Repair and Maintenance Cost Analysis of Diesel Engines of Same Make Models using Weibull Distribution Method: A Case Study on JKSRTC

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Abstract: ***Almost all the vehicles that are maintained and run by the Jammu and kashmir state road transport corporation run on diesel engines. For diesel engines the failure rate frequency increases with age and use of engine. The project discusses the prediction of accumulated repair and maintenance cost of the diesel engines against their usage in hours. Recorded data from the JKSRTC service station is used to determine regression models for predicting total repair and maintenance (R&M) costs based on total usage hours. The statistical result of the study indicates that in order to predict total R&M cost, it is more useful for replacement decisions than annual charge. The preventive and corrective maintenance cost of the diesel engines is very important for deciding the appropriate time to replace the diesel engine on the basis of repair and maintenance cost. There are various overall equipment effectiveness (OEE) techniques by virtue of which we can calculate the breakdown hours of individual machine for a definite period that is monthly or yearly which helps to get a detailed record for the management that how the mishandling of machines can increase the breakdown hour which in turn would affect the entire system. Many tools like calculating MTTR, MTTF, BDH, availability etc. help us to develop a genuine prediction schedule. The aim of this study is to provide a statistical analysis for the repair and maintenance cost of diesel engines in order to present an appropriate mathematical model implementation models for the repair and maintenance costs of diesel engines to provide planner and policy maker and also owners an opportunity to evaluate performance of diesel engine economics.***

Keywords: MTTR, MTBF, BDH, Availability, Maintenance.

1. Introduction

Diesel engines are most widely used for the generation of power. Diesel engines are widely used in different applications, the failure frequency of diesel engines increase with use and age. Costs of owning and operating including preventive and corrective maintenance cost of diesel engine is very important for deciding the appropriate time to replace the engine on the basis of repair and maintenance costs. The decision of replacing the diesel engine is based on the repair and maintenance (R&M) costs analysis and prediction of future repair and maintenance costs of diesel engines. The failure frequency of new diesel engine occurs rarely therefore less maintenance cost is incorporated, but as the age increases maintenance cost also increases.

As for my thesis is concerned i have taken repair and maintenance cost analysis from a semi government corporation in Jammu and Kashmir i.e. Jammu and Kashmir state road corporation abbreviated as Jksrtc. The Jksrtc is the leading corporation in Jammu Kashmir which has around 529 busses and 318 trucks in running condition according to key statistics of 2015-2017. The average revenue per vehicle per day of a single bus is Rs.4571. The average passengers carried per year is 37.57 lacs and average cargo carried per year is 35.42 lac million tonnes. These busses and trucks operate over around 150 routes. The jksrtc has its head offices at both the capitals of the state. The corporation has an approximate number of 60 busses and 15 trucks which have been condemned because of their maximum failure rate of engines. The corporation is the main source of income to the state but in past few years it is showing an economic decline and is running into a great loss situation. Presently the corporation represents a significant financial burden for the state government. The reason for such loss is because the corporation does not have the proper maintenance schedules and policies for the useful operation of services which results in wastage of resources and hence leads to loss. The cause also lies in irregular maintenance and supervision. Also the use of sub-standard components adds to the frequent failure. Further the unpunctuality of services, safety and security concerns and environmental conditions add to its failure.

The thesis discusses the prediction of accumulated repair and maintenance cost of the diesel engines against their usage in hours. Recorded data from the JKSRTC service station is used to determine regression models for predicting total repair and maintenance costs based on total usage in hours. The statistical result of study indicates that in order to predict the total R&M costs, it is more useful for replacement decisions than annual charge. The preventive and corrective maintenance cost of diesel engines is very important for deciding the appropriate time to replace the diesel engine on the basis of repair and maintenance costs. The analysis also will predict the suitable method for the corporation by which the R&M costs will be minimized.

There are various overall equipment effectiveness techniques by virtue of which we can calculate the break down hours of individual machine for a definite period that is monthly or yearly which helps to get detailed record for the management that how the mishandling of machines can increase the breakdown hours which in turn will help the overall system. Many tools like calculating, MTTR, MTBH, BDH etc. helps us to develop the genuine model.

The aim of the study is to provide the statistical analysis for the repair and maintenance costs of diesel engines in order to present an appropriate mathematical model.

Implementations of appropriate models for the repair and maintenance costs of diesel engines provide planner and policy makers an opportunity to evaluate performance of diesel engine economics.

2. Data Collection

The study was conducted from JKSRTC. Data was collected from busses of TATA company. Busses operating were selected randomly from the study area. Information sought was on buss characteristics and economic costs such as fuel consumption cost, lubrication oil cost, oil and fuel filter replacement cost and workmanship cost. For collecting data to formulate the proper model for R&M costs I examined the log books of various vehicles of same make models. Log books provided me the time to time repairment and its cost in a sequence of time and also maintenance and its cost. Also log books provided the time when the vehicle entered the service station and after being serviced when it was available for work again. This data helped in calculating many other useful data like mean time to failure(MTTF), total breakdown hours(BDH) and mean time between failure(MTBF). The mean operating hours per year was obtained separately then the mean annual replacement cost was also calculated for each bus. The accumulated operating hours per bus was calculated using equation:

$$X_n=\sum_{i=1}^{n} xi \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Where X is the accumulated operating hours, n is the age of the diesel engine in year(y), x is the mean annual operating hours per group in hour per year (h/y) for the group i. Also accumulated repair and maintenance cost was calculated using equation:

$$Y_n=\sum_{i=1}^{n} yi \quad \ldots\ldots\ldots\ldots\ldots(2)$$

Where Y is the accumulated repair and maintenance costs and 'y' is the mean annual repair and maintenance cost for group i. Based on the above relationships the cumulative repair and maintenance costs per group was estimated as the dependent variable and the cumulative hours were computed as independent variable. In order to determine the mathematical model for the study, regression analysis was performed on data using statistical analysis software (SAS, 2009). Five models were used to perform the regression analysis, which include the following:

$Y = a+bx$ Linear model
$Y=a+bx+cx^2$ Polynomial model
$Y=ae^{bx}$ Exponential model
$Y=a+b \ln x$ Logarithmic model
$Y=ax^b$ Power model

Both the dependent and independent variables were used to determine the best model for repair and maintenance cost from the above five models.

3. Maintenance

Maintenance is a routine and recurring activity of keeping a particular machine or facility at its normal operating condition so that it can deliver its maximum performance or services without causing any loss of time on account of accidental damage or breakdown. The idea of maintenance is very old and was introduced along with inception of the machine. In earlierdays, maintenance was not required for a machine until it stopped working. When it stopped working, it was either repaired, serviced or discarded. The costly machines need to be properly maintained/serviced during their entire life cycle to harness their availability. The development of mechanization and automation of production systems and associated equipment, with the accompanying developments of ancillary services and safety requirements, has made it mandatory for engineers to think about proper maintenance of the equipment.

Maintenance is the function to keep the machine /equipment in condition by replacing or repairing some of the components of machine with time. The maintenance concept is an outline plan of the maintenance function will be performed. Based on the feedback taken from the users and the past history of the equipment, detailed measures are taken to concretize the maintenance concept. The procedures thus developed are collectively called as maintenance plan. The development of such a maintenance plan is one of the most important requirements of the maintenance program that requires interaction between user's maintenance requirements.

Maintenance function also involves looking after the safety aspects of certain equipment where the failure of the component may cause a major accident.

4. Weibull distribution method

The weibull distribution method is one of the most widely used lifetime distributions in reliability engineering. It is a versatile distribution that can be used with the characteristics of other types of distributions, based on the value of the shape parameter 'β'. To determine the repair and maintenance costs per hour using weibull distribution method, the total cost as a function of failure time is given as:

$$C\ (T) = \frac{Cf\ F(t) + Cp\ R(t)}{\int_0^t R(t)dt}$$

Where,
C (T) = cost function.
Cf = failure cost,
Cp = preventive replacement cost,
F (T) = cumulative distribution function,
R (T) = reliability function.

In order to determine the cost function the values F (t) and R (t) are required. These functions are calculated using weibull distribution method and the values of these functions are determined by weibull method as.

$$F\ (T) = 1 - e^{-(\frac{t}{\eta})^{\beta}}$$

and

$$R\ (T) = e^{-(\frac{t}{\eta})^{\beta}}$$

Also,
F (T) + R(T) = 1
Where, t = failure time.
Beta,β = shape parameter
η= scale parameter (characteristics life).

Therefore after determining the values of F(T) and R(T), the cost distribution function becomes.

$$C(T) = \frac{Cf\ (1-e^{-(\frac{t}{n})^{\beta}} + Cp\ e^{-(\frac{t}{n})^{\beta}})}{\int_0^t Re^{-(\frac{t}{n})^{\beta}}\ dt}$$

The values of the failure cost (Cf) and preventive replacement cost (Cp) are calculated as :

$$C_f = C_r + C_d$$

And

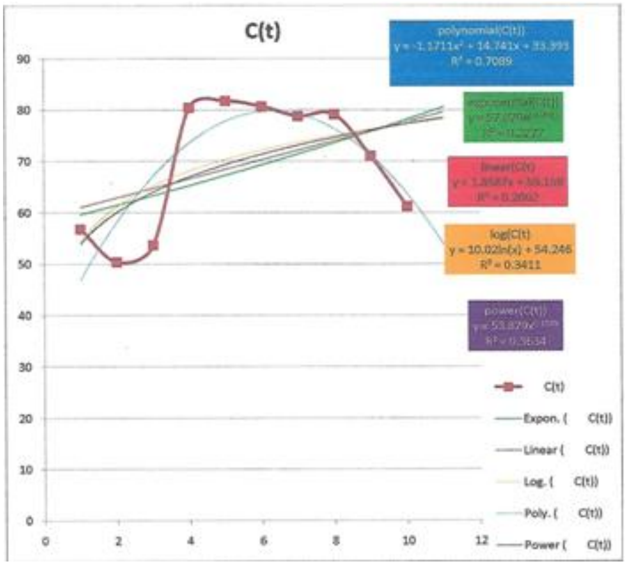
$$C_p = C_i + C_d$$

Where;

C_r = cost of replacement system and components.

C_i = cost of preventive servicing.

5. Model Development



6. Results and Discussions

The table given below presents regression models for prediction of the repair and maintenance cost of engines per hour. The polynomial model correlation coefficient has highest value (0.7089) as compared to other models. Therefore polynomial model is recommended for six cylinder diesel engines.

Most of the researchers published studies in this field like busses, trucks, lorries etc. also suggested that polynomial model gave better results or cost prediction with greater confidence and less variation than that of exponential and logarithmic models because of easiness in calculations. As per given table other models are less significant.

Type of Model	Regression Model C(T)	Value Correlation coefficient (R^2)
Linear	$Y = 1.8587\ X + 59.159$	0.2002
Logarithmic	$Y = 10.02\ln(x) + 54.246$	0.3411
Exponential	$Y = 57.87e^{0.0301x}$	0.2277
Power	$Y = 53.879X^{0.1569}$	0.3634
Polynomial	$Y = 1.1711\ X^2 + 14.741\ X + 33.393$	0.7089

7. Conclusions

The repair and maintenance cost prediction of diesel engines and deciding the time for replacement of engine with new one. The repair coefficients are generally dependent on factors such as research method performance and number of samples taken. Results of this study indicate that the repair and maintenance costs per hour increased with age. These results also confirm that there are considerable variations in repair and maintenance costs among engine models as well as individual ones. Estimates suggest that the repair and maintenance costs increase with age of engine. This method is best suited for replacement decisions than annual charge.

References

[1] Onur Golbasi, N.Demeriel, O. Golbasi (2017), “Risk based reliability allocation methodology to set a maintenance priority among system components” maintenance and reliability journal, 2017.

[2] Nayeema Sultana, Md. Rezaulkarim (2015),”optimal replacement age and maintenance cost: A case study” American journal of theoretical and applied statistics.

[3] Chandrahas, Santosh Kumar Mishra and Deepak Mahapatra (2015), “maintenance strategy and decision making – AHP method” intenational journal of advanced engineering research and studies.

[4] Khalid Aboura, Johnson I. Agbinya, Ali Eskandarian (2014), “weibull decision support systems in maintenance”, organizacija, volume 47.

[5] D.R Dolas[1], M.D Jaybhaye[2], Sudhir.D. Deshmukh[3] (2014), “Prediction of repair and maintenance costs of diesel engines”, international journal of recent advances in mechanical engineering (IJMECH) vol.3, No. 1, February 2014.

[6] Abubakar M.S ,zakari M.D, Shittu S.K and Attanda M.L (2013), “ Determination of repair and maintenance cost for MF375 tractor: A case study in Kano Metropolis, Nigeria”” ,Arid zone journal of engineering, technology and environment, August 2013; vol.9,27-35.

[7] K . Yao and D.A Relescu, (2013), “Age replacement policy in uncertain environment”, Iranian journal of Fuzzy systems Vol.10,No.2,PP 29- 39

[8] J. Sebo, J. Busa,P. Demec, J. Svetlik, (2013), “ optimal replacement time estimation for machines and equipments based on cost function,” METALURGIJA Vol.52,No 1, pp 119 – 122

[9] Issac, O. Ajao, Adedeji, A.Abdullahi and Ismail, I.Raji, (2012), “ polynomial regression model of making cost prediction in mixed cost analysis,” Mathematical theory and modelling Vol.2,No.2,pp14 -23

[10] Fereydoun Keshavarzpour, (2011), “ prediction of repair and maintenance cost of Massey Ferguson 285 tractors,” Agricultural Engineering Research Journal 1 (3),pp 63 – 67