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Reliability Analysis of Car Maintenance Scheduling and Performance

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Abstract

In car maintenance scheduling and performance control, 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 corrective and preventive maintenance schemes on car performance in the presence of system failure where the scheduling objective is to minimize schedule duration. It was shown that neither scheme is clearly superior, but the applicability of each depends on the scheduling environment itself. Furthermore, we 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 practitioners and to system machine administrators in car maintenance scheduling and elsewhere.

Keywords: Car Maintenance scheduling; Mean Time to failure MTTF; Performance Weibull probability.

Nomenclatures

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

1. Intoduction

in car maintenance scheduling performance control, good bounds are available for the problem of minimizing schedule durations, or the make span. Graham [1] provided the worst-case bound for the approximation algorithm, Longest Processing Time, and Coffman, Garey and Johnson [2] provided an improved bound using the heuristic, multifit. By combining these, Lee and Massey [3] were able to obtain an even tighter bound. 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. In a study, Lee [4] considered the problem of parallel machine scheduling with non-simultaneous available time. In another work, Lee [5] 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 [6] analyzed the availability constraints for both the deterministic and stochastic cases. Qi, Chen and Tu [7] conducted a study on scheduling the maintenance on a single-machine. The reader is referred to Schmidt [8] for a detailed literature review of machine scheduling with availability constraints. Other work on scheduling with maintenance is available, but with different scheduling environments and/or objectives. Lee and Liman [9] studied single-machine flow-time scheduling with maintenance while Kaspi and Montreuil [9] attempted to minimize the total weighted completion time in two machines with maintenance. Schmidt [8] discussed general scheduling problems with availability constraints, taking into account different release and due dates in a recent work.

These studies addressed the problem of maintenance, but in a limited way. They either considered only one deterministic maintenance (or availability) constraint or maintenance without machine failures. The results, however, are inadequate for solving real problems. Industrial systems, like automotive or machines, can fail due to heating or lack of lubrication, for example; in computer systems, the Internet is a typical example of system instability and breakdowns due to both hardware and software problems. In such cases, maintenance needs to be carried out, either periodically or after failure. Yet, even with maintenance, failures are not completely eliminated. Furthermore, the overall performance, in

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addition to its being the worst-case performance, is of greater relevance to the users and administrators of these systems.

In this work, we address this need and study the expected maintenance scheduling performance with both maintenance and failures. Since maintenance as well as failure is everyday occurrences in these systems, this study is particularly relevant to practitioners and systems administrators.

2. Methodology and Procedure

Data were collected from a private company that faced a problem in reliability analysis of car maintenance scheduling performance. Firstly, the data were analyzed, and rearranged according to the car systems (brake, steering, clutch, injection 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 engineer and to the manager [Montgomery and Runger 2003]

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 wearout 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.

3. 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 leads to the logic relation

$$F(t) + R(t) = 1.0 \quad (1)$$

R(t), MTTF and the mean failure rate (λ) were calculated for each system according to the following relations [10]:

$$R(t) = \exp(-\lambda \times t) = \exp\left\{\frac{-(t-t_0)}{\eta}\right\}^{\beta} \quad (2)$$

Where t is time, t_0 is initial time, β is slope and η is scale time parameter. By combining to Equations 1 and 2:

$$F(t) = 1 - \exp(-\lambda \times t) = 1 - \exp\left\{\frac{-(t-t_0)}{\eta}\right\}^{\beta} \quad (3)$$

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:

β < 1.0 indicates infant mortality
β = 1.0 means random failures (independent of age)
β > 1.0 indicates wear out failures

A comparison between the preventive time maintenance from the company database and fro

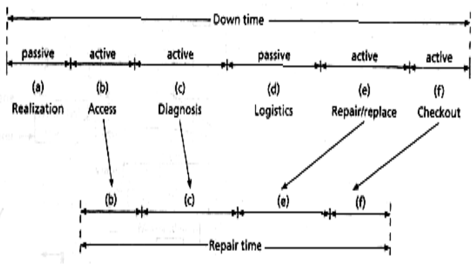

Figure 1. the difference between down time and Repair time

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 the following equation:

$$F_{(system)} = F_1 \times F_2 \times F_3 .... F_j ... F_n \quad (4)$$

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 a sequins way for each system:

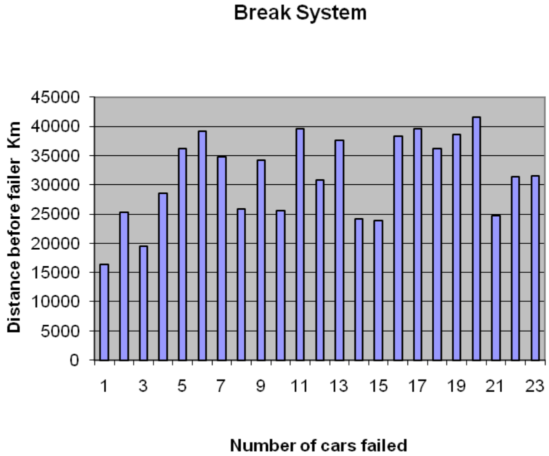

Figure 2. A bar diagram of the brake system data used in the analysis.

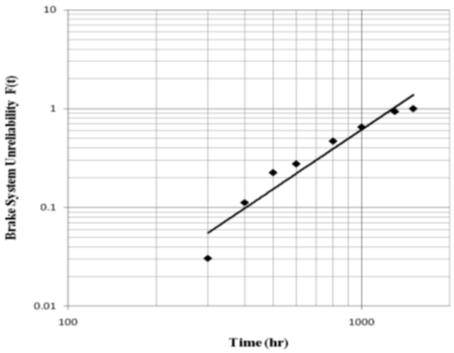

Figure 3. Brake system unreliability data plotted on a Weibull probability graph

η (Scale Parameter) = 1000 hr

β from slope =1.5

Results from statistics analysis:

Total Average of Distance between Failure (Km) = 23688.56

Mean Time to Failure (MTTF) =296.107

Failure rate model (λ) =0.003377 {means very good}

Time of repairing (TOR) = 0.5 hr

Reliability Failure model (R(t))= 0.9969 (at 15 000 Km)

Un-reliability Failure model F(t) =0.0030

R(t)= .85 at Distance= 20000 Km {primitive distance from company}

From statistical analysis and actual data

Distance=15000 Km

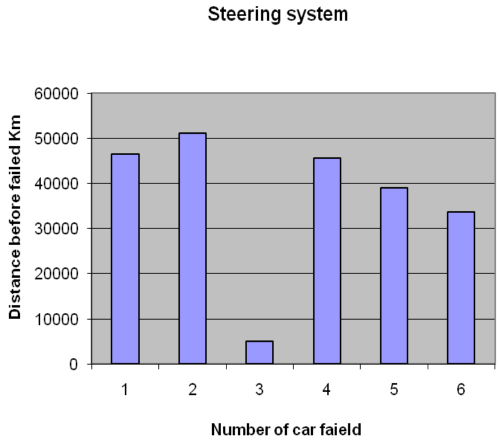

Figure 4. A bar diagram of the steering system data used in the analysis

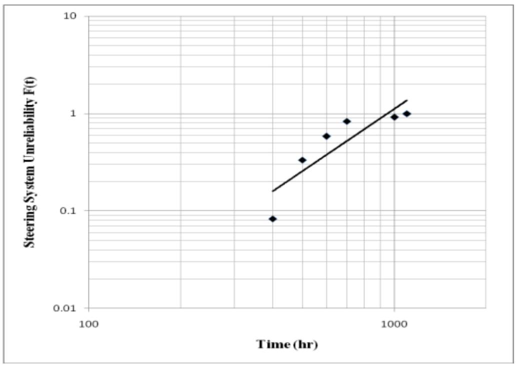

Figure 5. Steering system unreliability data plotted on a Weibull probability graph

η (Scale Parameter) =650 hr

β from slope = 2.4

Results from statistics analysis:

Total Average of Distance between Failure (Km) = 100367.9

Mean Time to Failure (MTTF) = 1254.599

Failure rate model (λ) = 0.000797{means very good}

Time of repairing (TOR) = 2 hr

Reliability Failure model R(t) =0.8612 (at 15 000 Km)

Un-reliability Failure model F(t) = 0.1388

R(t)= 0.68 at Distance= 40000 Km {primitive distance from company}

From statistical analysis and actual data

Distance=15000Km

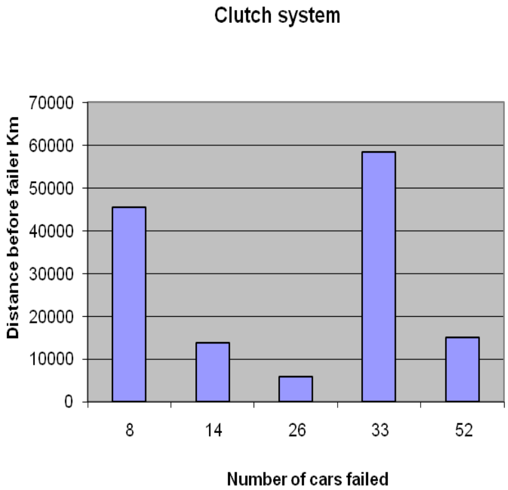

Figure 6. A bar diagram of the clutch system data used in the analysis steering

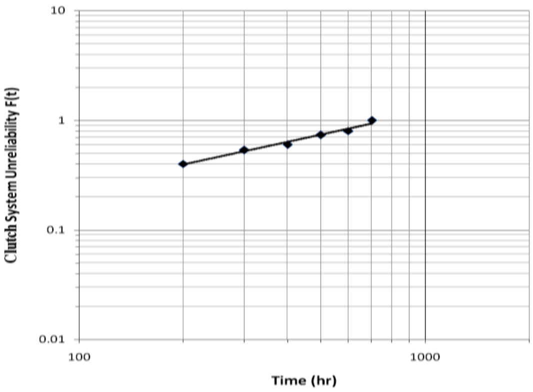

Figure 7. Clutch system unreliability data plotted on a Weibull probability graph

η (Scale Parameter) =580 hr

β from slope = 1.7

Results from statistics analysis:

Total Average of Distance between Failure (Km) = 112367

Mean Time to Failure (MTTF) =384.9573

Failure rate model (λ) = 0.002598{means very good}

Time of repairing (TOR) = 0.4 hr

Reliability Failure model R(t) =0.699 (at 15 000 Km)

Un-reliability Failure model F(t) = 0.301

R(t)=0.133 at Distance= 10000 Km {primitive distance from company}

From statistical analysis and actual data

Distance=15000 Km.

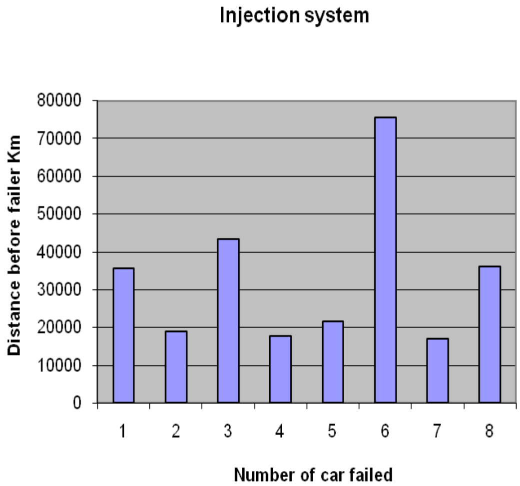

Figure 8. A bar diagram of the injection system data used in the analysis

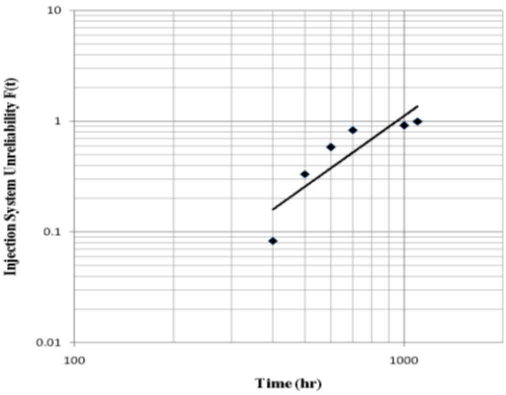

Figure 9. Injection system unreliability data plotted on a Weibull probability graph

η (Scale Parameter) = 680 hr

β from slope = 2.4

Results from statistics analysis:

Total Average of Distance between Failure (Km) = 38930.54

Mean Time to Failure (MTTF) =486.6318

Failure rate model (λ) = 0.002055{means very good}

Time of repairing (TOR) = 0.5 hr

Reliability Failure model (R(t)) = 0.9709 (at 15 000 Km)

Un-reliability Failure model F(t) = 0.0291

R(t)=.99 at Distance= 10000 Km {primitive distance from company}

From statistical analysis and actual data

Distance=15000 Km

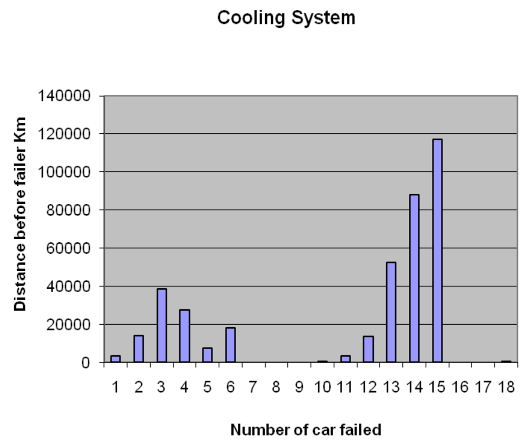

Figure 10. A bar diagram of the cooling system data used in the analysis

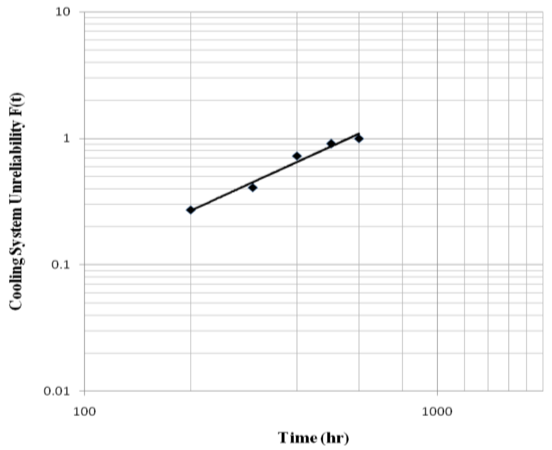

Figure 11. Cooling system unreliability data plotted on a Weibull probability graph

η (Scale Parameter) =620 hr
β from slope = 2.3
Results from statistics analysis:
Total Average of Distance between Failure (Km) = 23688.56
Mean Time to Failure (MTTF) =296.107
Failure rate model (λ 0.003377{means very good}
Time of repairing (TOR) = 0.5 hr
Reliability Failure model (R (t)) =0.642 (at 15 000 Km)
Un-reliability Failure model F (t) = 0.358
R (t) =0.42 at Distance= 4000 Km {primitive distance from company}
From statistical analysis and actual data
Distance=15000 Km.

As a result of calculating the Un-reliability function for each system in the automobile based on the statistical analysis and actual data Distance =15 000Km the total un-reliability of the automobile (overall system) as given in equation 4 is calculated as

F(t) =0.0030 x 0.1388x 0.301x0.0291x0.358= 0.0000013

4. 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 we 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, we 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 practitioners and to system machine administrators in car maintenance scheduling and elsewhere.

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