one or more independent variables. The data are usually fitted by a method of successive approximations.

The generalized non linear models allow dependence on the parameters to take place in a certain "linear" fashion. The deviance in the generalized non linear model is a measure of goodness of fit, similar to techniques used in "classical" linear regression. Just as in the case of "classical" linear regression, considering the model with no structure imposed on the mean response; that is, with no assumption of a smooth function of covariates. Ref [7] provided an expression for the deviance under other distributions in the scaled exponential family class. They stated that the deviance has the nice property that it is additive for nested sets of models, so it is in fact used as the basis for a sort of extension of the usual analysis of variance for examining the importance of factors in regression models.

2.2. Source of Data

The source of data for this study was secondary data obtained from the records department of Consolidated Construction Company Uli Asphalt Plant Anambra State, Nigeria. The data comprises material cost, labour cost, overhead cost, and transport cost for the production of binder and wearing for a period 2004-2013. Also, economic data were extracted from the Central Bank of Nigeria Statistical Bulletin 2013.

2.3 Computing Package

The "gnm" is an R-programming function for fitting the generalized nonlinear models using an over-parameterized representation.The function can be executed as

gnm(formula, eliminate = NULL, family = gaussian, data = NULL, method = "gnmFit", verbose = TRUE, model = TRUE, x = TRUE,...)

where, formula represents a symbolic description of the nonlinear predictor, eliminate represents a

factor to be included as the first term in the model. gnm will exploit the structure of this factor to improve computational efficiency, family represents a specification of the error distribution and link function to be used in the model. This can be a character string naming a family function; a family function, or the result of a call to a family function, data represents an optional data frame containing the variables in the model. If not found in data, the variables are taken from environment(formula), typically the environment from which gnm is called, method represents the method to be used: either "gnmFit" to fit the model using the default maximum likelihood algorithm, model represents the model frame if the model exists and x represents the designed matrix from the last iteration in the model which includes a component of model object.

The expected result of the "gnm" function include: (a) fitted values which are the fitted mean values obtained by transforming the predictors by the inverse of the link function, (b) the deviance which is the constant minus twice the maximized log-likelihood. Where the constant is chosen so that a saturated model has deviance equal to zero and (c) Akaike's *Information Criterion* represents minus twice the maximized log-likelihood plus twice the number of parameters for the assuming dispersion to be known. The AIC estimates the quality of each model, relative to each of the other model models. This is because it offers a relative estimate of the information lost when given a model and used to represent the process that generates the data. While comparing the fitted objects, the decision rule for the AIC is the smaller the AIC measure, the better the fit of the model.

3. RESULTS AND DISCUSSION

3.1. Results

The result of the generalized nonlinear models was summarized in tables 3 and 4 while summary of the estimated maintenance cost of roads from the designed model was presented in table 5. Also, table 6 shows the likelihood measure of estimated maintenance cost values between the two models designed.

Table 1:Summary of mcr and economic variables from 2004-2013

year	Mcr	IASPCA	SCRGDP	MCQCC	MCQCM
2004	57845868	20900	1.45	9.05E+06	40024
2005	61211163	30500	1.59	1.02E+07	39900
2006	83060565	35448	1.62	1.66E+06	38496
2007	152240042	52911	1.72	3.82E+10	38496
2008	201949343	65919	1.84	1.07E+11	1250520
2009	130670316	123731	1.92	5.03E+10	1290520
2010	182753103	219638	2	8.22E+10	1290520
2011	97130327	304898	2.08	9.02E+10	1300024
2012	141778800	462811	2.19	9.89E+10	1300024
2013	191931676	469728	2.15	1.03E+11	1300024

CGFCFPME	GDPCBPBC	LR	MRR	MeF
10890	7664	534.1	121.3	94.5
16943	8544	554.4	13.3	94.5
34577	9655	554.4	159.2	91.8
37146	10913	745.5	168.9	89.9
35422	12339	745.5	171.4	88.9
33471	13816	745.5	189.45	89.9
32568	146285	745.5	162.9	89.9
35942	14890	745.5	151.71	88.9
37119	15014	745.5	163.5	89.7
43289	16147	745.5	166.8	90.4

Table 2: Summary of Coefficients and parameter estimates for economic variables

Parameter	Estimate	Std. Error	z-valu	Pr(>|z|)
(Intercept)	-841700000	Inf	0	1
IASPCA	-889	Inf	0	1
SCRGDP	755000000	Inf	0	1
MCQCC	0	Inf	0	1
MCQCM	-125	Inf	0	1
CGFCFPME	3021	Inf	0	1
GDPCBPBC	114	Inf	0	1
LR	125200	Inf	0	1
MRR	1063000	Inf	0	1
MeF	75920000	Inf	0	1

(Dispersion parameter for gaussian family taken to be Inf)
Residual deviance: 3.7762e-11 on 0 degrees of freedom
AIC: -212.64
Number of iterations: 1

Table 3: Summary of Economic variables and quantity of Binder and Wearing

year	mcr	Qbp	Qwp	IASPCA	SCRGDP	MCQCC
2004	57845868	2514.7	272	20900	1.45	9.05E+06
2005	61211163	1227.9	1754	30500	1.59	1.02E+07
2006	83060565	1479.6	2571	35448	1.62	1.66E+06
2007	1.52E+08	2348.5	5521	52911	1.72	3.82E+10
2008	2.02E+08	3325.7	6529	65919	1.84	1.07E+11
2009	1.31E+08	2344	4028	123731	1.92	5.03E+10
2010	1.83E+08	4901.3	3973	219638	2	8.22E+10
2011	97130327	2992.6	1715	304898	2.08	9.02E+10
2012	1.42E+08	3394.6	3670	462811	2.19	9.89E+10
2013	1.92E+08	2777.7	6597	469728	2.15	1.03E+11

MCQCM	CGFCFPME	GDPCBPBC	LR	MRR	MeF
40024	10890	7664	534	121.3	94.5
39900	16943	8544	554	13.3	94.5
38496	34577	9655	554	159.2	91.8
38496	37146	10913	746	168.9	89.9
1250520	35422	12339	746	171.4	88.9
1290520	33471	13816	746	189.5	89.9
1290520	32568	146285	746	162.9	89.9
1300024	35942	14890	746	151.7	88.9
1300024	37119	15014	746	163.5	89.7
1300024	43289	16147	746	166.8	90.4

Table 4: Summary of Coefficients and parameter estimates for Economic variables and quantity of Binder and Wearing

Parameters	Estimate	Std. Error	z-value	Pr(>|z|)
(Intercept)	71390000	Inf	0	1
Qbp	16470	Inf	0	1
Qwp	19590	Inf	0	1
IASPCA	19	Inf	0	1
SCRGDP	-3804000	Inf	0	1

MCQCC	0	Inf	0	1
MCQCM	11	Inf	0	1
CGFCFPME	152	Inf	0	1
GDPCBPBC	74	Inf	0	1
LR	-15360	Inf	0	1
MRR	0	NA	NA	NA
MeF	0	NA	NA	NA

(Dispersion parameter for gaussian family taken to be Inf)

Std. Error is NA where coefficient has been constrained or is unidentified

Residual deviance: 1.3323e-14 on 0 degrees of freedom

AIC: -292.14

Number of iterations: 1

Table 5: Summary of observed maintenance cost of roads and estimated cost for the generalized nonlinear models

year	mcr	Estimated.economic	Estimated.Qbp.Qwp
2004	57845868	57845864	57845668
2005	61211163	61210151	61211063
2006	83060565	83060465	83060465
2007	152240042	152230042	152240032
2008	201949343	201949243	201949243
2009	130670316	130670216	130670216
2010	182753103	182753103	182753003
2011	97130327	97130327	97130317
2012	141778800	141778800	141778700
2013	191931676	191931626	191931636

The result of estimation from the two models was expressed in figure 1.

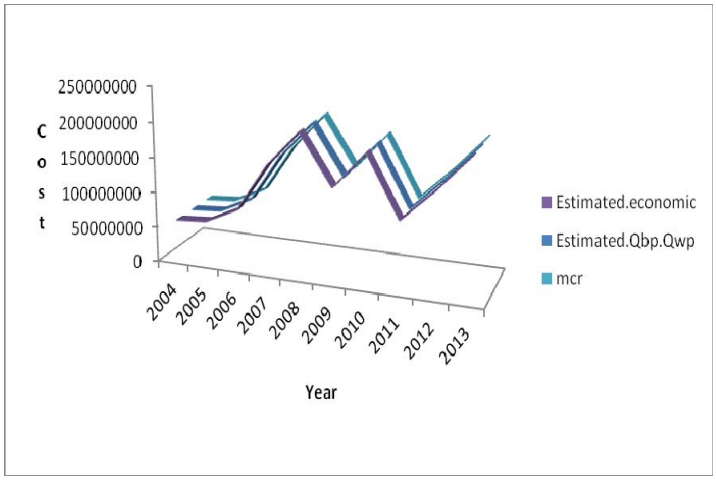

Figure 1: 3D plot of observed maintenance cost of roads (mcr) and estimated values from the Generalized non-linear models

Table 6: Summary result of estimates from the models and the observed mcr

Models	Correction coefficient measure	P-value
Model (1)	1.00	0.00^{**}
Model (2)	1.00	0.00^{**}

1. The solution of the generalized non-linear model for estimation of maintenance cost of roads using economic variable employing the data of table1 generated the result in table 2 and the corresponding model was expressed as Equation (1)

$$mcr = -8417 \times 10^{6} - 889 \times IASPCA + 755 \times 10^{6} \times SCRGDP - 125 \times MCQCM + 3021 \times CGFCFPME + 114 \times GDPCBPBC + 1252 \times 10^{2} \times LR + 163 \times 10^{3} \times MRR + 7592 \times 10^{4} \times Mef \quad (1)$$

2. The summarized result presented in table 2 also found a Pearson Chi-squared value of 3.776235e-11 and an Akakike Information Criterion value of -212.64 for the designed generalized nonlinear model.

3. In addition, the solution to the generalized non-linear model for estimation of maintenance cost of roads using economic variable and quantity parameters using data in table 3 was summarized in table 4 and expressed as equation (2).

$$mcr = 71390000 + 16470 \times Qbp + 19590 \times IASPCA - 38040000 \times SCRGDP + 11 \times MSQCM + 152 \times CCHCFRME + 741 \times GDPCBPRC - 153600 \times LR \quad (2)$$

The result of table 4 presents the coefficients and parameter estimates of the generalize nonlinear model for estimation of maintenance cost of roads using economic variable and quantity parameters. The result of generalized nonlinear model found a Pearson Chi-squared value of 1.332268e-14 and an Akakike Information Criterion (AIC) value of -292.44.

From the result of the AIC measure of the two models, it was found that model two which comprise of the economic and quantity parameters best describe the process of maintenance cost of roads in Anambra State since it has a lower AIC measure of -292.44

Table 5 presented a summary of observed maintenance cost of roads and predicted corresponding cost using the two generalized nonlinear models obtained.

The result of correlation analysis obtained in table 6 which was employed for testing the resemblance of the estimated cost values for the two models to the observed maintenance cost of roads in Anambra State revealed a positive perfect correlation for the estimates from the generalized nonlinear models since the correlation coefficient is +1.00.

4. Conclusions

1. The researcher was able to design an efficient generalized non-linear model for estimation of maintenance cost of roads using economic variable since the model generates efficient estimates of maintenance cost of roads in Anambra State.

2. Similarly, the researcher designed an efficient generalized non-linear model for estimation of maintenance cost of roads using economic variable and quantity parameters of asphalt. Also, it was found that the obtained model generates a more efficient estimates of maintenance cost of roads in Anambra State than the model with only economic variables. This result implies that the inclusion of quantity parameters of asphalt to the model produces more efficient estimates of maintenance cost of roads.

3. Based on the findings of this study, we recommend that government of Anambra State and contractors should use model (2) which comprises of economic variables and quantity parameters in estimating maintenance cost of roads in Anambra State especially for budgeting purposes since it preformed best in estimating maintenance cost f roads in Anambra State.

4. The researchers believe that since this model can estimate maintenance cost of roads in Anambra State efficiently, we recommend designing a generalized nonlinear model for estimating maintenance cost of roads in other states around Anambra such as Enugu state , Imo state and Delta state as an area for fruitful research.

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