International Journal of Mechanical Engineering and Technology (IJMET)
Volume 9, Issue 8, August 2018, pp. 691–701, Article ID: IJMET_09_08_074
Available online at http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=9&IType=8
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

DATA BASED ANALYTICAL IDENTIFICATION OF VEHICLE MAINTENANCE COST COMPONENTS AND USAGE DATA TRENDS

Aderibigbe Israel Adekitan
Department of Electrical and Information Engineering, Covenant University, Nigeria

ABSTRACT

Learning from past trends is vital for efficient planning and future decisions. Maintenance expenditure is a significant portion of the total operational cost of an organization. In corporate organizations, selected vehicles are dedicated as pool cars for conveying employees as they pursue their business objectives. For optimal performance of pool cars, adequate fund must be available for maintenance purposes and the usage and maintenance profile of each car should be adequately tracked by the maintenance team. The data, statistically analysed in this article contains the maintenance cost, fuel volume and cost, and mileage coverage data for 25 pool cars of a corporate organization. The data present the components that make up the total maintenance cost showing the major faults, the frequency of occurrence and the associated maintenance and repair costs. Monthly trends were developed and maintenance cost predictive analysis using the fuel expenses, fuel volume and mileage coverage data as predictors was performed by identifying the relationships between targets and predictors using Classification and Regression (C&R) Tree node analysis. The result shows that a significant correlation exists between the mileage covered by the vehicles and the maintenance cost, this therefore emphasizes the need for mileage based periodic maintenance of vehicles. This study serves as a basis and motivation for corporate organizations to collect relevant vehicle usage and maintenance data that can reveal vital information and trends about their vehicle maintenance culture and management.

Keywords: Classification and Regression (C&R) Tree, Data pattern recognition, fault frequency tracking, predictive cost analysis, road transportation, vehicle maintenance
Cite this Article: Aderibigbe Israel Adekitan, Data Based Analytical Identification of Vehicle Maintenance Cost Components and Usage Data Trends, International Journal of Mechanical Engineering and Technology, 9(8), 2018, pp. 691–701.
http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=9&IType=8

1. INTRODUCTION

Transportation is vital for socio economic interactions. Efficient and safe transportation requires a cost effective maintenance and risk analysis based strategy [1, 2]. In Nigeria, the road transport sub-sector contributes about 90% to the Gross Domestic Product. As at the end of 2017, the estimated number of vehicles in Nigeria was 11,583,331 [3, 4]. Road transportation support the movement of products and services from one region of a country to another. In Nigeria, road transportation is the major means of conveying products from the manufacturing industries located in one state to other states of the country where such products are needed, and this is usually managed by the supply and distribution department of such establishments [5, 6].

The efficiency and safety of road transportation is highly influenced by the quality of road infrastructure [7, 8], the mode of traffic management [9] and the operational state of the vehicles. Vehicles must be adequately maintained to minimize emissions [10], to ensure optimal performance and service longevity. The usage of a vehicle, and various operational and environmental factors [11] affect the vehicle's performance and maintenance requirements. A study was performed in 2009 by AAA Car Care, and the research reveals that more than 62% of vehicles operate under severe service conditions due to extensive start and stop operation in intense traffic, high environmental temperature, transportation of heavy cargos and low speed travels over long distances. These severe service conditions applies to most vehicles in Nigeria, and coupled with the poor state of a number of roads with pot holes and unpaved sections; the consequence of this operational reality is that vehicles in Nigeria tend to break down often thereby requiring frequent maintenance and a sizable budget for handling the recurrent repair expenses.

According to [12], the availability of data on maintenance and repair expenses is vital for determining the optimal time to replace a vehicle by observing maintenance trends that will allow the maintenance team to identify when there is a sporadic increase in breakdowns and repair cost for a given vehicle in order to prevent gradual vehicle decline into operational chaos because assets always depreciate. A defective vehicle is a hazard to other road users; the study by [7] shows that about 34% of road accidents are caused by a combination of road network related factors and other factors, while about 13% of vehicular crashes are caused by vehicle related factors.

Availability of vehicle usage data, and appropriate management and analysis of such data is vital for vehicle maintenance trend identification. In this study, an attempt is made to determine if truly vehicle usage and maintenance data provides any valuable information that can help management in vehicle maintenance cost management and in adopting an appropriate maintenance policy. To validate this research question, the maintenance cost, the fuel cost, the fuel volume per refuel for each car and the mileage covered by 25 operational pool cars of a corporate organization over a period of 5 months were analysed.

2. METHODOLOGY

Maintenance has several parameters that can be used for objective analysis [13]. In this study, raw data was collected from daily maintenance and operational records for 25 corporate pool cars, and these were grouped into totals per vehicle for comparative plots. 111 days with vehicle maintenance and fuel related data were logged while days without any data record were excluded. Four data parameters were collected and these are: the Fuel Volume taken per refuel in litres, Car Mileage, Fuel Cost and the Maintenance Cost (MC) per vehicle and per repair. The data was sorted to highlight the type of faults experienced, the frequency of occurrence and the percentage contribution to total maintenance cost. The study by [8, 9] shows the use of crash data for traffic safety analysis and planning. Likewise, learning and maintenance planning can also be further enhanced via pattern recognition from various vehicle usage and maintenance data [14].

The data collected was applied in analysing the maintenance cost trend for the 25 pool cars. This was done to enable pattern recognition, and relationship identification among the available data parameters such as the fuel volume, the cost of fuel, mileage and the maintenance cost over a period of 5 months. A total of 170 maintenance cost fault-components were identified as shown in Table 1.

Table 1 The breakdown of maintenance cost in terms of faults and frequency of occurrence

S/N	Faults & Expenses	Frequency	Cost (%)
1	Alignment	1	0.1564%
2	Belt	2	0.6569%
3	Bolt and nut	1	0.0469%
4	Brake adjuster	2	1.0166%
5	Brake disk	1	1.0948%
6	Brake drum	1	2.5023%
7	Brake lining	14	8.3672%
8	Brake oil	7	0.9071%
9	Brake pad	14	4.3791%
10	Brake pin	2	0.2972%
11	Bushing	2	0.2659%
12	Down clutch	1	0.3910%
13	Down link	4	3.6753%
14	Fan puller	1	0.3910%
15	Fuel filter	16	3.2374%
16	Fuel pump	1	0.9384%
17	Gear Box bushing	1	1.0948%
18	Gear box oil	3	1.6265%
19	Gear cable	1	0.3910%
20	Horn	1	0.3128%
21	Hub bearing	1	2.3147%
22	Key fibre	1	0.7820%
23	Labour cost	33	10.8696%
24	New tyre	1	8.4454%
25	Oil filter	16	2.5023%
26	Oil gallon	16	12.7620%
27	Patching of tyre	1	0.0938%
28	Plugs	8	5.8649%
29	Propeller	2	15.6397%
30	Servicing of nozzle	2	2.0332%
31	Set of hose	1	0.3128%
32	Set of oil seal	1	0.3441%
33	Set of tie rod	2	1.7204%
34	Shaft	1	1.8768%
35	Shutter hose	2	0.3128%
36	Up link	2	0.7038%
37	Valve cover parking	1	0.3441%
38	Washing of engine	1	0.3128%
39	Water pump fan	1	1.0166%
		170	100%

The tables, plots, graphs and figures presented, were obtained using similar methods to those applied by [15], and they provide vital trends and insights for reaching logical conclusions which can guide maintenance plans and policies.

3. PRESENTATION OF THE STATISTICAL ATTRIBUTES OF THE DATA COLLECTED

Statistical analyses were carried out to identify patterns and trends within the collected research data, and these are presented in tables and plots. Table 1 shows the maintenance cost component and the frequency of each car fault over a period of 5 months while Table 2 presents the descriptive statistics of the collected data.

Table 2 Descriptive statistics of the collected data

	MC (₦)	Mileage (km)	Fuel (L)	Fuel Cost (₦)
Count	*34*	*102*	*109*	*109*
Mean	18805.88	*1812.07*	*179.59*	*16158.49*
Sum	639400.00	*184831.00*	*19575.00*	*1761275.00*
Min	2000.00	*25.00*	*25.00*	*2175.00*
Max	65000.00	*6401.00*	*645.00*	*56115.00*
Range	63000.00	*6376.00*	*620.00*	*53940.00*
Variance	220222994.65	*1734043.25*	*18984.32*	*150723196.07*
Standard Deviation	14839.91	*1316.83*	*137.78*	*12276.94*
Standard Error of Mean	2545.02	*130.39*	*13.20*	*1175.92*
Median	15350.00	*1712.50*	*140.00*	*13050.00*
Mode	15200.00*	*1015.00*	*50.00*	*4350.00*

*Multiple modes exist, the smallest value is shown

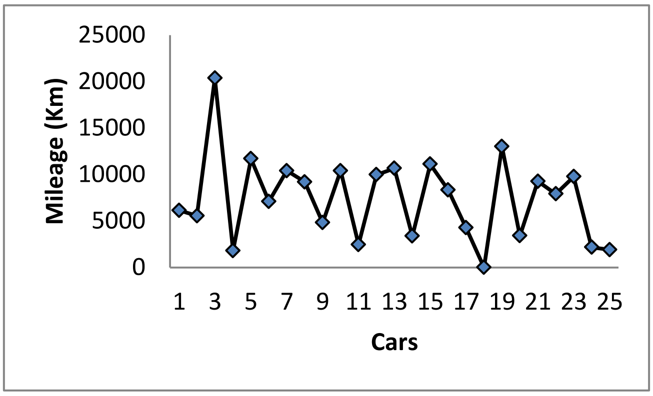

Figure 1 Total mileage per car across 5 months

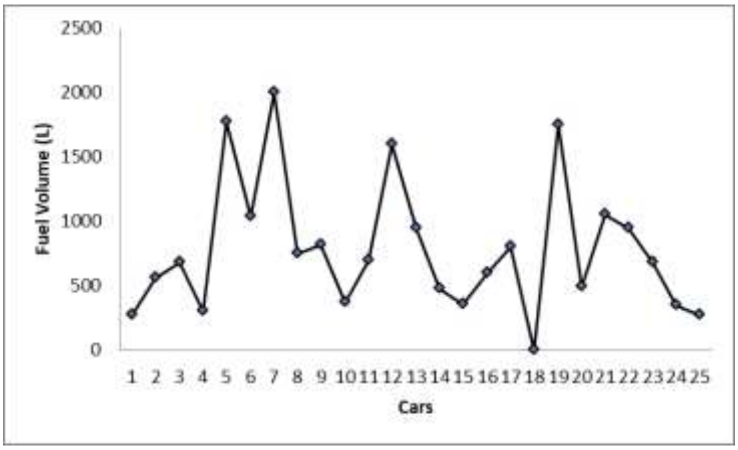

Figure 2 The total volume of fuel received per car across 5 months

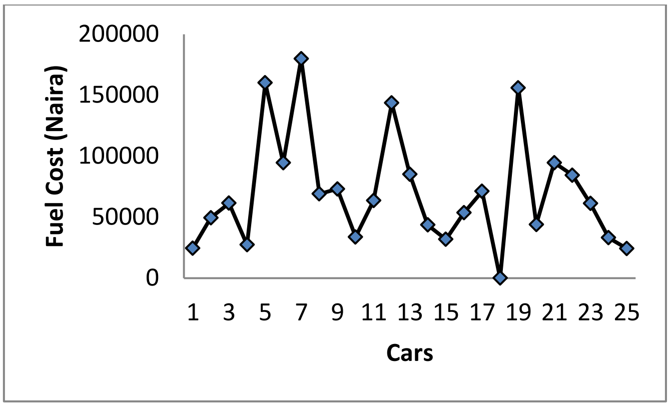

Figure 3 Total fuel cost per car across 5 months

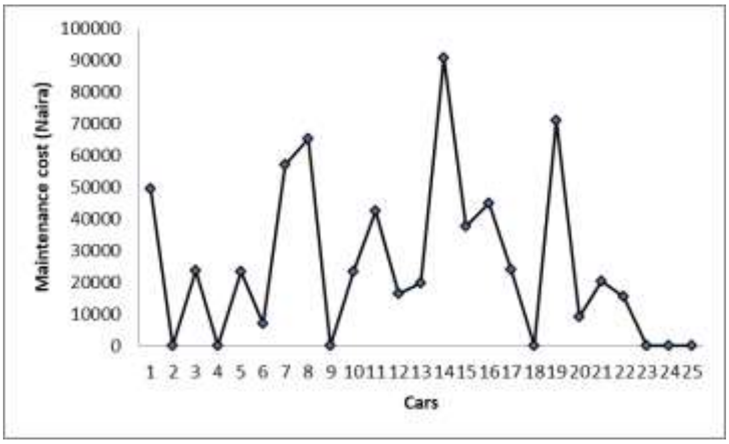

Figure 4 Total maintenance cost per car across 5 months

The total mileage covered by each car over the five month period is shown in Figure 1, Figure 2 shows the total volume of fuel taken by each car, while Figure 3 presents the total cost of refuelling each car, and in Figure 4 the total maintenance cost incurred per vehicle is displayed. For comparative analysis, box plots of the data variation across the five months are presented from Figure 5 to Figure 8.

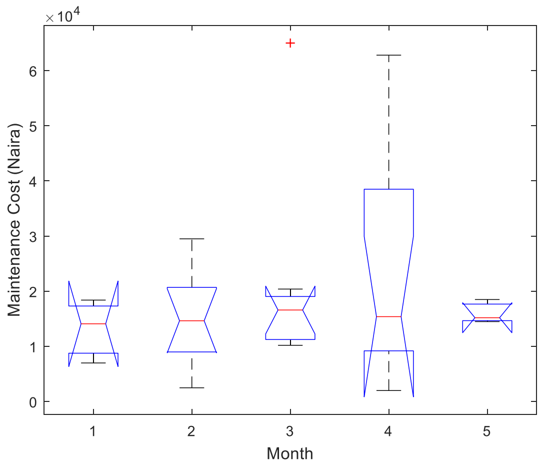

Figure 5 Box plot of the monthly maintenance cost across 5 months

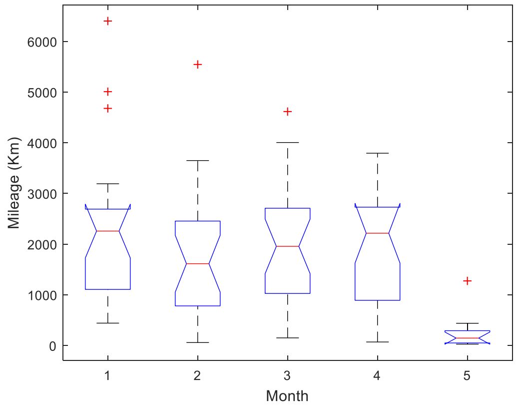

Figure 6 Box plot of the monthly car mileage across 5 months

Figure 5 reveals that more maintenance expense was incurred in the 4th month with a significant variation between the average cost and the maximum cost for that month. This may be due to increased business activity in the fourth month involving extensive travels as shown by the mileage box plot for the 4th month in Figure 6. Figure 7 shows the box plot of the monthly variation in fuel consumption while Figure 8 presents the box plot of the monthly fuel cost for the 25 pool cars.

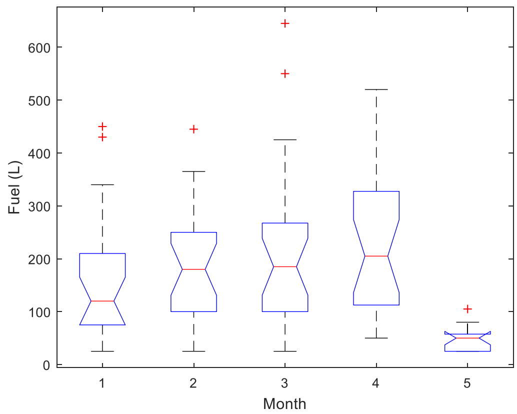

Figure 7 Box plot of the monthly fuel volume across 5 months

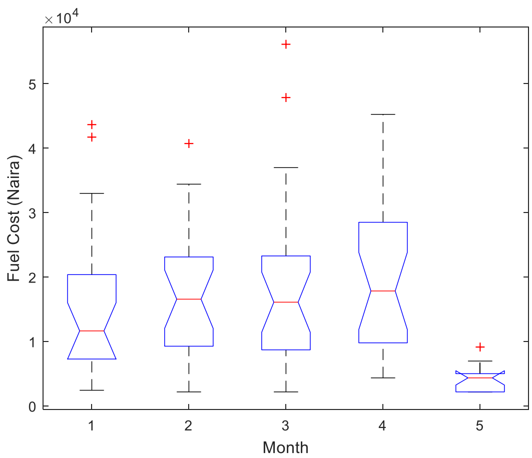

Figure 8 Box plot of the monthly fuel cost across 5 months

4. CLASSIFICATION AND REGRESSION (C&R) TREE NODE ANALYSIS

In order to identify any hidden pattern in the data set, SPSS modeller 18.0 was applied in carrying out parameter relationship analysis for the dataset using the Classification and Regression (C&R) Tree node which creates a decision tree that enables the prediction or classification of future observations.

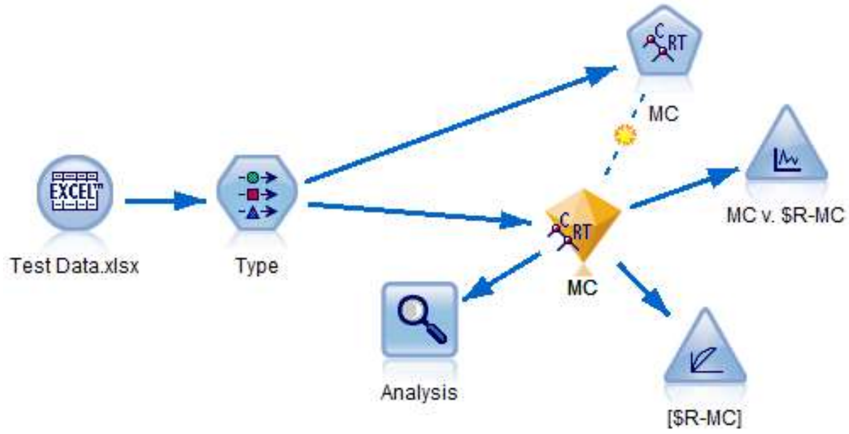

Figure 9 The model implemented for the data analysis

The C&R Tree node divides the parameter data into sections by reducing impurities at each stage. A C&R Tree Model was developed and the data run was executed to show the relationship that exists between the target field, Maintenance cost (MC) and the three predictor fields; the Fuel volume (L), Mileage and Fuel Cost (FC). The model implemented for the data analysis is shown in Figure 9.

5. THE RESULTS AND DISCUSSION

Table 3 Model performance in terms of the modelled and the actual maintenance cost

Parameter	Value
Minimum Error	-14926.667
Maximum Error	14573.333
Mean Error	362.286
Mean Absolute error	4384.952
Standard Deviation	5900.152
Linear Correlation	0.919
Occurrences	111

Table 3 presents the model output in terms of the predicted maintenance cost as compared to the target i.e. the actual maintenance cost. The linear correlation of the C&R Tree Model is 0.919. The C&R Tree node steps are shown in Figure 10. The predictive model accuracy using the gain plot is shown in Figure 11. The importance of each of the three predictors is presented in Figure 12, and it can be seen that the mileage data is more important in the prediction of the maintenance cost. This emphasizes the need for the vehicle maintenance team to establish and enforce mileage interval based maintenance strategy for the vehicles, such that after a vehicle covers a predetermined mileage, periodic maintenance must be carried out on the vehicle.

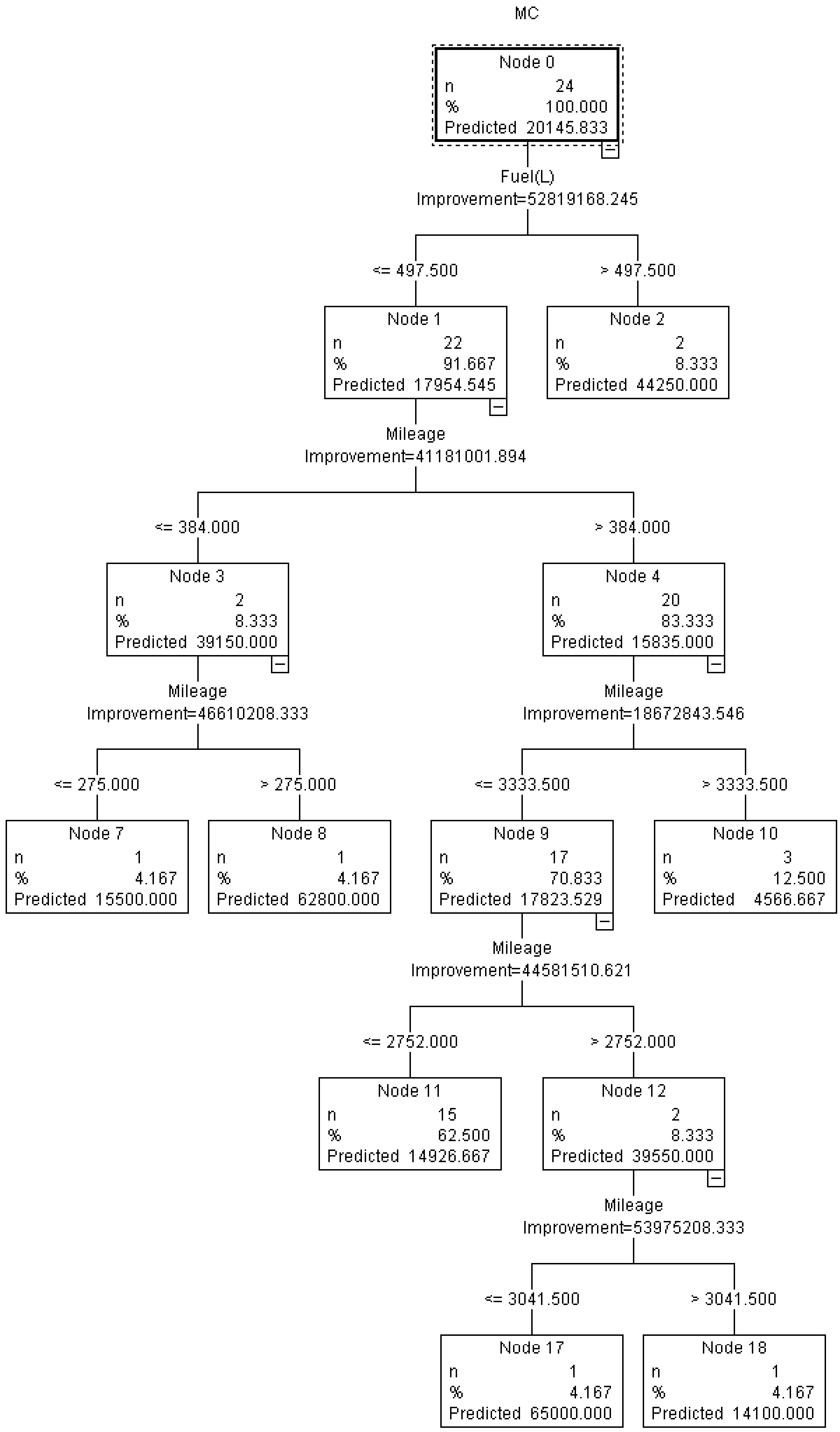

Figure 10 Graphical view of the C&R Tree depth

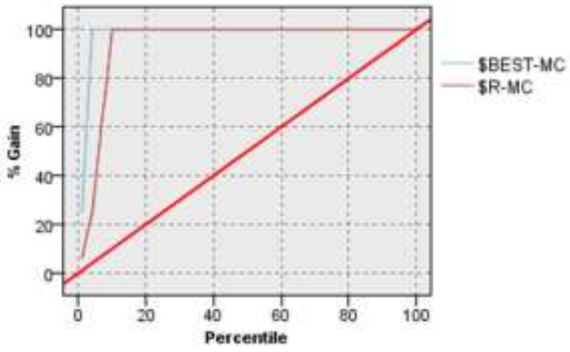

Figure 11 Model accuracy using Gain Plot

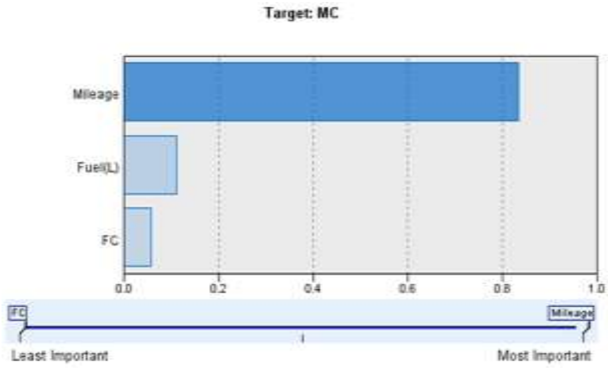

Figure 12 Predictor importance

Monitoring vehicle mileage data trend is vital for identifying vehicles that are intensively used so that such vehicles can get adequate attention in terms of maintenance. It will also help in juxtaposing vehicle usage with maintenance cost, so as to identify vehicles which incur a lot of maintenance cost but are seldom used which might be an indication that such vehicles are at the decline stage and may need to be extensively overhauled or replaced. The vehicle maintenance cost and expenses on fuel as presented in Figure 5 and Figure 8 can be used to observe cost trends, and by considering the minimum, average cost, and the maximum costs for a business year a data-based budget can be developed for the following year.

The box plots of Figure 13, Figure 14, Figure 15 and Figure 16 present the statistical properties of the data collected showing the mean, the quartiles, maximum and minimum values across the complete five months. Figure 13 depicts the vehicle maintenance cost, Figure 14 shows the mileage covered by the 25 vehicles across the five months, Figure 15 presents the box plot of the fuel volume and Figure 16 shows the fuel cost.

The frequency and the nature of the faults that contributed to the maintenance expenses as presented in Table 1 can be used to identify high frequency fault-prone car components, for example Table 1 shows that the brake pad and lining of 14 cars were replaced within five months. Also, by observing trends in maintenance cost and fuel data variation an enquiry may be triggered towards determining the operational factors responsible, in order to allow for future informed decisions, and to prevent fuel and resource mismanagement.

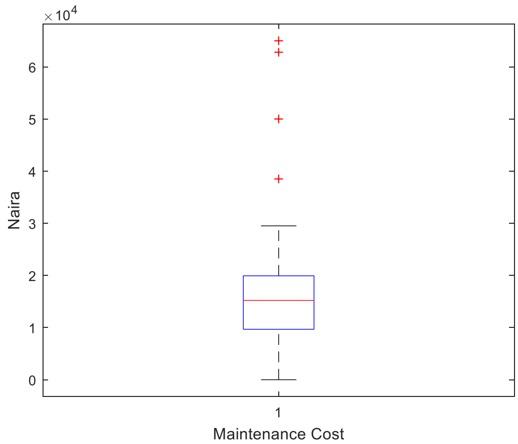

Figure 13 Boxplot of the Vehicle Maintenance Cost

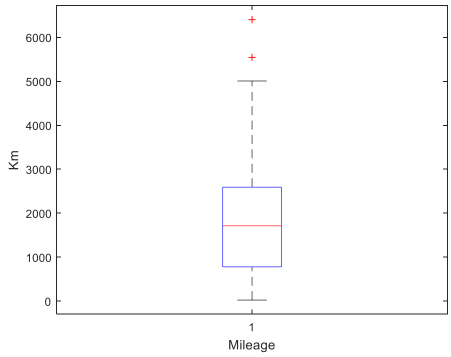

Figure 14 Boxplot of the Mileage covered by vehicles

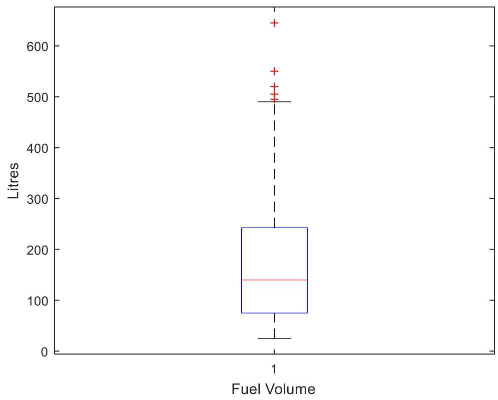

Figure 15 Boxplot of the Fuel Consumption by vehicles

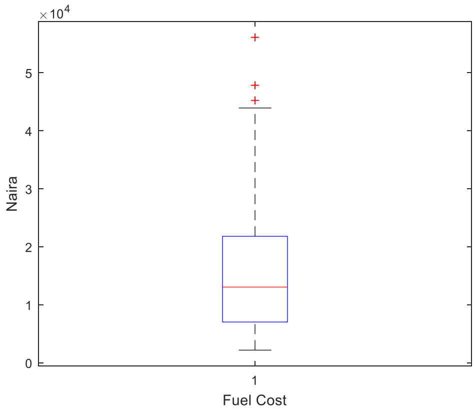

Figure 16 Boxplot of the Fuel Expenses on vehicles

6. CONCLUSION

In research, data is vital for monitoring trends and for identifying patterns which can help in reaching logical conclusions. Vehicle maintenance is necessary to ensure vehicle longevity and also for optimal performance, and as such it becomes imperative that an adequate maintenance policy is in place to guide vehicle maintenance in corporate organizations. Developing a proper policy requires knowledge of vehicle maintenance history and practices so as to identify weaknesses and deploy mitigations, and this requires data. In this study, the maintenance cost, mileage, fuel volume and fuel cost, and fault records for 25 corporate pool cars were extracted from logs; the data was filtered and analysed to identify useful trends and pattern.

A Classification and Regression (C&R) Tree node analysis was performed and it reveals that the mileage travelled by a car has a significant correlation with the maintenance cost. The data analysis shows variation in data trends across the five months, and it also reveals the car that travelled the most and the car that incurred the highest maintenance cost within the study period. This research has established that indeed valuable information can be extracted from vehicle usage and maintenance data which can help management in vehicle maintenance planning. This study therefore creates a platform and basis for further extensive analysis towards developing intricate data models; both qualitative and quantitative, for corporate car maintenance cost prediction and management.

ACKNOWLEDGMENTS

The Author appreciates Covenant University Centre for Research, Innovation and Discovery for the financial support that enabled the publication of this article

REFERENCES

[1] Adewumi, A.O. and O.J. Adeleke, A New Model for Optimizing Waste Disposal Based on Customers' Time Windows and Road Attributes. Applied Mathematical Sciences, 2016. 10(42): p. 2051-2063.

[2] Adekitan, A., Root Cause Analysis of a Jet Fuel Tanker Accident. International Journal of Applied Engineering Research, 2017. 12(24): p. 14974-14983.

[3] National Bureau of Statistics, Transport Statistics. 2017.

[4] National Bureau of Statistics, Road Transport Data Q4 2017.

[5] Kaleel Ahmed, A., C.B.S. Kumar, and S. Nallusamy, Significance of research design in supply chain management for small and medium enterprises. International Journal of Mechanical Engineering and Technology, 2018. 9(4): p. 763-770.

[6] Kaleel Ahmed, A., C.B. SenthilKumar, and S. Nallusamy, Role of supply chain management on indian industrial sectors. International Journal of Mechanical Engineering and Technology, 2018. 9(4): p. 460-467.

[7] Ahmed, I., Road infrastructure and road safety. Transport and Communications Bulletin for Asia and the Pacific, 2013. 83: p. 19-25.

[8] Khalili, M. and A. Pakgohar, Logistic regression approach in road defects impact on accident severity. Journal of Emerging Technologies in Web Intelligence, 2013. 5(2): p. 132-135.

[9] Oluwagbemi, O.O., Reducing road-traffic accidents on african roads through a computer simulation programming approach. Australian Journal of Basic and Applied Sciences, 2010. 4(8): p. 3016-3024.

[10] Boldin, A.P., V.I. Sarbaev, and P.V. Aksenov, Diagnostics of passenger cars and minibuses with diesel engines for compliance with euro emissions standards. International Journal of Mechanical Engineering and Technology, 2017. 8(12): p. 933-943.

[11] Liu, Y., Weather Impact on Road Accident Severity in Maryland. 2013.

[12] Bibona, S. How to Calculate Optimal Replacement Cycles. Fleet Financials 2015; Available from: https://www.fleetfinancials.com/155875/how-to-calculate-optimal-replacement-cycles.

[13] Bolu, C., Modeling maintenance productivity measurement of engineering production systems: Discrete event simulation approach. Vol. 13. 2013. 10-19.

[14] Adekitan, A.I., B. Adetokun, and K. Okokpujie, A data-based investigation of vehicle maintenance cost components using ANN, in International Conference on Engineering for a Sustainable World. 2018.

[15] Adekitan, A.I. and O. Omoruyi, Stock keeping accuracy: A data based investigation of storage tank calibration challenges. Data in Brief, 2018. 19: p. 2155-2162.