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Reliability Analysis of Car Maintenance Forecast and Performance

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ABSTRACT: *In reliability analysis of car maintenance forecast and performance, researchers have mostly dealt with problems either without maintenance or with deterministic maintenance when no failure can occur. This can be unrealistic in practical settings. In this work, a statistical model is developed to evaluate the effect of predictive and preventive maintenance schemes on car performance in the presence of system failure where the forecasting objective is to minimize schedule duration. It was shown that neither method is clearly superior, but the application of each depends on the forecast environment itself. Furthermore, we showed that parameter values can be chosen for which preventive maintenance perform better than predictive maintenance. The result provided in this study can be helpful to practitioners and system machine administrators, fairplus transport company in Rivers State and works and maintenance department, federal university wukari, taraba state, Nigeria.*

KEYWORDS: *Car maintenance, Reliability analysis, Mean Time to failure, Performance, Weibull probability*

I. INTRODUCTION

The origins of the field of reliability engineering, at least the demand for it, can be traced back to the point at which man began to depend upon machines for his livelihood. The Noria, for instance, is an ancient pump thought to be the world's first sophisticated machine. Utilizing hydraulic energy from the flow of a river or stream, the Noria utilized buckets to transfer water to troughs, viaducts and other distribution devices to irrigate fields and provide water to communities. If the community Noria failed, the people who depended upon it for their supply of food were at risk. Survival has always been a great source of motivation for reliability and dependability.

While the origins of its demand are ancient, reliability engineering as a technical discipline truly flourished along with the growth of commercial aviation following World War II. It became rapidly apparent to managers of aviation industry companies that crashes are bad for business. Karen Bernowski, editor of *Quality Progress*, revealed in one of her editorials research into the media value of death by various means, which was conducted by MIT statistic professor Arnold Barnett and reported in 1994.

Reliability engineering deals with the longevity and dependability of parts, products and systems. More poignantly, it is about controlling risk. Reliability engineering incorporates a wide variety of analytical techniques designed to help engineers understand the failure modes and patterns of these parts, products and systems. Traditionally, the reliability engineering field has focused upon product reliability and dependability assurance. In recent years, organizations that deploy machines and other physical assets in production settings have begun to deploy various reliability engineering principles for the purpose of production reliability and dependability assurance.

Increasingly, production organizations deploy reliability engineering techniques like Reliability-Centered Maintenance (RCM), including failure modes and effects (and criticality) analysis (FMEA,FMECA), root cause analysis (RCA), condition-based maintenance, improved work planning schemes, etc. These same organizations are beginning to adopt life cycle cost-based design and procurement strategies, change management schemes and other advanced tools and techniques in order to control the root causes of poor reliability. However, the adoption of the more quantitative aspects of reliability engineering by the production reliability assurance community has been slow. This is due in part to the perceived complexity of the techniques and in part due to the difficulty in obtaining useful data.

The quantitative aspects of reliability engineering may, on the surface, seem complicated and daunting. In reality, however, a relatively basic understanding of the most fundamental and widely applicable methods can enable the plant reliability engineer to gain a much clearer understanding about where problems are occurring, their nature and their impact on the production process – at least in the quantitative sense. Used properly, quantitative reliability engineering tools and methods enable the plant reliability engineering to more effectively apply the frameworks provided by RCM, RCA, etc., by eliminating some of the guesswork involved with their application otherwise. However, engineers must be particularly clever in their application of the methods because the operating context and environment of a production process incorporates more variables than the somewhat one-dimensional world of product reliability assurance due to the combined influence of design engineering, procurement, production/operations, maintenance, etc., and the difficulty in creating effective tests and experiments to model the multidimensional aspects of a typical production environment.

Despite the increased difficulty in applying quantitative reliability methods in the production environment, it is nonetheless worthwhile to gain a sound understanding of the tools and apply them where appropriate. Quantitative data helps to define the nature and magnitude of a problem/opportunity, which provides vision to the reliability in his or her application of other reliability engineering tools. This article will provide an introduction to the most basic reliability engineering methods that are applicable to the plant engineer that is interested in production reliability assurance. It presupposes a basic understanding of algebra, probability theory and univariate statistics based upon the Gaussian (normal) distribution e.g. measure of central tendency, measures of dispersion and variability, confidence intervals, etc. (Krishnamoorthi,1992; Dovich,1990).

1.1 Basic mathematical concepts in reliability engineering

Many mathematical concepts apply to reliability engineering, particularly from the areas of probability and statistics. Likewise, many mathematical distributions can be used for various purposes, including the Gaussian (normal) distribution, the log-normal distribution, the Rayleigh distribution, the exponential distribution, the Weibull distribution and a host of others. For the purpose of this brief introduction, we’ll limit our discussion to the exponential distribution and the Weibull distribution, the two most widely applied to reliability engineering. In the interest of brevity and simplicity, important mathematical concepts such as distribution goodness-of-fit and confidence intervals have been excluded.

In car maintenance forecast and performance control, good bounds are available for the problem of minimizing schedule durations or the make span provided the worst-case bound for the approximation algorithm, Longest Processing Tim and improved bound using the heuristic by combining these were able to obtain an even tighter bound Graham, R.L(1969). These studies, however, assumed the continuous availability of machines, which may not be justified in realistic applications where machines can become unavailable due to deterministic or random reasons.

It was not until the late 1980’s that research was carried out on machine scheduling with availability constraints. Some study considered the problem of parallel machine scheduling with non-simultaneous available time while some discussed various performance measures and machine environments with single unavailability. For each variant of the problem, a solution was provided using a polynomial algorithm. Turkcan, A (1999) analyzed the availability constraints for both the deterministic and stochastic cases. Chen,T et al (1999) conducted a study on scheduling the maintenance on a single-machine. Lee,C.Y and Liman,S.D (1929) studied single-machine flow-time scheduling with maintenance while attempted to minimize the total weighted completion time in two machines with maintenance. Schmidt,G(1988) discussed general scheduling problems with availability constraints, taking into account different release and due dates in a recent work.

1.2 Failure rate and mean time between/to failure (MTBF/MTTF)

The purpose for quantitative reliability measurements is to define the rate of failure relative to time and to model that failure rate in a mathematical distribution for the purpose of understanding the quantitative aspects of failure. The most basic building block is the failure rate, which is estimated using the following equation:

$$\lambda = r / T$$

Where:
λ = Failure rate (sometimes referred to as the hazard rate)
T = Total running time/cycles/miles/etc. during an investigation period for both failed and non-failed items.
r = The total number of failures occurring during the investigation period.

For example, if five electric motors operate for a collective total time of 50 years with five functional failures during the period, the failure rate is 0.1 failures per year.

Another very basic concept is the mean time between/to failure (MTBF/MTTF). The only difference between MTBF and MTTF is that we employ MTBF when referring to items that are repaired when they fail. For items that are simply thrown away and replaced, we use the term MTTF. The computations are the same.

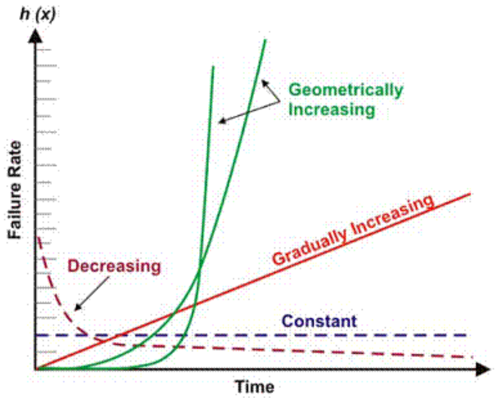
The basic calculation to estimate mean time between failure (MTBF) and mean time to failure (MTTF), both measures of central tendency, is simply the reciprocal of the failure rate function. It is calculated using the following equation.

$$\theta = T / r$$

Where:
θ = Mean time between/to failure
T = Total running time/cycles/miles/etc. during an investigation period for both failed and non-failed items.
r = The total number of failures occurring during the investigation period.

The MTBF for our industrial electric motor example is 10 years, which is the reciprocal of the failure rate for the motors. Incidentally, we would estimate MTBF for electric motors that are rebuilt upon failure. For smaller motors that are considered disposable, we would state the measure of central tendency as MTTF.

The failure rate is a basic component of many more complex reliability calculations. Depending upon the mechanical/electrical design, operating context, environment and/or maintenance effectiveness, a machine's failure rate as a function of time may decline, remain constant, increase linearly or increase geometrically (Figure 1).



Depending upon machine type, the failure rate may decrease, remain constant, gradually increase or geometrically increase as a function of time

Figure 1. Different Failure Rates vs. Time Scenarios

II. THE 7 STEPS FOR IMPLEMENTING RELIABILITY CANTERED MAINTENANCE (RCM)

There are several different methods for implementing RCM that are recommended by different organizations. In general, however, they can be summarized by the following 7 steps.

Step 1: Selection of equipment for RCM analysis

The first step is to select equipment for RCM analysis. The equipment selected for RCM should be critical, in terms of its effect on operations, its previous costs of repair and previous costs of preventative maintenance.

Step 2: Define the boundaries and function of the systems that contain the selected equipment

The equipment belongs in a system that performs a function that is important to the process. The system can be as large or small as necessary, but the function of the system should be known as should its inputs and outputs. For example, the function of a conveyor belt system is to transport goods. Its inputs are the goods and mechanical energy powering the belt, while its outputs are the goods at the other end. In this case, the electric motor supplying the mechanical energy would be considered as part of a different system.

Step 3: Define the ways that the system can fail - the failure modes

In step 3 the object is to list all of the ways that the function of the system can fail. In the case of the conveyor belt it can fail by being unable to transport the goods from one end to the other, or it can fail if it does not transport the goods sufficiently quickly.

Step 4: Identify the root causes of the failure modes

With the help of operators, experienced technicians, RCM experts and equipment experts, the root causes of each of the failure modes can be identified. Root causes for failure of the conveyor could include a lack of lubrication on the rollers, a failure of a bearing, or an insufficiently tight belt.

Step 5: Assess the effects of failure

In this step the effects of each failure mode are considered. The effects include the effects on safety, operations and other equipment. Criticality of each of these failure modes can also be considered.
There are various recommended techniques that are used to give this step a systematic approach. These include:

1. Failure, mode and effects Analysis (FMEA)
2. Failure, mode, effect and criticality analysis
3. Hazard and operability studies (HAZOPS)
4. Fault tree analysis (FTA)
5. Risk-based inspection (RBI)

The most important failure modes will be determined at the conclusion of the systematic analysis of each failure mode. This will be determined by asking questions such as "Does this failure mode have safety implications", and "Does this failure mode result in a full or partial outage of operations?". It is these important failure modes that are then prioritized for further analysis. Importantly, the failure modes that are retained include only those that have a real probability of occurring under realistic operating conditions.

Step 6: Select a maintenance tactic for each failure mode

At this step, the most appropriate maintenance tactic for each failure mode is determined. Importantly, the maintenance tactic that is selected has to technically and economically feasible.

Condition Based Maintenance is selected when it is technically and economically feasible to detect the onset of the failure mode.

Time or Usage Based **Preventative Maintenance** is selected when it is technically and economically feasible to reduce the risk of failure using this method.

For failure modes that do not have satisfactory condition based maintenance or preventative maintenance options, then a redesign of the system to eliminate or modify the failure mode should be considered.

Failure modes that were not identified as being critical in Step 6 may, at this stage, be identified as good candidates for a **run-to-failure maintenance** schedule.

Step 7: Implement and then regularly review the maintenance tactic that is selected.

Importantly, the RCM methodology will only be useful if its maintenance recommendations are put into practice. When that has been done, it is important that the recommendations are constantly reviewed and renewed as additional information is found.

III. METHODOLOGY AND PROCEDURE

Data were collected from a private transport company that faced a problem in reliability analysis of car maintenance forecast and performance. Firstly, the data were analyzed, and rearranged according to the car systems (brake, fuel pump, tyres, Alignment and cooling systems respectively) and according to the common troubleshooting method followed as shown in the figures 2, 4, 6, 8 and 10. Secondly, the traditional standard maintenance technique that is used in car maintenance companies and machine maintenance was applied to choose the best statistical analysis approach. In analyzing the collected data, the Weibull distribution was selected and applied according to several characteristics that make Weibull distribution the best distribution method to be used for these data.

The primary advantage of Weibull analysis is the ability to provide reasonably accurate failure analysis and failure forecasts with extremely small samples. Another advantage of Weibull analysis is that it provides a simple and useful graphical plot. The data plot is extremely important to the engineers and others. Many statistical distributions were used to model various reliability and maintainability parameters. Whether to use one distribution or another is highly depending on the nature of the data being analyzed. Some commonly used statistical distributions are: 1. Exponential and Weibull. These two distributions are commonly used for reliability modeling – the exponential is used because of its simplicity and because it has been shown in many cases to fit electronic equipment failure data. On the other hand, Weibull distribution is widely used to fit reliability and maintainability models because it consists of a family of different distributions that can be used to fit a wide variety of data and it models, mainly wear out of systems (i.e., an increasing hazard function) and in electronic equipment failures, 2. Tasks that consistently require a fixed amount of time to complete with little variation. The lognormal is applicable to maintenance tasks where the task time and frequency vary, which is often the case for complex systems and products.

IV. RESULTS AND DISCUSSION

The aim of using the traditional technique for car maintenance is to calculate reliability function of time R (t) of the overall system (the car). This was done by calculating R (t) for each subsystem in the car parallel to the other.

For calculating the reliability function R (t) for each system, the collected data were converted from Mean Distance to Failure (MDTF) to Mean Time To Failure (MTTF). This is because the reliability function which was used in this study is a function of time, where the reliability decreases as time increases. Hence, the Unreliability function F (t) increases as time increases, which lead to the logic relation, show in equation 1

$F(t) + R(t) = 1.0$ ………………………………………………equ (1)

R (t), MTTF and the mean failure rate (λ) were calculated for each system according to the relations depicted in equation 2.

$R(t) = \exp(-\lambda \text{ x } t) = \exp \left\lceil \frac{-(t-t_o)}{\eta} \right\rceil \beta$ …………………equ (2)

Where t is time, t_o is initial time, β is the slope and Ƞ is scale time parameter. By combining to Equations 1 and 2 is illustrated in equation 3.

$F(t) = 1 - \exp(-\lambda \text{ x } t) = 1 - \exp \left\lceil \frac{-(t-t_o)}{\eta} \right\rceil \beta$ …………….equ (3)

For calculating λ(t), η was calculated by setting the initial time for all subsystems equal to zero. Therefore, F(t) = (1- e^t) =0.632. Then, the unreliability function was drawn on a Weibull probability graph paper as a straight line to estimate η (scale time parameter) from the intersection of the line with the x-axis, and β from the slope of the line plotted for each system as shown in the figures 3, 5, 7, 9 and 11. Then, F(t) was found for each subsystem by applying Equation1. The slope of the Weibull plot, beta, (β), determines which member of the family of Weibull failure distributions best fits or describes the data. The slope, β, also indicates which class of failures is present:

$\beta < 1.0$ indicates infant mortality

$\beta = 1.0$ means random failures (independent of age)

$\beta > 1.0$ indicates wear out failures

Statistical approach was performed; and recommendations were reported to the car company to change preventive time maintenance of the company database to that obtained from statistical approach.

In addition to the above analysis, Unreliability test was made for the overall system, and this was by considering each system work separate to the other (parallel to the other), and this leading to equation 4.

$F_{system} = F_1 \text{x} F_2 \text{x} F_3 \text{x} F_n$ ……………………………….equ 4

For this approach, the real primitive time maintenance was found to make the car Reliable and Available every time of use and this is safe time significantly comparing to break down maintenance as in graph.

The results were divided in string way, namely breaking system, fuel pump, tyres, Alignment and cooling system.

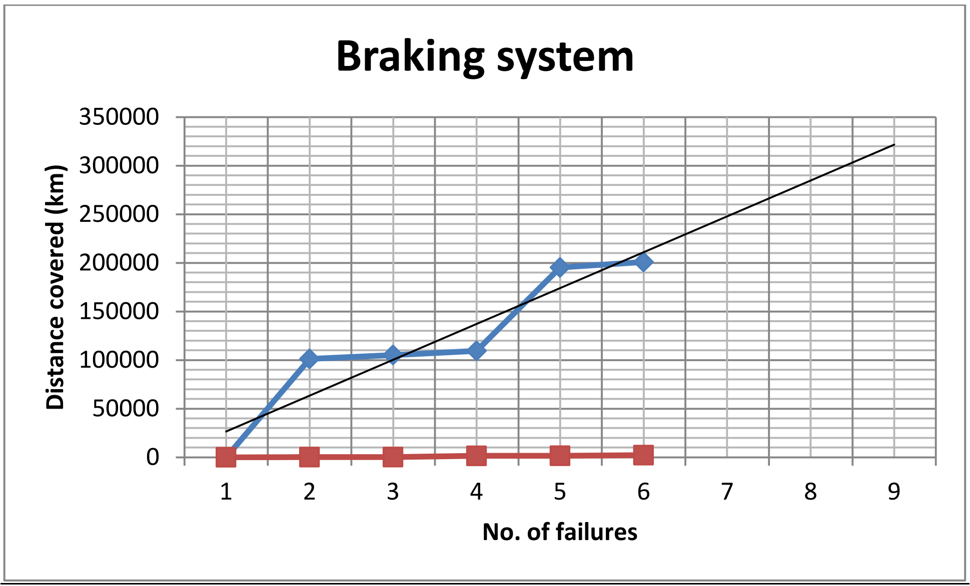


Figure 2. Braking system

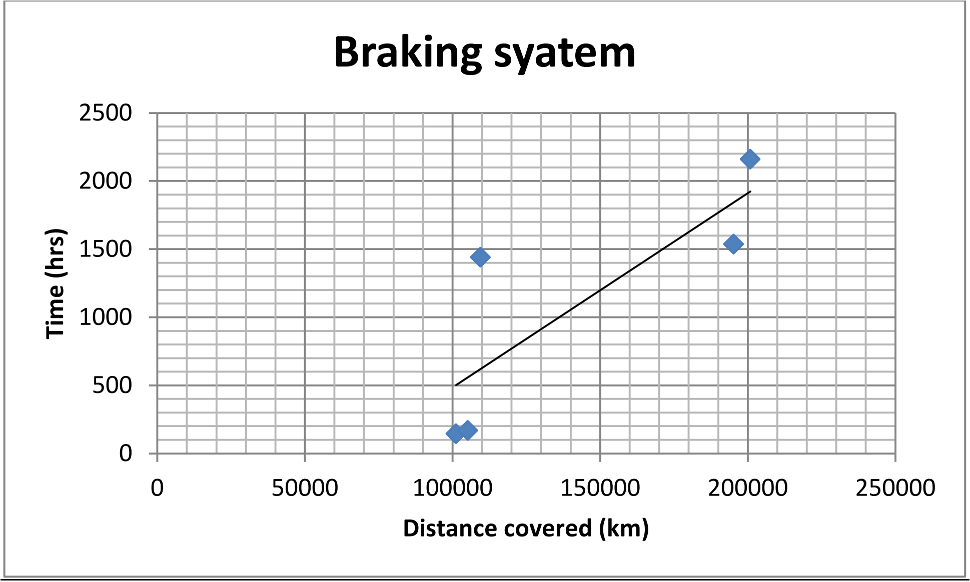


Figure 3. Brake system unreliability data plotted on a Weibull probability graph

η (Scale Parameter) = 1400 hr
β from slope =1.67
Results from statistics analysis showed the following:
Total Average of Distance between Failure (Km) = 10000
Mean Time to Failure (MTTF) = 650
Failure rate model (λ) = 0.047{means very good}
Time of repairing (TOR) = 1.58 hr
Reliability Failure model (R(t)) = 1.200 (at 10 000 Km)
Un-reliability Failure model F(t) = 0.085
R(t)=.99 at Distance= 10000 Km {primitive distance from company}

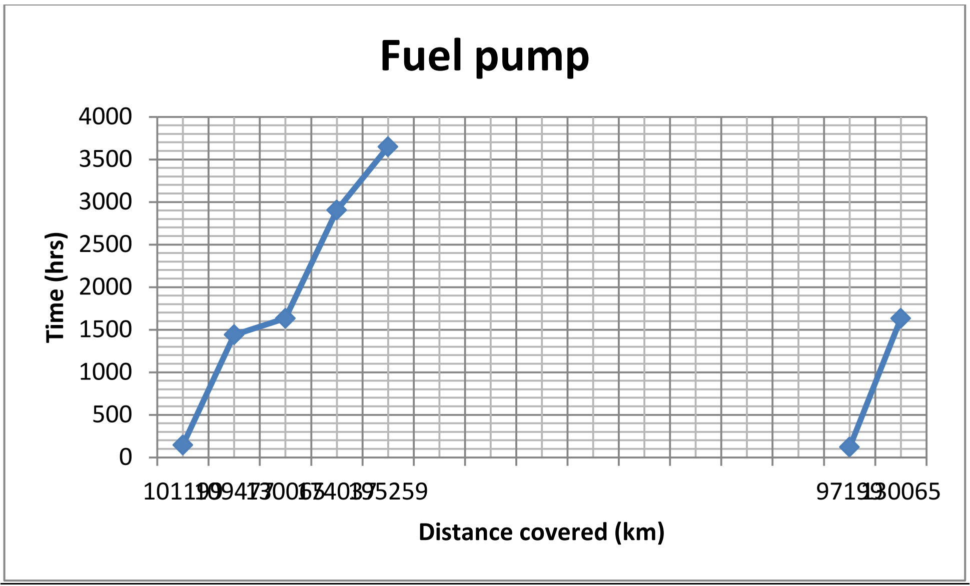


Figure 4. Fuel pump

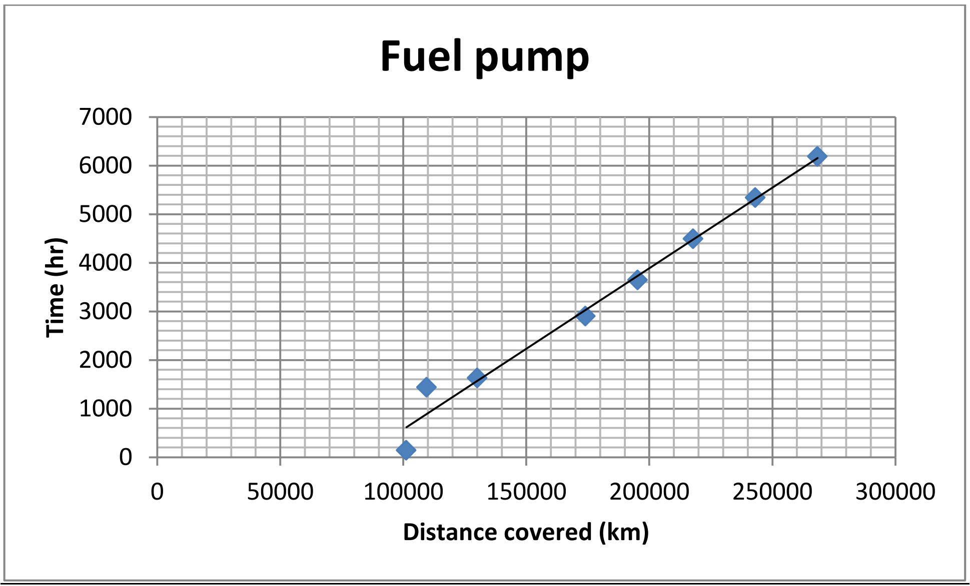


Figure 5. Fuel pump system unreliability data plotted on a Weibull probability graph

η (Scale Parameter) =4200 hr
β from slope = 4.0
Results from statistics analysis showed the following:
Total Average of Distance between Failure (Km) = 20000
Mean Time to Failure (MTTF) = 3000
Failure rate model (λ) = 0.09{means very good}
Time of repairing (TOR) = 4.4 hr
Reliability Failure model R(t) =0.978 (at 100 000 Km)
Un-reliability Failure model F(t) = 0.86
R(t)= 0.90 at Distance= 240000 Km {primitive distance from company}

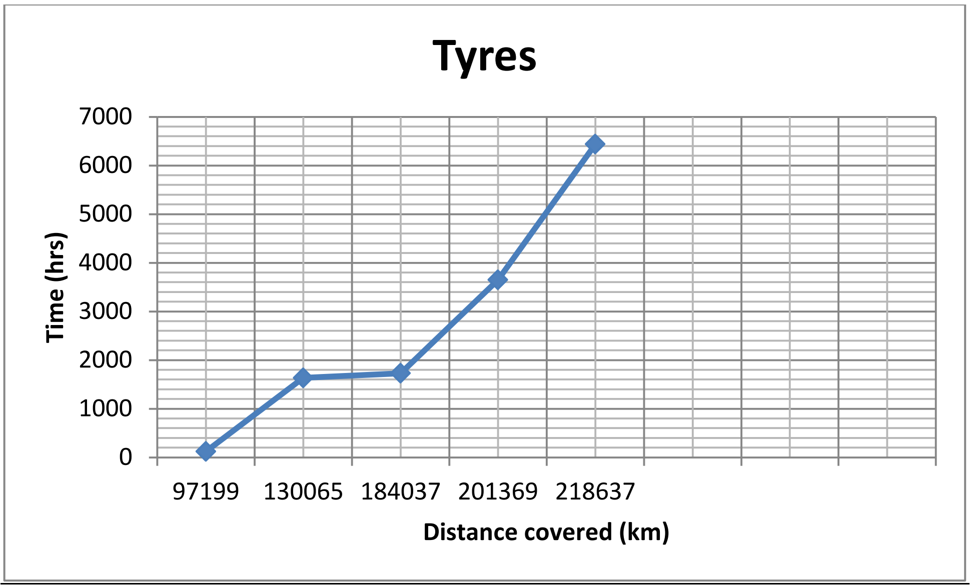


Figure 6. Tyre

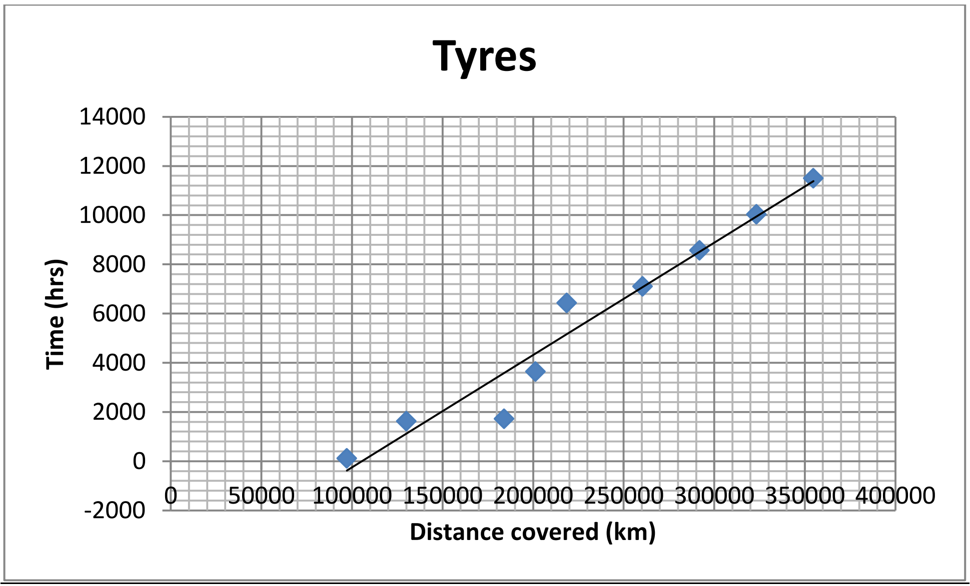


Figure 7. Tyre unreliability data plotted on a Weibull probability graph

η (Scale Parameter) = 1000 hr
β from slope = 3.5
Results from statistics analysis are as follows:
Total Average of Distance between Failure (Km) = 158000
Mean Time to Failure (MTTF) = 620
Failure rate model (λ) = 0.002808{means very good}
Time of repairing (TOR) = 1.2 hr
Reliability Failure model R(t) = 0.93 (at 200 000 Km)
Un-reliability Failure model F(t) = 0.75
R(t)=0.65 at Distance= 200000 Km {primitive distance from company}

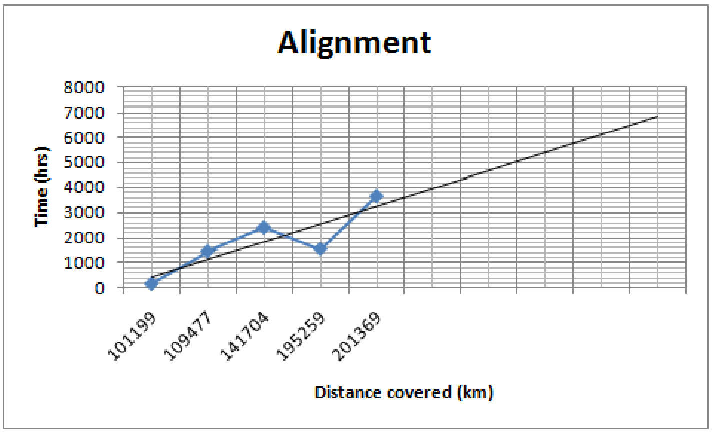


Figure 8. Alignment system

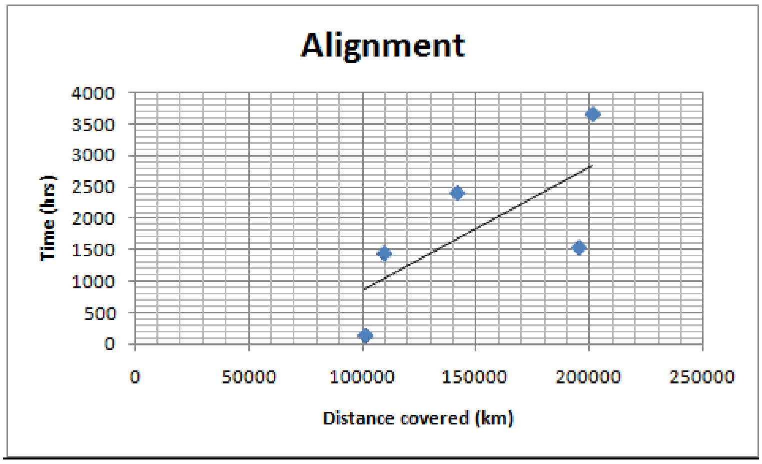


Figure 9. Alignment system unreliability data plotted on a Weibull probability graph

η (Scale Parameter) = 2400 hr
β from slope = 1.8
Results from statistics analysis are as follows:
Total Average of Distance between Failure (Km) = 1400
Mean Time to Failure (MTTF) = 1600
Failure rate model (λ) = 0.08{means very good}
Time of repairing (TOR) = 1 hr
Reliability Failure model (R(t)) = 1.30 (at 150 000 Km)
Un-reliability Failure model F(t) = 0.067
R(t)=.80 at Distance= 100000 Km {primitive distance from company}

V. CONCLUSION

The primitive distance specified from the company was not matching the distance calculated from the statistical analysis based on the real data collected from the work shop. It was found for most of the automobile systems, 15000 -20000km was found to perfect distance for scheduling preventive maintenance to guarantee the reliability and the availability of the automobile for operation. It was assumed that all systems work in parallel, so if one system fails then the other systems still work independently. However, if one assumed all systems to work in series then it means that the overall system configuration will fail. This is not the case in this study. The effect of corrective and preventive maintenance schemes on car performance in the presence of system failure was proven to minimize schedule duration. It was shown that neither scheme is clearly superior, but the applicability of each depends on the scheduling environment itself. Further, the undertaken research work showed that parameter values can be chosen for which preventive maintenance does better than corrective maintenance. The results provided in this study can be useful to system machine administrator in car maintenance, fairplus transporters and motor & generator unit of federal university wukari, taraba state, Nigeria.

Nomenclatures

F(t)	Unreliability function
MTTF	Mean time to failure
MDTF	Mean distance to failure
TOR	Time of repairing
R(t)	Reliability function
Ƞ	Scale time parameter
β	the slope of the weibull graph
t	Time (hr)
λ	The mean failure rate

REFERENCES

[1]. Bernowski, K (1997) “Safety in the Skies,” *Quality Progress*, January.

[2]. Chen,T., Qi,X and Tu,F (1999) "Scheduling the maintenance on a single machine". Journal of the Operational Research Society, Vol. 50, pp. 1071–1078.

[3]. Coffman Jr. E.G, Garey, M.R and Johnson, D.S (1978) "An application of bin-packing to multiprocessor scheduling". SIAM Journal on Computing, Vol. 7, pp 1–17

[4]. Dovich, R. (1990) Reliability Statistics, ASQ Quality Press, Milwaukee, WI.

[5]. Graham,R.L(1969) "Bounds on multiprocessing timing anomalies". SIAM Journal of Applied Mathematics, Vol. 17, pp. 263–269.

[6]. Krishnamoorthi, K.S. (1992) Reliability Methods for Engineers, *ASQ Quality Press*, Milwaukee, WI.

[7]. Lee, C.Y. (1996) "Machine scheduling with an availability constraint". Journal of Global Optimization, Vol. 9, pp, 395–416.

[8]. Lee, C.Y. (1991) "Parallel machines scheduling with no simultaneous machine available time". Journal of Discrete Applied Mathematics, Vol. 30, pp. 53–61.

[9]. Lee, C.Y. and Massey, J.D(1988) "Multiprocessor scheduling: Combining LPT and MULTIFIT". Discrete Applied Mathematics, Vol. 20, pp. 233–242.

[10]. Lee, C.Y. and Liman, S.D. (1929) “Single machine flow-time scheduling with scheduled maintenance". Acta Informatica, No. 92, pp. 375–382.

[11]. Montgomery D. and Runger J.(2007) Applied Statistics and Probability for Engineers, John Wiley and Sons, Inc 4the edition

[12]. Schmidt, G (1988)"Scheduling independent tasks with deadlines on semi-identical processors". Journal of Operational Research Society, Vol. 39, pp. 271–277.

[13]. Troyer, D. (2006) Strategic Plant Reliability Management Course Book, Noria Publishing, Tulsa, Oklahoma

[14]. Turkcan,A(1999) “Machine Scheduling with Availability Constraints". Available at: benli.bcc.bilkent.edu.tr/~ie672/docs/present/turkcan.ps, 1999.