Journal of Engineering Research and Reports

18(1): 31-38, 2020; Article no.JERR.61768
ISSN: 2582-2926

Alternative Method for Estimating the Maintenance Cost of Roads in Anambra State, Nigeria

Godspower Onyekachukwu Ekwueme[1], John Obatarhe Emunefe[2], Nkechi Udochukwu Otty[3] and Charles Okechukwu Aronu[4*]

[1]Department of Industrial Production Engineering, Nnamdi Azikiwe University, Awka, Nigeria.
[2]Department of General Studies, Mathematics and Statistics Unit, Petroleum Training Institute, Effurun, Delta State, Nigeria.
[3]Department of Environmental Health Sciences, School of Health Technology, Federal University of Technology Owerri, Imo State, Nigeria.
[4]Department of Statistics, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria.

Authors' contributions

'This work was carried out in collaboration among all authors. Author GOE managed the literature searches. Author JOE wrote the introduction. Authors NUO and COA designed the study and performed the statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2020/v18i117200
Editor(s):
(1) Dr. P. Elangovan, SRM TRP Engineering College, India.
Reviewers:
(1) Ehsan Movahednia, Behbahan Khatam Alanbia University of Technology, Iran.
(2) Satish Kumar, Degree College Dharampur, Solan, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/61768

Original Research Article

Received 05 August 2020
Accepted 10 October 2020
Published 03 November 2020

ABSTRACT

Aims: This study proposed an alternative method for the estimation of maintenance cost of roads in Anambra State, Nigeria. The proposed method referred to as the permuted quadratic model (PQM) involves permuting of the dependent variable of the quadratic model.

Place and Duration of Study: The data used in this study was secondary data sourced from the records department of consolidated construction company asphalt plant Anambra state, Nigeria from 2004 to 2019.

Methodology: The linear regression model and the permuted quadratic model were used to analyze the data for the study.

Results: The result found that 74.0% correlation exists between the observed maintenance cost of roads and the predicted maintenance cost of roads using the linear model while the predicted maintenance cost of roads using the permuted quadratic model has 75.8% correlation with the

**Corresponding author: Email: padre4baya@gmail.com;*

observed maintenance cost of roads. This result indicates that the proposed permuted quadratic model performed better than the linear model for the estimation of the maintenance cost of roads in Anambra State.

Conclusion: The study recommends the proposed model for the estimation of maintenance cost of roads in Anambra State until future studies prove otherwise.

Keywords: Linear model; maintenance cost; permutation; quadratic model; roads.

1. INTRODUCTION

The provision of good roads between the urban and the rural communities has the potential to reduce the poverty rate thereby harnessing important social benefits and development. Road networks form important links between production centres and markets. Also, because of the multiple functions of providing access to labour, social, health and educational services, the road network is vital in the fight against poverty by opening up more areas and promoting economic and social development.

The problem of poor road maintenance is widespread around the world, particularly in developing countries like Nigeria. New roads cost money to build, but without properly maintaining the roads, they deteriorate very quickly. If nothing is done, roads with a lifespan of decades may need replacing or major repairs in as little as a few years. However, a backlog of outstanding maintenance has led to an irreversible deterioration in the road network.

In Nigeria, investment on building new roads is believed to be of political benefit. This does not provide the same opportunity to policymakers to showcase maintenance as an achievable project. Road condition in most parts of Nigeria does not only require urgent attention rather they are in critical conditions. Decision-makers need to understand the cost of road maintenance and the cost of road non-maintenance. The money saved in the maintenance budget when the roads are not maintained is ultimately paid for by users and society. This can be called an invisible tax, and the total cost to the economy is enormous. However, the need to advocate the importance of road maintenance must not be overemphasized. Also, reliable data on road maintenance is required to help policymakers plan and make effective decisions. It has been observed that all the methods used in the literature to estimate the cost of road maintenance are largely parametric and most authors failed to indicate that the data used for the analysis meet the required assumption of normality, independence and constant variance. An alternative to the parametric approach, which does not rely on strict assumptions, is the permutation method. The present study, therefore, tries to propose an alternative method for estimating the maintenance costs of roads in the state of Anambra.

2. LITERATURE REVIEW

The study by [1] employed the multiple regression approach for the estimation of maintenance cost of roads in Nigeria. The study considered the impact of factors such as the length of the road in kilometres, type of road defects, the width of the road, terrain and year of awarding the maintenance contract on maintenance cost of roads. The result of the study found a coefficient of determination value of 70.0%, which indicates that the model is adequate for the estimation of the maintenance cost of roads within the observed period.

The study by [2] employed the Markov-based model for the minimization of both the maintenance cost of roads and user cost subject to several constraints including the average annual budget limit and the performance requirement. They modelled the road deterioration process as a discrete-time Markov process in which the states of the road performance were defined in relation to the road roughness and the state transition probabilities were estimated taking into account the effects of deterioration and maintenance measures. The findings of the study showed that the optimal road maintenance plan obtained from the model was practical to implement and is cost-effective when compared to the periodical road maintenance plan. The authors concluded that with more frequent maintenance, the maintenance costs for the life cycle increase and the user costs for the life cycle decrease.

The study by [3] examined the maintenance cost of roads in Anambra State using the times series approach. The study used the simple linear model for determining the trend of the road maintenance cost for the period 2004-2013. The study found that the maintenance cost of roads has an increasing trend over time. Forecast from the study revealed that the maintenance cost of roads in Anambra State was estimated to be about N237, 226,028 in the year 2018.

The study by [4] examined freight transportation prices to account for external costs, including maintenance costs on roads and bridges, delays due to traffic congestion, injuries, fatalities, and property damage from accidents and harmful effects of Exhaust missions in the United States. The results suggest that measures such as an increase in the existing tax on diesel fuel, the introduction of a tax on the transport of shipping containers, or an increase in the existing tax on truck tires are expected to results to a shift of 3.6 per cent-tonne-miles from trucking.

The study by [5] proposed a mathematical model for estimating the emergency costs of a road maintenance contract. The model was used to predict the emergency costs for each of the road maintenance activities included in the contract using an artificial neural network model based on the historical change orders (CO) data. The authors argued that designing an efficient model will help in providing reliable estimates of the contingency cost of the project and this will, in turn, be useful in the efficient management during the construction or maintenance phase of the project.

According to [6], roads remain the dominant mode of passenger and freight transport in Africa and the need for a better road network is growing rapidly. As argued by most of the literature reviewed in the present study, African countries are not doing enough to ensure the sustainability of road infrastructure, as it has been widely reported that roads are affected by premature deterioration to varying degrees. Most African countries have adopted institutional reforms, such as the creation of road funds and road agencies, and have made significant progress in road maintenance. However, in all of them, many challenges remain to be addressed to ensure adequate maintenance. Poorly maintained roads limit mobility, significantly increase vehicle operating costs, increase accident rates and the associated costs for people and property, and exacerbate isolation, poverty, poor health and illiteracy in rural communities.

The study by [7] compared the variation between the road agency costs and the road user's costs from maintenance and rehabilitation treatment on the selected road network in Iran. The study dwelled more on the usefulness of road user's costs in long-term economic analysis and planning of future maintenance and rehabilitation activities. The findings of the study revealed that the road user's cost was higher than road agency costs on each route of the selected roads network. Also, traffic composition was identified as one of the major factors that contributed significantly to the road user's cost.

According to [8], both the construction and the use of roads have several environmental impacts which call for the evaluation of the sources of their exposure to take correct mitigation measures. Life cycle analysis (LCA) is a useful way of providing verifiable, accurate and non-misleading information for decision-makers. The study focused on the effects of the construction, and maintenance phases, the lighting, and the use of the vehicles on the built road. The results of using the SimaPro model showed that almost half of the impacts occurred during the construction phase rather than the use phase. The authors, therefore, concluded that the introduction of greener road design practices, the use of low impact methods in the manufacture of materials, and the use of secondary raw materials could have the greatest potential for reducing environmental impact.

Speaking on the importance of maintenance, [9] stated that maintenance management has become increasingly important in the development of highways and government investments, but lack of funding is still a problem. The authors noted that if the administrative department checks the cost, the existing valuation method cannot be applied to the current national state and the calculation process is too complicated. To improve this situation, their study examined the various factors that affect maintenance costs and determines the quantitative relationship between the six most important influencing factors such as traffic volume, time, location, number of lanes, overlaps and major refurbishments. Also, the authors proposed a regression analysis model for estimating maintenance costs that can be automatically updated according to market conditions. Their study used data from 18 typical highways in Guangdong Province, China. The result of their study found that their model can be used as a guide for cost planning and capital allocation in sustainable maintenance and that it has achieved good results in its application, so it is worth promoting in other areas.

The study by [10] considered a comparative review of cost models and cost factors published in several studies on freight transport. The authors tried to determine and categorize cost factors from various perspectives in the reviewed studies, including cost factors (operating costs, time value and external costs), study area (Europe, USA, North America and Asia) and cost models (process costing (ABC), statistical models, Surveys, data mining, geographic information system (GIS), meta-analysis and mathematical models). The road freight transport cost model and the methods for estimating road freight transport costs and data collection were proposed by the authors. They argued that the proposed models are used to identify gaps between cost types or inconsistencies in cost factors and consist of an overall structure and multiple substructures.

3. METHODS AND MATERIALS

3.1 Method of Data Collection

The data used in this study is secondary data sourced from the records department of Consolidated Construction Company Asphalt Plant Anambra State, Nigeria.

3.2 Method of Data Analysis

Suppose we consider the model

$$Y = X\beta + \varepsilon \tag{1}$$

Where,

Y is a n x1 random vector called the response or dependent variable,
X is an n x (k+1) matrix of scalars
ε is a n x 1 random vector called the random error with mean 0 and variance $\sigma^2 I$

To estimate the regression parameters β properly using the method of least-squares estimation, the assumption that n > k must hold. Here *n* is the number of observations while k is the number of regression coefficients. The unbiased estimate of the regression coefficients is defined as

$$b = (X'X)^{-1} X' Y \tag{2}$$

The present study considers a situation where the response variable Y is permuted large number of times to generate a distribution of permuted regression coefficients. In this case, equation (2) can be redefined as

$$b^* = (X'X)^{-1} X' Y^* \tag{3}$$

In equation (3) Y is replaced by the permuted response variable Y^* and this is expected to produce a permuted regression estimate b^*.

$$b^* = mean \begin{bmatrix} b^*_{01} + b^*_{02} + \cdots + b^*_{0p} \\ b^*_{11} + b^*_{12} + \cdots + b^*_{1p} \\ \vdots \\ b^*_{k1} + b^*_{k2} + \cdots + b^*_{kp} \end{bmatrix} \tag{4}$$

Where p is the number of permutations

A permutation test calculates the probability of obtaining a value that is equal to an observed value of a test statistic under a particular null hypothesis. This can be achieved by recalculating the test statistic after randomly shuffling the data. Permutation test has gained the attention of the natural and behavioural sciences since the advent of a generally accessible high-speed computer. Permutation methods have proven to be very useful because of their flexibility, freedom of distribution, and intuitive formulation, which makes it easy to convey the general principles of such test procedures to users [11].

3.3 Model Specification

The permuted quadratic model where the dependent variable is being permuted was proposed in this study. The model is specified from equation (1) as given

$$y^* = \beta_0 + \beta_1 t + \beta_2 t^2 + \varepsilon \tag{5}$$

Where, y* is the permuted dependent variable, *t* is the time which is annually and represents the dependent variable, β_0, …, β_2 are model coefficients to be estimated, and ε is the random error.

The general procedure for running the permuted quadratic model analysis is as follows:

1. Permute the dependent variable y at random to obtain y^*
2. Compute the estimate of the permuted regression model using equation (5) and the permuted dependent variable obtained in step (1) above
3. Repeat step 1 and 2, 1000 times to obtain the distribution of the permuted regression coefficients.
4. Compute the mean of the permuted coefficients using equation (4)

3.4 Data Presentation

Table 1. The distribution of annual maintenance cost of roads (MCR) in Anambra state in billions of Naira

Year	MCR	t code
2004	57.846	1
2005	61.211	2
2006	83.061	3
2007	152.24	4
2008	201.949	5
2009	130.67	6
2010	182.753	7
2011	97.13	8
2012	141.779	9
2013	191.932	10
2014	179.088	11
2015	170.255	12
2016	155.544	13
2017	170.645	14
2018	200.14	15
2019	231.11	16

Source: Consolidated Construction Company (CCC) Asphalt Plant Anambra State, Nigeria

4. DATA ANALYSIS AND RESULTS

In this section, the result of the permuted quadratic model and the linear model will be presented. The linear model was used to examine the performance of the proposed permuted quadratic model.

4.1 Test of Normality of MCR

The test of normality of the variable was conducted using the Anderson-Darling test for normality. The null hypothesis that the variable is normally distributed was evaluated at 5% significance level. The null hypothesis was accepted in each if and only if the *p*-value of the test statistic is greater than the significant level, otherwise reject the null hypotheses. The need for the test for normality is to enable the appropriate fitting of the simple linear model which will be used to validate the result obtained from the proposed model.

The result obtained in Table 2 indicates that variable MCR is normally distributed since a *p*-value of 0.265 which was found to be greater than the α-value of 0.05 was obtained. Hence, the variable is approximately normally distributed and meets the assumption of normality required to perform the regression analysis.

4.2 Result of the Linear Model (LM) and the Permuted Quadratic Model for Estimating MCR

The result of the linear regression model was expressed as

$$y = 81.83 + 8.07 * t \qquad (6)$$

While the permuted quadratic model was expressed as

$$y = 64.23 + 17.21*t - 0.55*t^2 \qquad (7)$$

The result presented in Table 3 shows the actual MCR, predicted MCR using the LM and PQM. This result was further expressed in Fig. 1 and this result indicates that there is little variation between the actual MCR and the predicted MCR using the LM and the PQM. In other to validate the aforementioned claim, a correlation analysis was performed between the actual and the predicted MCR of the models. The result presented in Table 4 showed that 74.0% degree of linear relationship exists between the actual MCR and the predicted MCR using the LM while 75.8% correlation was found between the actual MCR and the predicted MCR using the PQM. Also, Table 5 in the Appendix shows the 1000 permuted coefficients used to obtain equation (7).

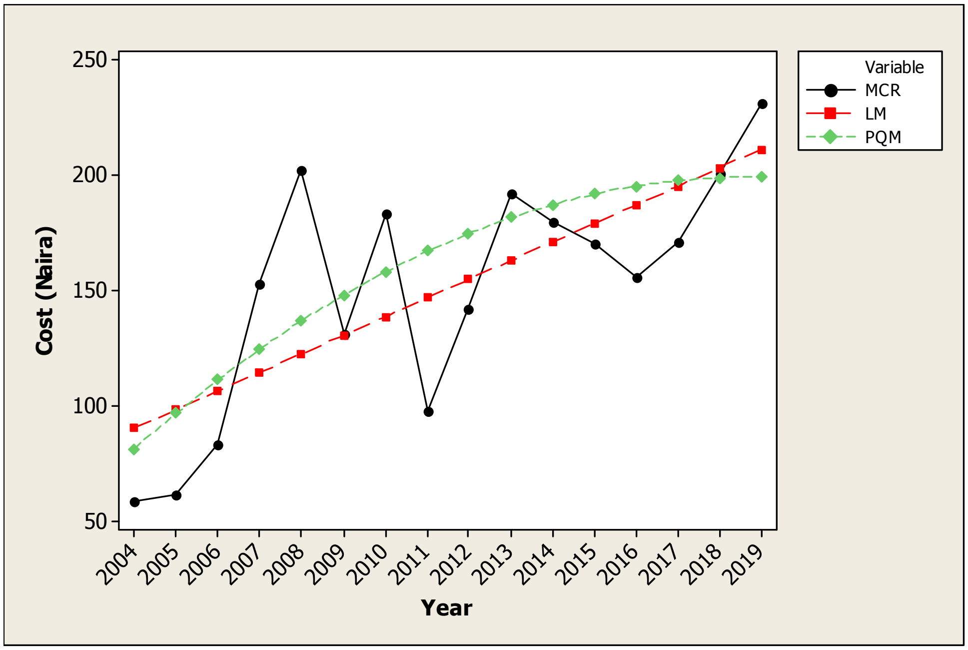

Fig. 1. Graph showing the actual MCR and the predicted MCR using the LM and the PQM

Table 2. Summary of test for normality for MCR

Variable	Anderson-Darling Test Statistic value	P-value	Remark
MCR	0.433	0.265	Normally Distributed

Table 3. MCR and the predicted MCR using the LM and the PQM

Year	MCR	LM	PQM
2004	57.846	89.9	80.89
2005	61.211	97.97	96.45
2006	83.061	106.04	110.91
2007	152.24	114.11	124.27
2008	201.949	122.18	136.53
2009	130.67	130.25	147.69
2010	182.753	138.32	157.75
2011	97.13	146.39	166.71
2012	141.779	154.46	174.57
2013	191.932	162.53	181.33
2014	179.088	170.6	186.99
2015	170.255	178.67	191.55
2016	155.544	186.74	195.01
2017	170.645	194.81	197.37
2018	200.14	202.88	198.63
2019	231.11	210.95	198.79

Table 4. Result of correlation analysis between the observed MCR, the predicted MCR for the linear model and the permuted quadratic model

Model	MCR	P-value
Linear Model	74.0%	0.001*
Permuted Quadratic model	75.8%	0.001*

Note: Asterisks (*) denote statistical significance at a 5% level

5. CONCLUSION

This study proposed an alternative method for the estimation of maintenance cost of roads in Anambra State, Nigeria. The proposed method referred to as the permuted quadratic model (PQM) involves permuting of the dependent variable of the quadratic model. The linear model was fitted to assess the performance of the proposed model. The performance of the proposed for the estimation of the maintenance cost of roads was better than the linear model since the predicted maintenance cost of roads using proposed model recorded a higher correlation coefficient than the linear model. Hence, the present study recommends the proposed model for the estimation of maintenance cost of roads in Anambra State until future studies prove otherwise.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Oladele AS, Adedimila AS, Egwurube JA. Highway Maintenance Cost Estimation Modeling for Developing Countries: A Case Study of Nigeria. Botswana Journal of Technology. 2011;1-8.
2. Gao H, Zhang X. A Markov-Based Road Maintenance Optimization Model Considering User Costs. Computer-Aided Civil and Infrastructure Engineering. 2013. DOI: 10.1111/mice.12009.
3. Ihueze CC, Ekwueme OG. Modelling and forecasting the Maintenance Cost of Roads in Anambra State. International Journal of Scientific & Engineering Research. 2015;6(9):353-357.
4. Austin D. Pricing freight transport to account for external costs. Working Paper Series. Washing- ton (DC): Congressional Budget Office; 2015. DOI: 10.13140/RG.2.1.1122.7040
5. Shresthaa , Shrestha PP. A Contingency Cost Estimation System for Road Maintenance Contracts. Procedia Engineering. 2016;145:128–135. DOI: 10.1016/j.proeng.2016.04.030
6. Mostafa HM. Road Maintenance in Africa: Approaches and Perspectives. E3S Web of Conferences. 2018;38:01005. Available:https://doi.org/10.1051/e3sconf/20183801005.
7. Semnarshad M, Saffarzadeh, M. Evaluation of the Effects of Maintenance and Rehabilitation Projects on Road User Costs via HDM-4 Software. International Journal of Transportation Engineering. 2018;6(2):157-176.
8. Trunzo G, Moretti L, D'Andrea A. Life Cycle Analysis of Road Construction and Use. Sustainability. 2019;11:377. DOI: 10.3390/su11020377
9. Yang Y, Huang L, Wang J, Xia Y. Research on Reference Indicators for Sustainable Pavement Maintenance Cost Control through Data Mining. Sustainability. 2019;11:877. DOI: 10.3390/su11030877
10. Amir Izadi, Mohammad Nabipour, Omid Titidezh Cost Models and Cost Factors of Road Freight Transportation: A Literature Review and Model Structure. Fuzzy Information and Engineering; 2020. DOI: 10.1080/16168658.2019.1688956
11. Aronu CO, Nworuh GE. Permutation Methods for Chow Test Analysis an Alternative for Detecting Structural Break in Linear Models. *Advances in Science,* Technology and Engineering Systems Journal. 2019;4(4):12-20. Available:https://dx.doi.org/10.25046/aj040402

APPENDIX

Table 5. Summary result of permuted quadratic (PQM) regression coefficient for the estimation of MCR

p	b0	b1	b2
1	59.0166	15.6779	-0.4473
2	159.325	0.7802	-0.16574
3	141.066	3.3852	-0.20727

p	b0	b1	b2
4	160.622	-10.0179	0.80203
5	175.226	-0.8012	-0.19203
6	129.001	2.7146	-0.01727
7	185.474	-3.8641	-0.0231
8	99.654	13.0205	-0.6403
9	210.881	-19.317	1.10988
10	167.348	4.49	-0.5888
11	88.07	19.7322	-1.1265
12	175.999	-7.0318	0.36611
13	187.769	-8.0464	0.33247
14	158.312	-3.8619	0.2671
15	171.809	-4.873	0.21466
16	152.201	-4.0933	0.3535
17	161.316	-4.4846	0.29159
18	172.117	-7.2657	0.42889
19	191.927	-14.6316	0.88665
996	190.929	-8.8767	0.37415
997	107.471	15.6943	-0.96698
998	146.263	-2.0561	0.23181
999	91.676	14.5434	-0.69342
1000	-9097.4	1915.79	-64.93
Mean	64.23001	17.20993	-0.5460

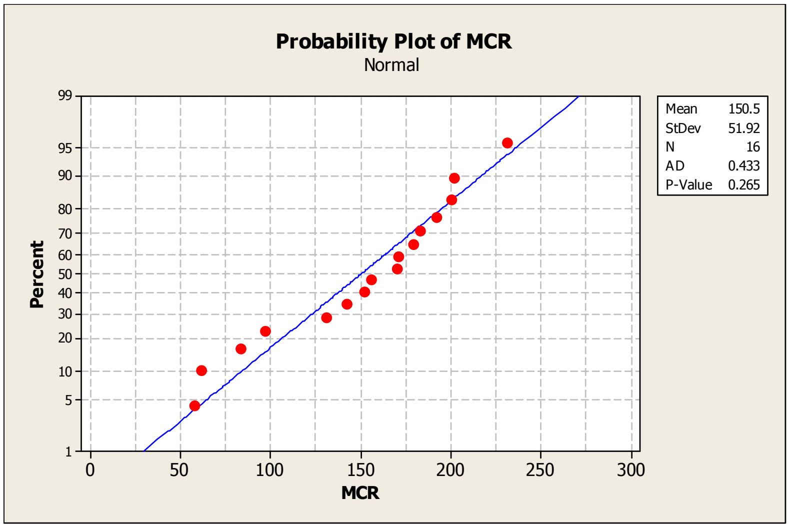

Fig. 2. Probability plot of the MCR

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/61768