The International Journal of Engineering and Science (IJES)
|| Volume || 9 || Issue || 01 || Series I || Pages || PP 23-29|| 2020 ||
ISSN (e): 2319-1813 ISSN (p): 23-19-1805

Optimal Maintenance of Water Borehole Schemes

*A.O. Ibeje[1], B.C.Okoro[2], J.C. Agunwamba[3]and M. C. Nwachukwu[4]
[1]Department of Civil Engineering, Imo State University, P.M.B. 2000, Owerri, Nigeria.
[2]Department of Civil Engineering, Federal University of Technology, Owerri, Nigeria.
[3]Department of Civil Engineering, University of Nigeria Nsukka.
[4]Department of Hydrology, Anambra-Imo River Basin Authority, Agbala, Nigeria
*Corresponding Author: *A.O. Ibeje*

---*ABSTRACT*---
The least-cost maintenance model was derived and applied to water boreholes in south-eastern states of Nigeria in order to determine optimal frequency of maintenance. Comparative analysis of the cost of the existing maintenance strategy and optimum maintenance policy was made. Optimization results showed that in Enugu, Anambra, Imo and Abia states, optimal preventive maintenance frequencies of 4, 4, 5 and 6times per year; 9, 10, 10 and 12 per year; and 12, 19, 16 and 17 per year respectively for water boreholes pumping once, twice and thrice in each of the states. Savings in cost of $ 42757.02;$209965.51; $33020.72; $59776.74 for water boreholes pumping once;$44056.46; $145760.21; $ 154929.56; $95402.73 for pumping twice and $816.2611; $95713.3; $548596; $399735.14 for pumping thrice respectively were achieved for each state when the model was compared with the current maintenance policy. This model would be useful to borehole operators in the evaluation of water borehole projects especially in south-eastern states of Nigeria.

KEYWORDS;-*least-cost maintenance, water borehole, pumping, model.*

Date of Submission: 30-12-2019 Date of Acceptance: 12-01-2020

I. INTRODUCTION

The concept of preventive maintenance is to reduce failure probabilities by maintenance before failure or significant degradation has occurred. This often translates into trying to avoid costs of corrective maintenance and other costs that belong to unexpected failures (Nwachukwu, 2015). Corrective maintenance is performed after fault recognition and is intended to put the component or system back in a state in which it can perform a required function. The component is used until it fails and must be replaced and the system put back into a functional state. Preventive maintenance can be a periodical maintenance. Preventive maintenance is not even part of management policy and budget. For instance, Akabo (1991) reported that six boreholes schemes in Arochukwu of Abia State were all abandoned due to faulty submersible pumps. Regular inspection of facilities could have remedied the problems and hence corrected the fault before their breakdown. All boreholes and water schemes need to be operated and carefully maintained. Success or failure of a scheme depends primarily on whether it can be maintained. Preventive maintenance is the bedrock for sustainability of water boreholes schemes and project that requires the use of machines and equipment.

Maintenance optimization is the discipline within operations research concerned with maintaining a system in a manner that maximizes profit or minimizes cost. Maintenance optimization strategies (Barlow et al. 1963; Both 1989; Brandr and Umuaye 1970) are often constructed by using the stochastic models by concentrating on finding the optimal time or the optimal acceptable degree of system degradation before maintenance and/or replacement is implemented. Normally it is done under these categories, cost based optimization, and risk based optimization, or combined optimization policy. Nwachukwu (2015) reported that all maintenance activities are carried out for merely one reason, which is to reduce or minimize the overall cost of operations, and industrial plant availability and economics strongly depends on the maintenance activities planned. The cost-based approach to maintenance planning was originally developed by Jardine (1973). He assumed that the overhaul will return the equipment to the as-good-as-new condition and that the failure repair between preventive maintenance actions makes it possible to run the machine up to the next interval (i.e., it results in a bad-as-old condition). He also estimated that the optimal interval between preventive replacements of equipment subject to breakdowns, and may be applied to preventive maintenance. Many attempts have been made to optimize the maintenance tasks based on the cost factor. Kenne et al. (2007) claims to have developed a model for the joint determination of an optimal age-dependent buffer inventory and preventive maintenance policy in a production environment that is subject to random machine breakdowns. Bris (2000) demonstrated an efficient simulation algorithm for the quantification of reliability performance indicators of a complex system that is based on Monte Carlo method by introducing a cost- optimization problem which may be fully solved by the algorithm using additional genetic algorithms as an applicable optimization technique, while Barata (2002) used Monte Carlo simulation to model continuously monitored deteriorating systems and embedded the resulting model within an 'on condition' maintenance optimization scheme that aims at minimizing the expected total system cost over a given mission time. In the area of water boreholes, application of coordinated corrective maintenance model to submersible pumps, generator set, and pipes resulted in savings of $299.27 per scheme for all the present long downtime and high frequency of breakdown associated with boreholes (Agunwamba 2000b). This study is focused on cost optimization of maintenance of borehole in south-eastern states of Nigeria. Also the optimal maintenance policy and existing maintenance policy were compared in the study. The study considered only motorized water boreholes that pump once, twice and thrice per day in south-eastern states of Nigeria.

II. MATERIALS AND METHOD

The following data were used in the study: service logs from operating water borehole projects, which cover submersible pumps; spare parts price lists from manufacturers and receipts from actual projects and interviews with operators and technicians about maintenance strategies, time to repair components, and time required for servicing.

Study Area

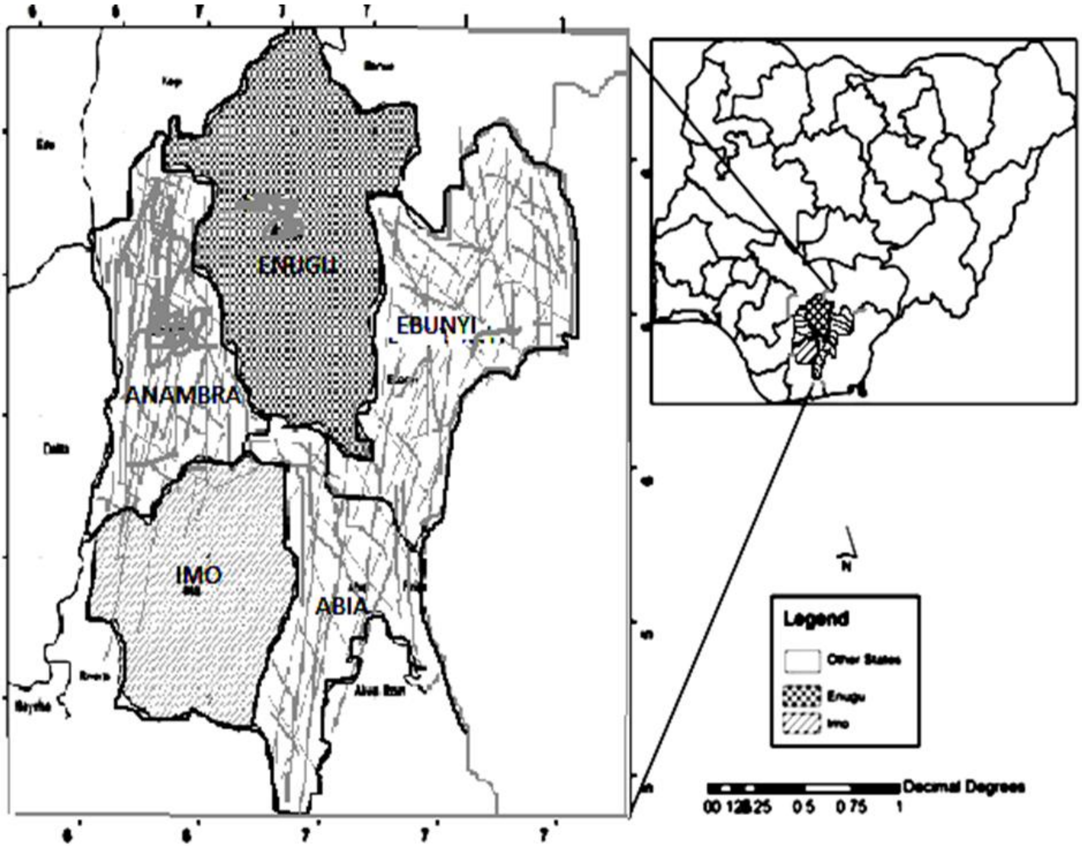

Fig1 Major Towns of South-eastern Nigeria (Source: Ofomata 2001)

South-eastern Nigeria is an area covering about 76,358km^2 east of the lower Niger and south of the Benue valley. The region is located between latitudes 4^0N and 7^0N and between longitudes 7^0E and 9^0E. In terms of relief, the land surface of eastern Nigeria can be classified into three broad units. These are the plains and lowlands (including the river valleys) and the highlands (Ofomata 1975a). Climate-wise, eastern Nigeria is characterized by seasonal distribution of rainfall which depends on the interaction of the Tropical Continental air mass, the Tropical Maritime air mass and the Equatorial Easterlies. The rainfall pattern which is controlled by the movement of the Inter-Tropical Convergence Zone (ITCZ) is characterized by a long wet season from April to July, with a short dry season in August, followed by a short wet season from September to October (Ofomata 1975a). The rainfall of utmost importance for soil erosion within the region are the short duration rains that fall at the beginning and at the end of the rainy season due to their intensity and violence (Ofomata 1975b). Five major soil classes are recognized within eastern Nigeria based on morphology, degree of profile development, mineral properties of the underlying rocks, and the slope of the terrain. These are the lithosols, young soils derived from recently deposited materials, ferruginous tropical soils, ferrallitic soils and hydromorphic soils (Ofomata, 1975a). In geo-political terms, it contains five out of the 36 states of Nigeria, namely Abia, Anambra, Ebonyi, Enugu and Imo. Ebonyi State was excluded because of its peculiar geology of low transmissivity; very few boreholes. The data was arranged according to observed pumping durations and number of pumping times per day. The preventive maintenance cost (R_2C) and production cost (R_3C) were computed for each borehole for various pumping durations and number of pumping times.The data was then screened for the components of the scheme that broke down, replaced and repaired and their corresponding downtimes. The frequencies of repair and replacement, downtime and salaries of repair crew (S_A) as well as corrective maintenance costs (S_o) were deduced.

The Total Operation Cost (TOC) of rural water scheme in a community was expressed as:

$$TOC = R_1C + R_2C + S_0 + S_A \quad (1)$$

in which,
R_1C = Production cost;
R_2C = Preventive maintenance material and travel cost;
S_0 = Corrective maintenance material and travel cost and
S_A = Salaries of the repair crew
Okere (2010) expressed the production cost as;

$$R_1C = a_i + b_i t^n (2)$$

where,
a_i = The constant cost parameter representing the pump operator's initial salary and bulbs for lighting the pump house in i^{th} community.
b_i = Includes salary increment, fuel consumption which increases with time for the i^{th} component, and
n = The degree of polynomial describing the best cost function.

Model Parameters

The parameters required to formulate the proposed model were essentially those associated with the Total Operations Cost, TOC. Total operations cost included production cost and maintenance cost. The production cost is the cost associated directly with the pumping and has pumping duration, fuel consumption during pumping and salaries of operators as parameters of interest. The maintenance cost (preventive and corrective) are the cost associated with component replacement and repair, downtime and has frequency of repair, frequency of replacement, frequency of break down as parameters of interest.

Model Assumptions

i. The pump price per litre of AGO was taken as an average of **$**0.666 for the analysis
ii. The maintenance of the generators was assumed to be carried out twice every year
iii. The volume of engine oil used for the maintenance of generator ranges from 3 -30 litres with respect to the rating of the generator
iv. A litre of engine oil was taken to be **$**2.778
v. The salary are as obtained from the field work
vi. The cost for the replacement of burnt bulbs was taken to be **$**1.111 with an interval of 6months
vii. The consumption rate of the generating set according to their respective rating is as obtained from the chart annexed to this document.

Model Formulation

The model by Agunwamba (2000b) is adopted and modified to allow for once a day and thrice a day pumping scenarios and considering different durations in each scenario. For pumping twice per day by Agunwamba (2000a), in a given typical day, t_0 is the water supply period, while t_1 and t_2 are the idle times during the day and night periods. The period between major repairs is T. Hence, the number of breakdown cycles per year is 1/T. Let K_i be the number of repairs (both corrective and preventive) for component I within a cycle. Therefore, the number of preventive maintenance is (K_i-1) per cycle and T/K is the time between preventive maintenance. Hence, the total production cost over a cycle for J component is

$$R_1C = \sum_{i=0}^{J} \left\{ \int_0^{2t_0T/k_i} k_i(a_i + b_it^n)dt + \int_0^{t_1T/k_i} k_i(a_i + b_it^n)dt + \int_0^{t_2T/k_i} k_i(a_i + b_it^n)dt \right\} \quad (3)$$

The total production cost per component in Equation (3) is modified by considering once per day pumping scenario and thrice per day pumping scenario. Then the appropriate total production cost equation is derived for each scenario. Hence, the total production cost equation for pumping once a day can be deduced by substituting $T = t_0 + t_1$ into Equation 3 to have

$$R_1C_2 = \sum_{i=0}^{J} \left\{ \int_0^{t_0T/k} k_i(a_i + b_i t^n)dt + \int_0^{t_1T/k_i} k_i(a_i + b_i t^n)dt \right\} (4)$$

Similarly, the total production cost equation for pumping thrice a day can be deduced by substituting $T = 3t_o + 2t0+t2+t1$ into Equation (3) to have

$$R_1C_3 = \sum_{i=0}^{J} \left\{ \int_0^{3t_0T/k_i} k_i(a_i + b_i t^n)dt + \int_0^{2t_0T/k_i} k_i(a_i + b_i t^n)dt + \int_0^{t_1T/k_i} k_i(a_i + b_i t^n)dt \ldots\ldots + \int_0^{t_2T/k_i} k_i(a_i + b_i t^n)dt \right\} \qquad (5)$$

Model Solution

Model Solution for Pumping Once per Day

$$\int_0^{t_0T/K_i} K_i(a_i + b_i t^n)dt + \int_0^{t_1T/K_i} K_i(a_i + b_i t^n)dt$$

$$= \left[K_i\left(a_i t + \frac{b_i t^{n+i}}{n+i}\right)\right]_0^{\frac{t_0T}{K_i}} + \left[K_i\left(a_i t + \frac{b_i t^{n+i}}{n+i}\right)\right]_0^{\frac{t_1T}{K_i}}$$

$$= K_i \frac{a_i t_o T}{K_i} + \frac{K_i b_i}{n+i}\left(\frac{t_0T}{K_i}\right)^{n+i} + K_i \frac{a_i t_1 T}{K_i} + \frac{K_i b_i}{n+i}\left(\frac{t_1T}{K_i}\right)^{n+i}$$

$$= a_i T(t_0 + t_1) + \frac{b_i K_i}{n+i}\left[\left(\frac{t_0T}{K_i}\right)^{n+i} + \left(\frac{t_1T}{K_i}\right)^{n+i}\right]$$

$$= a_i T(t_0 + t_1) + \frac{b_i K_i}{n+i}\left(\frac{T}{K_i}\right)^{n+i} \left[t_0^{n+i} + t_1^{n+i}\right] \qquad (6)$$

Model Solution for Pumping Twice per Day

$$\int_0^{2t_0T/K_i} K_i(a_i + b_i t^n)dt + \int_0^{t_1T/K_i} K_i(a_i + b_i t^n)dt + \int_0^{t_2T/K_i} K_i(a_i + b_i t^n)dt$$

$$= \left[K_i\left(a_i t + \frac{b_i t^{n+i}}{n+\mathrm{i}}\right)\right]_0^{\frac{2t_0T}{K_i}} + \left[K_i\left(a_i t + \frac{b_i t^{n+i}}{n+i}\right)\right]_0^{\frac{t_1T}{K_i}} + \left[K_i\left(a_i t + \frac{b_i t^{n+i}}{n+i}\right)\right]_0^{\frac{t_2T}{K_i}}$$

$$= K_i \frac{2a_i t_o T}{K_i} + \frac{K_i b_i}{n+i}\left(\frac{2t_0T}{K_i}\right)^{n+i} + K_i \frac{a_i t_1 T}{K_i} + \frac{K_i b_i}{n+i}\left(\frac{t_1T}{K_i}\right)^{n+i} + K_i \frac{a_i t_2 T}{K_i} + \frac{K_i b_i}{n+i}\left(\frac{t_2T}{K_i}\right)^{n+i}$$

$$= a_i T(2t_0 + t_1 + t_2) + \frac{b_i K_i}{n+i}\left[\left(\frac{2t_0T}{K_i}\right)^{n+i} + \left(\frac{t_1T}{K_i}\right)^{n+i} + \left(\frac{t_2T}{K_i}\right)^{n+i}\right]$$

$$= a_i T(2t_0 + t_1 + t_2) + \frac{b_i K_i}{n+i}\left(\frac{T}{K_i}\right)^{n+i} \left[(2t_0)^{n+i} + t_1^{n+i} t_2^{n+i}\right] \qquad (7)$$

Model Solution for Pumping Thrice per Day

$$\int_0^{3t_0T/K_i} K_i(a_i + b_i t^n)dt + \int_0^{2t_0T/K_i} K_i(a_i + b_i t^n)dt + \int_0^{2t_1T/K_i} K_i(a_i + b_i t^n)dt + \int_0^{t_2T/K_i} K_i(a_i + b_i t^n)dt$$

$$= \left[K_i\left(a_i t + \frac{b_i t^{n+i}}{n+i}\right)\right]_0^{\frac{3t_0T}{K_i}} + \left[K_i\left(a_i t + \frac{b_i t^{n+i}}{n+i}\right)\right]_0^{\frac{2t_0T}{K_i}} + \left[K_i\left(a_i t + \frac{b_i t^{n+i}}{n+i}\right)\right]_0^{\frac{2t_1T}{K_i}} + \left[K_i\left(a_i t + \frac{b_i t^{n+i}}{n+i}\right)\right]_0^{\frac{t_2T}{K_i}}$$

$$= K_i \frac{3a_i t_o T}{K_i} + \frac{K_i b_i}{n+i}\left(\frac{3t_0T}{K_i}\right)^{n+i} + K_i \frac{2a_i t_o T}{K_i} + \frac{K_i b_i}{n+i}\left(\frac{2t_0T}{K_i}\right)^{n+i} + K_i \frac{a_i 2t_1 T}{K_i} + \frac{K_i b_i}{n+i}\left(\frac{2t_1T}{K_i}\right)^{n+i} + K_i \frac{a_i t_2 T}{K_i} + \frac{K_i b_i}{n+i}\left(\frac{t_2T}{K_i}\right)^{n+i}$$

$$= a_i T(3t_0 + 2t_0 + 2t_1 + t_2) + \frac{b_i K_i}{n+i}\left[\left(\frac{3t_0T}{K_i}\right)^{n+i} + \left(\frac{2t_0T}{K_i}\right)^{n+i} + \left(\frac{2t_1T}{K_i}\right)^{n+i} + \left(\frac{t_2T}{K_i}\right)^{n+i}\right]$$

$$= a_i T(3t_0 + 2t_0 + 2t_1 + t_2) + \frac{b_i K_i}{n+i}\left(\frac{T}{K_i}\right)^{n+i}\left[(3t_0)^{n+i} + (2t_0)^{n+i} + 2t_1^{n+i}t_2^{n+i}\right] \qquad (8)$$

Model Calibration

Random selection of three different boreholes was used to determine the values slope, **n** and intercept, **a,** from regression of $\log_{10}$ (R_1C *a) on $\log_{10}$ t. Trial and error method was adopted to obtain value of **a** that gives the highest R^2 and this was adopted as the value of **a** for all the subsequent computation of **n**. For the first, second and third trials, **'a'** values ranging from 100, 150 to 200 were chosen for **t** of 0.8 intervals. From Equation (2), the unknown parameter, b was estimated by substituting the respective values of **a, t, n** and R_1C into the regression equations. The various equations for frequency of replacement, frequency of breakdown, frequency of repair were then deduced from the related regression equations. The equations for the frequencies derived were then applied to the model assuming various combinations of preventive maintenance frequencies for the components. Thus, the TOC for each combination frequency was calculated. The combination with the least cost TOC was considered the optimal solution.

III. RESULTS AND DISCUSSION

The least cost of preventive maintenance for each pumping scenario for the submersible pump is given in Tables 1, 2 and 3. The optimal maintenance frequencies and least costs were evaluated based on the estimated model parameters given in Tables 1, 2 and 3.

Table 1 Optimum Maintenance Model for Pumping once daily

State	TOC (**$**)	T (days)	Frequency per year	No. of cycles per year	Frequency of preventive maintenance per cycle
Enugu	1512.53	86.608	4	4	1
Anambra	1338.4	82.939	4	4	1
Imo	1540.03	68.404	5	5	1
Abia	1319.83	64.414	6	6	1

In Enugu, Anambra, Imo and Abia States, for water boreholes pumping once, the least total operation cost was determined as **$**1512.53, **$**1338.4, **$**1540.03, and **$**1319.83 respectively as shown in Table 1 at preventive maintenance frequencies per cycle of 1 for submersible pump and corrective maintenance interval of approximately 86, 82, 65 and 65days respectively. The number of cycles for the four states was also computed as 4, 4, 5 and 6 per year respectively. Hence, the frequency per year is 4, 4, 5 and 6respectively.

Table 2 Optimum Maintenance Model for Pumping twice daily

State	TOC (**$**)	T (days)	Frequency per year	No. of cycles per year	Frequency of preventive maintenance per cycle
Enugu	5718.78	39.051	9	9	1
Anambra	9017.705	35.010	10	10	1
Imo	5232.85	38.343	10	10	1
Abia	6627.327	30.388	12	12	1

Table 2 shows that for pumping twice, the least total operation cost for Enugu, Anambra, Imo and AbiaStates, is **$**5718.78, **$**9017.705, **$**5232.85, **$**6,627.327 respectively at preventive maintenance frequencies per cycle of 1 for submersible pump and corrective maintenance interval of approximately 39, 35, 38 and 30days respectively. The number of cycles for the four states was also computed as 9, 10, 10 and 12 per year respectively. Hence, the frequency per year is 9, 10, 10 and 12respectively.

Table 3 Optimum Maintenance Model for Pumping thrice daily

State	TOC ($)	T (days)	Frequency per year	No. of cycles per year	Frequency of preventive maintenance per cycle
Enugu	1477084	30.373	12	12	1
Anambra	584062	19.232	19	19	1
Imo	608265	23.277	16	16	1
Abia	645786	20.973	17	17	1

Table 3 shows that for pumping thrice, the least total operation cost for Enugu, Anambra, Imo and AbiaStates, is **$**8206.02, **$**3244.79, **$**3379.25 and **$**3587.7 respectively at preventive maintenance frequencies per cycle of 1 for submersible pump and corrective maintenance interval of approximately 30, 19, 23 and 20days respectively. The number of cycles for the four states was also computed as 12, 19, 16 and 17 per year respectively. Hence, the frequency per year is 12, 19, 16 and 17.

Table 4 Comparisons of Optimal TOC and Existing TOC for all Pumping Scenarios

State	Optimal TOC ($)			Average Existing TOC ($)		
	Once	Twice	Thrice	Once	Twice	Thrice
Enugu	1512.533	5718.783	8206.022	44269.572	277616.703	47,911.1722
Abia	1319.827	6627.327	3587.7	211285.333	152387.533	99301.022
Imo	1540.027	5232.85	3379.25	34560.75	160162.405	551975.667
Anambra	1338.4	9017.705	3244.788	61115.144	104420.438	402979.927

Optimization results obtained by Agunwamba (2000a) in Enugu state showed that the optimal preventive maintenance frequencies of 6 and 6 times respectively for water boreholes and generator sets gave a savings in total operation cost of $475.716 with no downtime. The little difference in the results obtained by Agunwamba (2000a) and the results of this study is due to the fact that Agunwamba (2000a) conducted his study on 14 boreholes in Nsukka zone while about 53 public boreholes were considered in this research.

Table 5 Net Savings in Total Operation Cost

State	Net Savings in TOC($) (Pumping Once)	Net Savings in TOC($) (Pumping Twice)	Net Savings in TOC ($)(Pumping Thrice)
Enugu	42757.038	440564.585	39705.15
Anambra	209965.505	145760.205	95713.320
Imo	33020.722	154929.555	548596.422
Abia	59776.744	75402.733	399735.138

IV. CONCLUSION

The study, derivation of a model for least-cost maintenance policy for water boreholes in south-eastern states was considered, and optimal frequency of maintenance was determined. The cost of the existing maintenance strategy and optimum maintenance policy were compared. An existing cost maintenance policy was modified to account for actual mode of operations of different boreholes. The model presented is useful for evaluation of existing maintenance schemes and the optimal design of new ones. The model included all the major cost contribution and was based historical operating data from a water borehole schemes. This model would prove useful to project developers, owners and operators in the evaluation of water borehole projects especially in south eastern states in Nigeria.

ACKNOWLEDGMENT

My profound gratitude goes to the Managing Director of Anambra-Imo River Basin Development Authority for his sincere cooperation and prompt attention. He assisted me with the data used in the entire research. This appreciation would never be complete if I fail to recognize and appreciate the role played by my research assistants: Ugochukwu Uwalaka and Emeka Johnson.

CONFLICT OF INTEREST

There is no conflict of interest associated in this work

REFERENCE

[1]. Agunwamba JC (2000a) Rural Water Supply: Success and Failures in Rural Processes and Prospects. In Elohi EC, Ayichi D, Okoye CU (eds). Central Publishing co. Ltd., Lagos, pp103-118

[2]. Agunwamba JC (2000b) Water Engineering Systems. Immaculate Publishes Ltd. Enugu, pp 30-45

[3]. Akabo KJ (1991) Farm Mechanization and Rural Development. Proc. Int. conf/workshop on Energy for Accelerated Rural Dev. Eds. Anazodo U.G.N. et al. Faculty of Energy. UNN. pp 205-215

[4]. Barata J (2002) Simulation Modelling of Repairable Multi-Component Deteriorating Systems for on Condition Maintenance Optimization. Reliability Engineering and System Safety. 76(3): 255-264

[5]. Barlow RF, Hunter, LC, Proschan, F (1963) Optimum Checking Procedures SIAM. J. 11:1078 – 1095.

[6]. Both H (1989) Maintenance and Failure Behaviour of Technical Systems: Design and Application of a Simulation Model. Desertation, University of Eindhoven

[7]. Brandr EB, Umaye DR (1970). MAD Mathematical Analysis of Downtime. Nov. Res. Log. Quat., 17 (1970) :525-535.

[8]. Bris R (2000) Parallel Simulation Algorithm for Maintenance Optimization based on directed Acyclic Graph. Reliability Engineering and System Safety, Liverpool, (7): 137-201

[9]. Jardine AK (1973) Maintenance, Replacement and Reliability: Theory and Applications, Boca Raton, FL: CRC Press

[10]. Kenne JP, Gharbi A, Beit M (2007) Age-dependent Production Planning and Maintenance Strategies in Unreliable Manufacturing Systems with lost sale. European Journal of Operational Research 178(2): 408-420

[11]. Nwachukwu MC (2015) Model Development of Least Cost Maintenance of Water Borehole Schemes in South-Eastern States of Nigeria Desertation, Department of Civil Engineering, Federal University of Technology, Owerri

[12]. Ofomata GEK (2001) Soil Erosion in Enugu Area of Nigeria. Nigerian Geographical Journal (8): 45-49

[13]. Okere EO (2010) Cost Optimization of Preventive Maintenance of Boreholes in Abia and Imo States. Unpublished Master's thesis. Federal University of Technology, Owerri

[14]. Ofomata GEK (1975a) Soil in Nigeria in maps: Eastern States. In: Ofomata GEK (ed) Ethiope Publishing House, Benin City, pp40-50

[15]. Ofomata GEK (1975b) Soil Erosion in Nigeria in maps: Eastern States. In: Ofomata GEK (ed) Ethiope Publishing House, Benin City, p30

A.O. Ibeje, Etal. "Optimal Maintenance of Water Borehole Schemes" *The International Journal of Engineering and Science (IJES)*, 9(01) (2020): PP 23-29