Journal of Engineering Research and Reports

2(2): 1-14, 2018; Article no.JERR.43711

Modeling and Optimization of Operational Costs of Nissan Urvan Vehicles of a Fleet Operator

Harold C. Godwin[1], Patrick S. Aguh[1] and Anthony O. Umeozokwere[2*]

[1]Department of Industrial and Production Engineering, Nnamdi Azikiwe University Awka, Nigeria.
[2]Department of Mechanical Engineering Technology, Federal Polytechnic Oko, Anambra State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author HCG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors PSA and AOU managed the analyses of the study. Author AOU managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2018/v2i29916
Editor(s):
(1) Dr. Djordje Cica, Associate Professor, Faculty of Mechanical Engineering, University of Banja Luka, Bosnia and Herzegovina.
Reviewers:
(1) Akshat Pandey, India.
(2) Seung-Bok Choi, Inha University, Korea.
(3) Subrata Kumar Mandal, India.
(4) Cornelius Ogbodo Anayo Agbo, University of Nigeria, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/26246

Case Study

Received 04 June 2018
Accepted 29 August 2018
Published 15 September 2018

ABSTRACT

This study focused on Modeling and Optimization of the operational costs of Nissan Urvan Vehicles of a fleet operator in Anambra State Nigeria. The special design used to fit a second order model needed to optimize the operational costs of Nissan Urvan Vehicles was Box - Behnken design while response surface method (RSM) was used to model and optimize performance characteristics of the vehicles. The response function of the second order model is best characterized by multivariate power equation. Ten (10) years operation data were collected from two sources, namely primary and secondary sources. The primary source of data was from the workshop manager and the statistical office of the company, and from Metrological Institute of Nigeria. The secondary source of data was from Books consulted at different Libraries. The outcome of the analysis of variance (ANOVA) for RSM optimization of operational costs of Nissan Urvan vehicles showed that all the control factors are significant except factors (B, C, D) of replacement costs. From the result of the

**Corresponding author: E-mail: umeoztony@gmail.com;*

income generated at optimum condition and the sum of the maintenance & replacement costs compared, by the year 2013 the income generated is less than the sum of maintenance & replacement costs. It was observed that the operation of the transportation system is economical for a period of 8 years (from 2005 – 2012), where the income generated is more than the maintenance & replacement costs.It is hereby recommended that response surface model should be deployed for the operation analysis of the case study company vehicles to enhance efficient utilization and profitability.

Keywords: Nissan Urvan vehicles; operational costs; response surface model; numerical optimization.

1. INTRODUCTION

The design life of most vehicles requires periodic maintenance. Failure to perform maintenance activities intended by the equipment's designer shortens the operating life of the equipment [1]. Vehicles and equipment are subject to deterioration due to their use and exposure to environmental conditions as a result of wear and tear of parts in relative motion and improper lubrication of the sliding parts. Maintenance is necessary to enhance utilization of vehicles with minimum cost of stoppage and repair. If deterioration and breakdown are not checked they may render the vehicles unserviceable, therefore, it is necessary to attend to them from time to time, repair and recondition them so as to enhance their life economically and protect them from failure [2]. This has brought the role of maintenance and replacement as an important activity in the transportation industries [3]. Maintenance is defined as the combination of activities to restore the component or equipment to a state in which it can perform its designated functions [4]. Every vehicle requires maintenance even if it is best designed; the maintenance must be done at such a period when it will have least disruptions of service, therefore, vehicles, machines undergo maintenance when not in use or their use may be postponed without affecting service and operation [5]. However, in reality most of the equipment failures are influenced not only by the internal factor (age-time usage) but also by the external factor. The external factors would be the effects of the environment (dust, humidity, precipitation, temperature and heat), human skills, product types and maintenance activities. The timely maintenance of vehicles in the fleet is one of the fundamental programs that serve as a backbone of a successful transport system [6]. Vehicle maintenance expenses usually increase as the age of a vehicle advances thereby triggering replacement. The vehicles are subject to breakdowns and deterioration therefore, maintenance policy can be beneficial in order to prevent failures during operation [7]. Besides, vehicle maintenance is an important service function of an efficient operational/productive system. It helps in maintaining and increasing the operational efficiency of the transport facilities and thus contributes to increase in revenue by reducing the operating costs and increasing the effectiveness of production [8]. Conversely, poorly maintained vehicles may lead to more frequent parts failures, poor utilization and delayed operation schedules. Also, poor maintenance may mean more frequent vehicle replacement because of shorter life. For many asset-intensive industries the maintenance costs are a significant portion of the operational costs, the maintenance expenditure accounts for 20-50% of the service cost for the industry depending on the level (age) of the equipment [9].

Prior to this study, the case company was challenged with high cost of maintaining company's vehicles which reduces and generally affect the total net profit of the company. However, this research work is geared towards optimization of the operational costs of Nissan Urvan vehicles of the case company by the application of response surface method which is best characterized by multivariate power law model [10]. This would help in making an optimal replacement policy so that a particular vehicle is replaced when it has reached its optimum service.It would also help the company to prevent losses by making the proper decisions based on relevant information.

Although, many approaches and models have been used in the past to analyze the operational costs of transportation industries, but they could not be used widely to fit second order model to the response surface and were not able to display the extent of the significance of the control factors on the yield [11]. With these proposed model an optimal replacement policy can be made so that a particular vehicle is replaced when it has reached its optimum service. The accomplishment of the response surface method for automobile replacement policy stated would assist the case study company and other transport service providers nationwide to better access and manage their vehicles that need particularly maintenance and replacement. The creation of a more effective equipment replacement system would be of tremendous benefit both in potential labor and vehicle maintenance Naira savings. Finally, the study would be used as a guide for organizations to improve or promote their maintenance strategies and also benefit future researchers in this field on how to adopt maintenance measures. The objective of this study is to optimize the operational costs of Nissan Urvan vehicles of a fleet operator using response surface method.

2. MATERIALS AND METHODS

2.1 Data Collection

In this study, data on the type and number of vehicles, maintenance costs, replacement costs and income generated from 2005 to 2014 were collected from the maintenance workshop of the company, while data on environmental factors were obtained from the Metrological Institute of Nigeria. The data obtained were presented in Table 1.

2.2 Fitting a Second Order Model to the Data Collected

In this study the data obtained from the statistical office of the fleet operator is linearized on the assumption that the sample results follow a power law model of the form:

$$Y = a_0 A^{a1} B^{a2} C^{a3} \ldots N^{an} \qquad [10] \qquad (1)$$

and that the response surface is optimized by a second order polynomial
equation stated as:

$$Y = \beta_0 + \sum_{i=1}^{q} \beta_i x_i + \sum_{i=1}^{q} \beta_{ii} x_i^{\,2} + \sum_{i=1}^{q-1} \sum_{j=2}^{q} \beta_{ij} + \varepsilon \qquad (2)$$

Where, Y is the predicted response (dependent variable),
q is the number of factors (independent variables),

X_i is the input factors (i = 1, 2 etc),

β_o is the constant coefficient, and
β_i, β_{ij} and β_{ii} are the coefficients of linear, interaction and quadratic terms respectively.

For four factors, three level design equation (1) reduces to:

$$Y = a_0 A^{a1} B^{a2} C^{a3} D^{a4} \qquad (3)$$

And equation (2) expanded to:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_{11} x_1^{\,2} + \beta_{22} x_2^{\,2} + \beta_{33} x_3^{\,2} + \beta_{44} x_4^{\,2} + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{14} x_1 x_4 + \beta_{23} x_2 x_3 + \beta_{24} x_2 x_4 + \beta_{34} x_3 x_4 \qquad (4)$$

Table 1. Environmental factors and data collected from Nissan Urvan fleet operator’s office

$Year$	$Factor\ A$ $Dist.(Km)$	$Factor\ B$ $Preci.(Cubic)$	$Factor\ C$ $Temp.(^oC)$	$Factor\ D$ $Relative\ humidity$	$Maint.\ Cost$ $(\#x1000)$	$Replace.\ Cost$ $(\#x1000)$	$Income\ generated$ $(\#x1000)$
2005	101616	1620	29.2	148	1969	1992	9807.30
2006	102784	1500	28.5	156.9	2250	2240	9782.40
2007	105120	1650.3	28.96	176.98	2520	2400	9660.00
2008	113296	1507	28.15	159.56	2815	2500	9515.00
2009	116800	1579.1	28.3	126.2	3030	2568	9020.00
2010	117384	1506.6	27.8	122.65	3240	2681	8850.00
2011	117968	1695.4	28.85	129.7	3360	2705	8610.00
2012	118552	1662	27.9	148	3590	2805	8489.70
2013	119720	2294.7	28.3	122.65	3995	2856	8340.00
2014	120304	1695	24.4	129.68	4005	2943	8300.00

Km= kilometer, ˚C= degree Celsius, Dist.= Distance, Temp.=Temperature

The coefficient parameters were estimated by linearizing the data of maintenance cost, replacement cost and income generated of Table 1 and using regression as analysis tool for evaluating transformed log data of input parameters presented in Table 2, 3 and 4, and expressed them as power law models of the form of equation (3).

$$Y_{mcost} = 2.933607451E\text{-}14A^{3.183453789}B^{0.4665364202}C^{-0.80574072}D^{0.274461545} \quad (5)$$

$$Y_{rcost} = 6.418851538E\text{-}07A^{1.813623751}B^{0.139777175}C^{-0.378185139}D^{0.247298984} \quad (6)$$

$$Y_{income\ gen.} = 22976659.8A^{-0.668996929}B^{-0.147041359}C^{0.240003793}D^{0.046911726} \quad (7)$$

Where, factors A, B, C and D are the distance covered, precipitation, temperature and relative humidity respectively.

The power law models of Eqs. (5) – (7) were used to evaluate the design matrix of Box – Behnken design and presented in Tables 5, 6 and 7 for maintenance, replacement and income generated respectively.

Table 2. Log transformed data for maintenance cost

Factor A	*Factor B*	*Factor C*	*Factor D*	Re*sponse Y*	*Log A*	*Log B*	*Log C*	*Log D*	*Log Y*
101616	1620	29.2	148	1969	5.007	3.2095	1.4654	2.1703	3.2942
102784	1500	28.5	156.9	2250	5.012	3.1761	1.4548	2.1956	3.3522
105120	1650.3	28.96	176.98	2520	5.0217	3.2176	1.4618	2.2479	3.4014
113296	1507	28.15	159.56	2815	5.0542	3.1781	1.4495	2.2029	3.4495
116800	1579.1	28.3	126.2	3030	5.0674	3.1984	1.4518	2.1011	3.4814
117384	1506.6	27.8	122.65	3240	5.0696	3.1780	1.4440	2.089	3.5105
117968	1695.4	28.85	129.7	3360	5.0718	3.2293	1.4601	2.1129	3.5263
118552	1662	27.9	148	3590	5.0739	3.2206	1.4456	2.1703	3.5551
119720	2294.7	28.3	122.65	3995	5.0782	3.3607	1.4518	2.0887	3.6015
120304	1695	24.4	129.68	4005	5.0803	3.2292	1.3874	2.1129	3.6026

Table 3. Log transformed data for replacement cost

Factor A	*Factor B*	*Factor C*	*Factor D*	Re*sponse Y*	*Log A*	*Log B*	*Log C*	*Log D*	*Log Y*
101616	1620	29.2	148	1992	5.007	3.2095	1.4654	2.1703	3.2993
102784	1500	28.5	156.9	2240	5.012	3.1761	1.4548	2.1956	3.3502
105120	1650.3	28.96	176.98	2400	5.0217	3.2176	1.4618	2.2479	3.3802
113296	1507	28.15	159.56	2500	5.0542	3.1781	1.4495	2.2029	3.3979
116800	1579.1	28.3	126.2	2568	5.0674	3.1984	1.4518	2.1011	3.4096
117384	1506.6	27.8	122.65	2681	5.0696	3.1780	1.4440	2.089	3.4283
117968	1695.4	28.85	129.7	2705	5.0718	3.2293	1.4601	2.1129	3.4322
118552	1662	27.9	148	2805	5.0739	3.2206	1.4456	2.1703	3.4479
119720	2294.7	28.3	122.65	2856	5.0782	3.3607	1.4518	2.0887	3.4558
120304	1695	24.4	129.68	2943	5.0803	3.2292	1.3874	2.1129	3.4688

Table 4. Log transformed data for income generated

Factor A	*Factor B*	*Factor C*	*Factor D*	Re*sponse Y*	$Log\,A$	$Log\,B$	$Log\,C$	$Log\,D$	$Log\,Y$
101616	1620	29.2	148	1992	5.007	3.2095	1.4654	2.1703	3.9915
102784	1500	28.5	156.9	2240	5.012	3.1761	1.4548	2.1956	3.9904
105120	1650.3	28.96	176.98	2400	5.0217	3.2176	1.4618	2.2479	3.9850
113296	1507	28.15	159.56	2500	5.0542	3.1781	1.4495	2.2029	3.9784
116800	1579.1	28.3	126.2	2568	5.0674	3.1984	1.4518	2.1011	3.9552
117384	1506.6	27.8	122.65	2681	5.0696	3.1780	1.4440	2.089	3.9469
117968	1695.4	28.85	129.7	2705	5.0718	3.2293	1.4601	2.1129	3.9350
118552	1662	27.9	148	2805	5.0739	3.2206	1.4456	2.1703	3.9289
119720	2294.7	28.3	122.65	2856	5.0782	3.3607	1.4518	2.0887	3.9212
120304	1695	24.4	129.68	2943	5.0803	3.2292	1.3874	2.1129	3.9191

Table 5. Design matrix of Box-Behnken design for optimization of maintenance costs

Std. order	Run order	Distance	Precipitation	Temp.	Relative humidity	Response maintenance cost
23	1	110960	1500.00	26.8	176.980	2970.01
14	2	110960	2294.70	24.4	149.815	3729.47
3	3	101616	2294.70	26.8	149.815	2613.34
2	4	120304	1500.00	26.8	149.815	3670.10
8	5	110960	1897.35	29.2	176.980	3092.00
18	6	120304	1897.35	24.4	149.815	4415.72
26	7	110960	1897.35	26.8	149.815	3165.11
22	8	110960	2294.70	26.8	122.650	3273.18
11	9	101616	1897.35	26.8	176.980	2503.97
13	10	110960	1500.00	24.4	149.815	3060.03
27	11	110960	1897.35	26.8	149.815	3165.11
15	12	110960	1500.00	29.2	149.815	2647.79
10	13	120304	1897.35	26.8	122.650	3875.47
1	14	101616	1500.00	26.8	149.815	2144.24
21	15	110960	1500.00	26.8	122.650	2685.64
16	16	110960	2294.70	29.2	149.815	3227.05
25	17	110960	1897.35	26.8	149.815	3165.11
5	18	110960	1897.35	24.4	122.650	3231.25
9	19	101616	1897.35	26.8	122.650	2264.22
24	20	110960	2294.70	26.8	176.980	3619.76
19	21	101616	1897.35	29.2	149.815	2232.31
12	22	120304	1897.35	26.8	176.980	4285.82
20	23	120304	1897.35	29.2	149.815	3820.84
6	24	110960	1897.35	29.2	122.650	2795.95
17	25	101616	1897.35	24.4	149.815	2579.86
7	26	110960	1897.35	24.4	176.980	3573.39
4	27	120304	2294.70	26.8	149.815	4473.01

Table 6. Design matrix of Box-Behnken design for optimization of replacement cost

Std. order	Run order	Distance	Precipitation	Temp.	Relative humidity	Response maintenance cost
23	1	110960	1500.00	26.8	176.980	2613.64
14	2	110960	2294.70	24.4	149.815	2757.82
3	3	101616	2294.70	26.8	149.815	2269.18
2	4	120304	1500.00	26.8	149.815	2904.24
8	5	110960	1897.35	29.2	176.980	2614.72
18	6	120304	1897.35	24.4	149.815	3109.61
26	7	110960	1897.35	26.8	149.815	2591.88
22	8	110960	2294.70	26.8	122.650	2533.20
11	9	101616	1897.35	26.8	176.980	2302.62
13	10	110960	1500.00	24.4	149.815	2598.71
27	11	110960	1897.35	26.8	149.815	2591.88
15	12	110960	1500.00	29.2	149.815	2428.08
10	13	120304	1897.35	26.8	122.650	2856.34
1	14	101616	1500.00	26.8	149.815	2138.26
21	15	110960	1500.00	26.8	122.650	2387.05
16	16	110960	2294.70	29.2	149.815	2576.74
25	17	110960	1897.35	26.8	149.815	2591.88
5	18	110960	1897.35	24.4	122.650	2555.86
9	19	101616	1897.35	26.8	122.650	2103.00
24	20	110960	2294.70	26.8	176.980	2773.66
19	21	101616	1897.35	29.2	149.815	2139.14
12	22	120304	1897.35	26.8	176.980	3127.48
20	23	120304	1897.35	29.2	149.815	2905.43
6	24	110960	1897.35	29.2	122.650	2388.03
17	25	101616	1897.35	24.4	149.815	2289.47
7	26	110960	1897.35	24.4	176.980	2798.47
4	27	120304	2294.70	26.8	149.815	3082.05

The regression model resulting from the evaluation of the design matrix of Box-Behnken design for maintenance cost is presented as equation (8) for uncoded factors. Also the test for statistical significance of the response model is presented as Table 8.

The regression model resulting from the evaluation of the design matrix of Box-Behnken design for replacement cost is stated as equations (9)for uncoded factors.Also the test for statistical significance of the response model is presented as Table 9.

The regression model equation for uncoded factors is presented in equation (10). Also, the test for statistical significance of the response model is presented as Table 10.

2.3 Optimization Plots

Optimization plot is a graphical representation of the dependent and independent variables at their optimal value settings. The optimization plots are presented in Figs. 1, 2 and 3. The optimal values of the factors were indicated in the plots in squared parentheses. The optimization plots showed the maximum predicted values of ₦1,916,643.30 for maintenance cost, ₦1,971, 390.00 for replacement cost and ₦10,040,000.00 for income generated. The optimized plot was obtained with the response surface optimizer of Minitab 16 software.

2.4 Model Validation

The fitted models were checked to ensure that they provide adequate approximations to the real systems. Unless the models show adequate fits, proceeding with the optimization of the fitted response surfaces is likely to give misleading results. The graphical optimization method (optimization plot) was used as a primary tool for optimization. The graphical techniques were validated using a numerical method. There are three optimization parameters namely maximum, minimum and target that define each desirability index, d_i. The desirability function d_i is defined differently based on the objective of the response according to Relia Wiki [12], and is expressed as:

(i) If the response is to be maximized, d_i is defined as:

$$d_i = \begin{cases} 0 & Y_i < L \\ \dfrac{Y_i - L}{T - L} & L \le Y_i \le T \\ 1 & Y_i > T \end{cases} \tag{11}$$

Where, T represents the target value of the i^th^ response (the highest value) and

L represents the acceptable lower limit value for the response.

(ii) If the response is to be minimized, di is defined as:

$$d_i = \begin{cases} 1 & Y_i < T \\ \dfrac{U - Y_i}{U - T} & T \le Y_i \le U \\ 0 & Y_i > U \end{cases} \tag{12}$$

Where, U represents the acceptable upper limit of the response and T is the
smallest value.

(iii) For a specific target response value, d_i is defined as:

$$d_i = \begin{cases} 0 & Y_i < L \\ \dfrac{Y_i - L}{T - L} & L \le Y_i \le T \\ \dfrac{U - Y_i}{U - T} & T \le Y_i \le U \\ 0 & Y_i > U \end{cases} \tag{13}$$

Table 7. Design matrix of Box-Behnken design for optimization of income generated

Std. order	Run order	Distance	Precipitation	Temp.	Relative humidity	Response income generated
27	1	110960	1897.35	26.8	149.815	8889.55
4	2	120304	2294.70	26.8	149.815	8189.29
19	3	101616	1897.35	29.2	149.815	9624.49
15	4	110960	1500.00	29.2	149.815	9393.46
24	5	110960	2294.70	26.8	176.980	8712.29
11	6	101616	1897.35	26.8	176.980	9502.40
21	7	110960	1500.00	26.8	122.650	9116.12
1	8	101616	1500.00	26.8	149.815	9759.88
16	9	110960	2294.70	29.2	149.815	8824.23
13	10	110960	1500.00	24.4	149.815	8997.20
22	11	110960	2294.70	26.8	122.650	8563.69
6	12	110960	1897.35	29.2	122.650	8989.66
14	13	110960	2294.70	24.4	149.815	8451.97
7	14	110960	1897.35	24.4	176.980	8759.83
2	15	120304	1500.00	26.8	149.815	8717.56
8	16	110960	1897.35	29.2	176.980	9145.64
25	17	110960	1897.35	26.8	149.815	8889.55
23	18	110960	1500.00	26.8	176.980	9274.30
20	19	120304	1897.35	29.2	149.815	8596.63
26	20	110960	1897.35	26.8	149.815	8889.55
3	21	101616	2294.70	26.8	149.815	9168.45
9	22	101616	1897.35	26.8	122.650	9340.33
5	23	110960	1897.35	24.4	122.650	8610.43
10	24	120304	1897.35	26.8	122.650	8342.82
18	25	120304	1897.35	24.4	149.815	8233.98
12	26	120304	1897.35	26.8	176.980	8487.58
17	27	101616	1897.35	24.4	149.815	9218.48

The maintenance and replacement cost responses were evaluated by minimisation method while the generated income response was evaluated by maximization method.

By the evaluation of equation (12) for minimization at a desirability index of 1, with the maximum and minimum values of maintenance cost response in Table 5 for $Y_i > U$.

$$1 = \left(\frac{4,473.01 - Y_i}{4,473.01 - 2,144.24} \right)$$

Which gives $Y_i < 2,144.24$

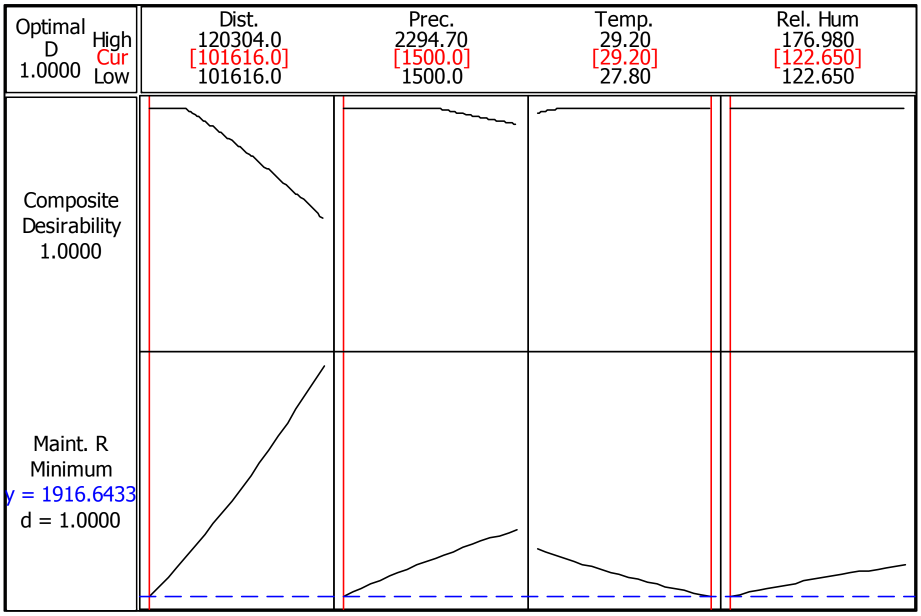

Fig. 1. Optimization plot for maintenance cost

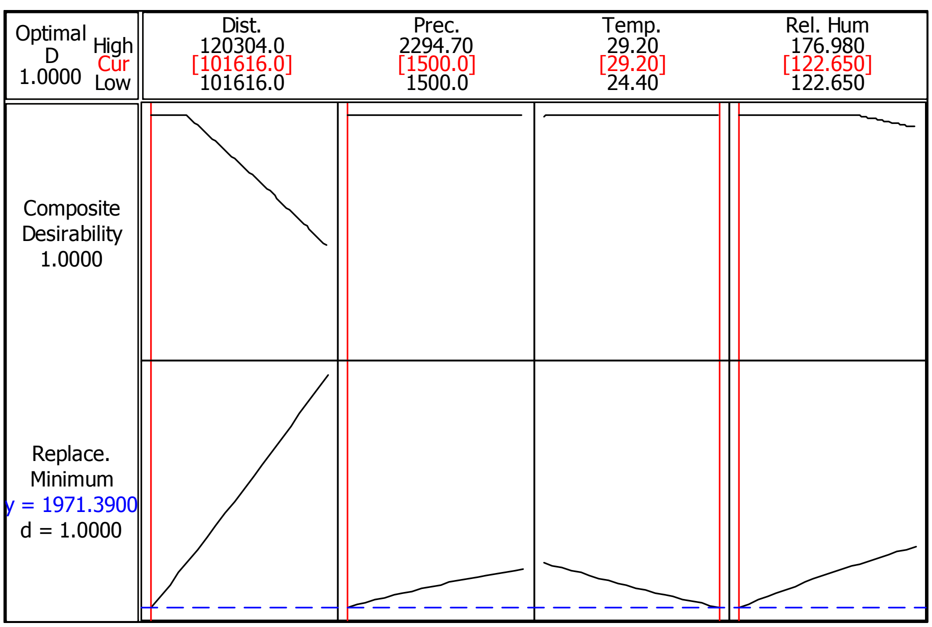

Fig. 2. Optimization plot for replacement cost

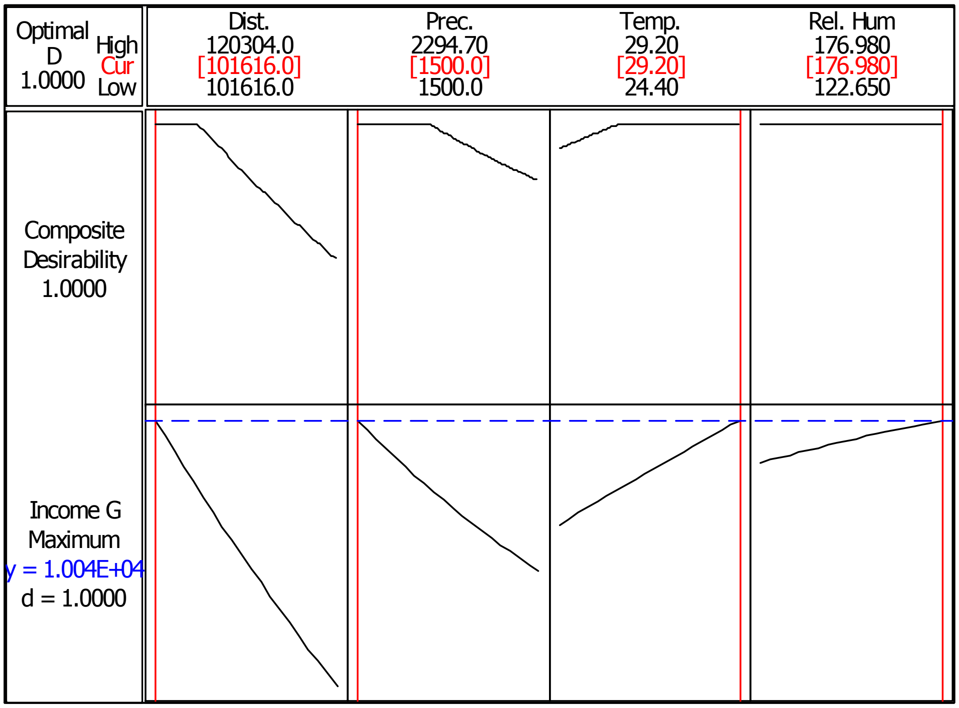

Fig. 3. Optimization plot for income generated

From the optimization plot of Fig. 1, Y_i= ₦1,916.64.The result of the validation of the model is an adequate approximation of the result obtained from the optimization plot.

Similarly, the replacement cost response was evaluated with equation (12) for minimization at a desirability index of 1, with the maximum and minimum values of replacement cost response in Table 6 for Y_i>U.

$$1 = \frac{3{,}127.48 - Y_i}{3{,}127.48 - 2{,}103.00}$$

Which gives $Y_i < 2{,}103.00$

From the optimization plot of Fig. 2, Y_i = ₦1,971.39. The result of the validation of the model is an adequate approximation of the result obtained from the optimization plot.

By the evaluation of equation (11) for maximization at a desirability index of 1, with the maximum and minimum values of income generated a response in Table 7 for Y_i>T.

$$1 = \frac{Y_i - 8{,}189.29}{9{,}759.88 - 8{,}189.29}$$

Which gives $Y_i > 9{,}759.88$

From the optimization plot of Fig. 3, Y_i = ₦10,040.00. The result of the validation of the model is an adequate approximation of the result obtained from the optimization plot.

3. RESULTS AND DISCUSSION

3.1 Response Surface Models Obtained from the Evaluation and Optimization of Maintenance, Replacement Costs and Income Generated

The response surface models are second order regression models with $\{(n+1)(n+2)/2\}$ numbers of regression parameters, with n being the number of factors. The regression parameters include the coefficients for main effects A, B, C and D, coefficients for quadratic main effects A^2, B^2, C^2 and D^2 and the coefficients for two factors interaction effects AB, AC, AD, BC, BD and CD and a constant value.

For uncoded factors, the regression models for maintenance, replacement and generated income are presented thus:

$$Y_{m\cos t} = 3708.23 - 0.101076A - 0.862676B + 106.003C - 6.46065D + 8.92869E - 07A^2 \\ -1.12127E - 04B^2 + 3.26418C^2 - 0.0143282D^2 + 2.24767E - 05AB - 0.00275723AC \\ + 0.000168026AD - 0.0236410BC + 0.00144085BD - 0.176736CD. \tag{8}$$

$$Y_{r\cos t} = -187.693 + 0.007A + 0.036B - 6.526C + 0.796D + 0.000A^2 - 0.000B^2 + 0.947C^2 \\ - 0.011D^2 + 0.000AB - 0.001AC + 0.000AD - 0.003BC + 0.000BD - 0.061CD. \tag{9}$$

$$Y_{income\ gen.} = 17296.9 - 0.1A - 1.8B + 203.2C + 7.0D + 0.0A^2 - 0.0B^2 - 1.2C^2 \\ - 0.0D^2 + 0.0AB - 0.0AC - 0.0AD - 0.0BC - 0.0BD + 0.0CD. \tag{10}$$

3.2 Test for Statistical Significance

The summary of the Analysis of variance (ANOVA) for RSM optimization for maintenance costs of Nissan Urvan vehicles is displayed in Table 8. The significance of each term in the model is represented by the p-value associated with the term. A term is not significant if p-value is greater than 0.05. The value 0.05 indicates the significance level of the observed effects. The significance level is the probability of the observed significant effect being due to pure error.

Table 8. Analysis of variance (ANOVA) for RSM optimization for Maintenance costs of Nissan Urvan vehicles

Source	DF	Seq SS	Adj . SS	Adj . MS	F	P
Re grssion	14	10902679	10902679	778763	17416 .70	0.000
Linear	4	10800127	10800127	2700032	60385 .08	0.000
A	1	8675135	8675135	8675135	194015 .75	0.000
B	1	1176880	1176880	1176880	26320 .44	0.000
C	1	641155	641155	641155	14339 .15	0.000
D	1	306957	306957	306957	6864 .96	0.000
Square	4	48595	48595	12149	271 .70	0.000
A * A	1	42509	32412	32412	724 .88	0.000
B * B	1	2499	1672	1672	37 .38	0.000
C * C	1	2991	1885	1885	42 .17	0.000
D * D	1	596	596	596	13 .33	0.003
Interactio n	6	53958	53958	8993	201 .13	0.000
A * B	1	27857	27857	27857	623 .02	0.000
A * C	1	15293	15293	15293	342 .02	0.000
A * D	1	7276	7276	7276	162 .73	0.000
B * C	1	2033	2033	2033	45 .47	0.000
B * D	1	968	968	968	21 .64	0.001
C * D	1	531	531	531	11 .88	0.005
Re sidual error	12	537	537	45		
Lack of fit	10	537	537	54		
Pure error	2	0.0000	0.0000	0.0000		
Total	26	10903216				

The summary of the Analysis of variance (ANOVA) for RSM optimization for replacement costs of Nissan Urvan vehicles is illustrated in Table 9. The outcome of the analysis indicated that some control variables are significant while others are not.

The outcome of the Analysis of variance (ANOVA) for RSM optimization for Income Generation of Nissan Urvan vehicles is shown in Table 10. From the result obtained it could be observed that all the control factors, that is linear factors, square factors, interaction factors and lack of fit are all highly significant. The degree of freedom in the regression model is fourteen. However, the analysis shows that the degree of freedom in linear factors is four, while the degree of freedom in square factors is also four. Finally, the degree of freedom in interaction factors is six. The ANOVA shows an excellent analysis of the data collected and what the data portrays.

Table 11 presented the income generated at optimum condition and the sum of the maintenance & replacement costs. It was observed that by the year 2013 the income generated was less than the sum of maintenance & replacement costs. Fig. 4 showed the chart of the combined plot of optimized income, and the non-optimized sum of maintenance and replacement costs against the operational period.

From the chart presented, it can be seen that by the year 2013 the income generated is less than the sum of maintenance & replacement costs. This shows that the operation of the transportation system is economical for a period of 8 years (from 2005 – 2012), where the income generated is more than the maintenance & replacement costs.

Table 9. Analysis of variance (ANOVA) for RSM optimization for replacement costs of Nissan Urvan vehicles

Source	*DF*	*Seq SS*	*Adj . SS*	*Adj . MS*	*F*	*P*
Re *grssion*	14	2209518	2209518	157823	131063 .99	0 .000
Linear	4	2204234	53	13	11 .08	0 .001
A	1	1875049	32	32	26 .52	0 .000
B	1	70943	2	2	1 .87	0 .197
C	1	93246	2	2	1 .43	0 .254
D	1	164996	5	5	4 .09	0 .066
Square	4	2592	2592	648	538 .23	0 .000
*A * A*	1	1594	979	979	812 .90	0 .000
*B * B*	1	256	260	260	215 .51	0 .000
*C * C*	1	397	159	159	131 .78	0 .000
*D * D*	1	345	345	345	286 .79	0 .003
Interactio n	6	2692	2692	449	372 .61	0 .000
*A * B*	1	550	550	550	456 .61	0 .000
*A * C*	1	725	725	725	602 .08	0 .000
*A * D*	1	1278	1278	1278	1061 .68	0 .000
*B * C*	1	27	27	27	22 .66	0 .000
*B * D*	1	48	48	48	39 .96	0 .000
*C * D*	1	63	63	63	52 .69	0 .000
Re *sidual error*	12	14	14	1		
Lack of fit	10	14	14	1	*	*
Pure error	2	0 .0000	0 .0000	0 .0000		
Total	26	2209533				

Table 10. Analysis of variance (ANOVA) for RSM optimization for income generation of Nissan Urvan vehicles

Source	*DF*	*Seq SS*	*Adj . SS*	*Adj . MS*	*F*	*P*
Re *grssion*	14	4510855	4510855	322204	184137 .62	0.000
Linear	4	4493294	26388	6597	3770 .20	0.000
A	1	3046344	10862	10862	6207 .74	0.000
B	1	934424	5518	5518	3153 .46	0.000
C	1	442454	1673	1673	956 .05	0.000
D	1	70072	383	383	218 .63	0.000
Square	4	15833	15833	3958	2262 .14	0.000
*A * A*	1	6598	6727	6727	3844 .56	0.000
*B * B*	1	8867	6105	6105	3489 .15	0.000
*C * C*	1	118	241	241	137 .68	0.000
*D * D*	1	249	249	249	142 .37	0.000
Interactio n	6	1728	1728	288	164 .55	0.000
*A * B*	1	997	997	997	569 .95	0.000
*A * C*	1	470	470	470	268 .61	0.000
*A * D*	1	75	75	75	42 .79	0.000
*B * C*	1	144	144	144	82 .33	0.000
*B * D*	1	23	23	23	13 .11	0.004
*C * D*	1	18	18	18	10 .52	0.007
Re *sidual error*	12	21	21	21		
Lack of fit	10	21	21	21	475431 .43	0.000
Pure error	2	0.0000	0.0000	0.0000		
Total	26	4510876				

Table 11. Optimized income generated compared with the sum of Non-optimized maintenance and replacement costs

Year	Optimized income₦(x1000)	Non-Optimized sum of Maint & Replac costs₦(x1000)
2005	10165.57	3961.00
2006	10033.30	4490,00
2007	9931.47	4920.00
2008	9540.79	5315.00
2009	9150.10	5598.00
2010	8926.72	5921.00
2011	8639.81	6065.00
2012	8569.29	6605.00
2013	6842.48	6851.00
2014	6762.03	6948.00

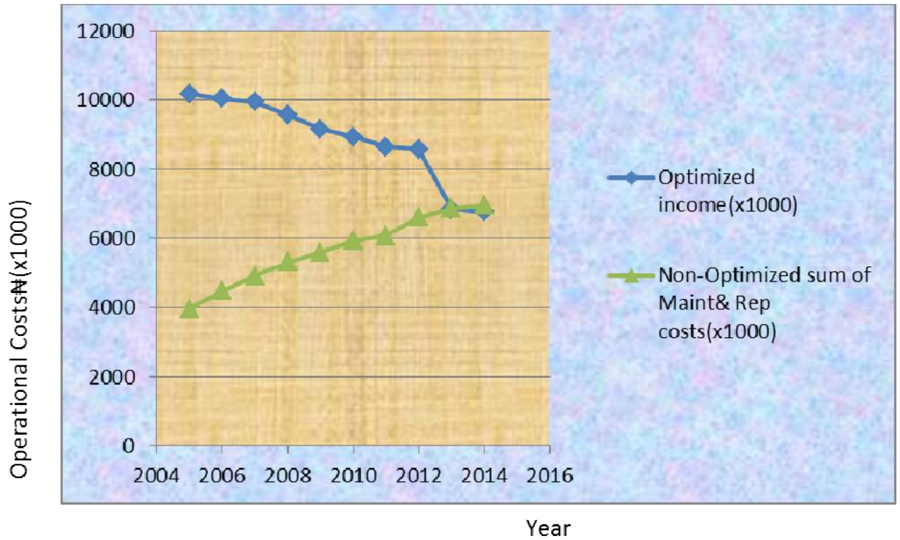

Fig. 4. Plot of Optimized income, and Non-optimized sum of maintenance and replacement costs of Nissan Urvan vehicles against the operational period

4. CONCLUSION

The work has demonstrated the application of Numerical optimization in validating the optimized operationof Nissan Urvan vehicle(s). From the study carried out, the following conclusions were drawn:

1. The results of statistical analysis (ANOVA) show that all the control and interaction factors have significant effects on the maintenance and income generated, while the control factors B, C, and D of replacement cost have no significant effect on replacement cost.
2. The response models of Nissan Urvan Vehicle(s) operations are representable with a nonlinear power law (equations 5 – 7) and second order polynomial equations (equations 8 – 10).
3. The income and costs values of the vehicle(s) operation obtained from the validation of the models are in the ranges of those estimated using the models. It implied that numerical optimization approach was appropriate for validating the optimized performance characteristics of Nissan Urvan Vehicle(s).
4. From Table 11 and Fig. 4, comparing the income generated at optimum condition and the sum of the maintenance & replacement costs by the year 2013 the income generated is less than the expenditures. This shows that the operation of the transportation system was economical for a period of 8 years from 2005 – 2012. It is hereby recommended that response surface model should be deployed for the operational analysis of the case study company to enhance efficient utilization and profitability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Abdul R. Dynamic Programming Based Bus Replacement Policy. Kumasi Press. Ghana; 2011.
2. Goldberg MA, Gomaa AH, Mohib AM. A genetic algorithm for preventive maintenance scheduling in a multiunit multistate system. Journal of Engineering and Applied Science. 2004;51(4):795-811.
3. Latham A. Differences in Forecasting Demand for a Product versus a Service; Demand Media; 2008.
4. Duffuaa SO, Ben-Daya M, Al-Sultan KS, Andijani AA. A generic conceptual simulation model for maintenance systems. Journal of Quality in Maintenance Engineering. 2001;7(3):207- 219.
5. Clarotti R, Martinis P, Murthi V. Simulation based approach for

determining maintenance strategies. International Journal of COMADEM. 2004; 7(3):32-41.
6. Gertsbalch M. Simulation analysis of maintenance policies in just-in-time production systems. International Journal of Operations and Production Management. 1997;17(3):256-266.
7. Steven S. Applications of dynamic programming. State University of New York Stony Brook, NY 11794–4400. 2009;13-20.
8. Zeqing AP, Price JWH. Optimal maintenance intervals for multi-component system. Production Planning and Control. 2006;17(8): 769-779.
9. Parida KL. Recursive utility and dynamic programming. Barbera PH, Seidl C. (editors), Handbook of Utility Theory. 2007; 1 chapter 3 93.121.
10. Chapra SC, Canale RP. Numerical Methods for Engineers, 5th Edition, McGraw-Hill, New York. 2006;460-462 & 623-625.
11. Amponsa K. Optimization technique. University Press, KNUST, Kumasi. 2006; 70–75.
12. Relia Wiki: Response Surface Methods for Optimization. Available:http://reliawiki-org/index.php/Response_Surface_methods_for_opti... (Accessed December 19, 2013)

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/26246