BUY A NEW AUTOMOBILE OR REPAIR THE OLD ONE

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Abstract

This paper illustrates that repairable systems are those systems which, in the event of a failure, can be repaired, e.g., by replacing a component, and be returned to regular operation. In some cases, the reliability of a system, after a repair, returns to the same state as before the failure.

Key Words: *Automobile, Repair, MTBF.*

Introduction

There are two types of systems. The first is repairable systems, and the second is non-repairable systems. If we assume the system is an automobile. Most automobiles are repairable systems and not replaced when they fail. But on the long run we should replace it when the cost of repairing it becomes very high. In this paper we will investigate this point.

Repairable systems are those systems which, in the event of a failure, can be repaired, e.g., by replacing a component, and be returned to regular operation. In some cases, the reliability of a system, after a repair, returns to the same state as before the failure.

For major repairable systems, a repair will be carried out when the system fails, or before failure, according to a preventive or predictive repair

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strategy. In both cases, the system may be repaired on-site or off-site. On-site repairs usually are minor corrections. When the system failure is more severe, it usually must be taken out of operation and taken to the repair shop. In both cases however the steps to undertake are the same, the system is disassembled, evaluated and finally the repair is carried out. In the evaluation process, it is determined which subsystems have failed and must be addressed and which non-failed subsystems will be addressed as well. Assuming that subsystems are subject to aging, the more subsystems are replaced, the closer the system gets to its "new" state (good-as-new) and when only few subsystems are replaced, the state of the system will likely be close to its state just before the repair (bad-as-old). The state of the system therefore reflects how good (new) or bad (old) the system really is.

The Bathtub Curve

The life of a system can be divided into three distinct periods. Figure 1 shows the reliability "bathtub curve" which models the cradle to grave instantaneous failure rates vs. time. If we follow the slope from the start to where it begins to flatten out this can be considered the first period. The first period is characterized by a decreasing failure rate. This first period is also called infant mortality period. The next period is the flat portion of the graph. It is called the normal life. Failures occur more in a random sequence during this time. It is difficult to predict which failure mode will manifest, but the rate of failures is predictable. Notice the constant slope. The third period begins at the point where the slope begins to increase and extends to the end of the graph. This is what happens when system become old and begin to fail at an increasing rate.

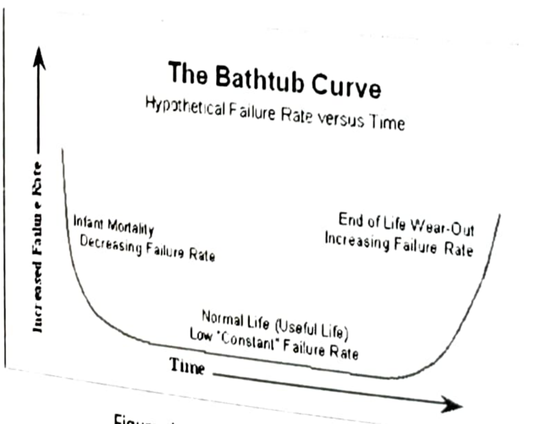
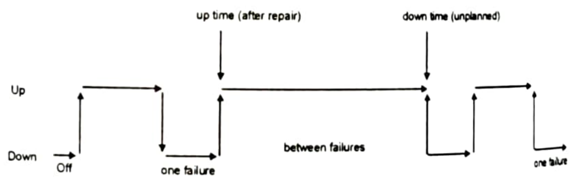


Figure 1 : Reliability Bathtub Curve

Life Data

The term life data refers to measurements of the life of products. Product lifetimes can be measured in days, hours, miles, cycles or any other metric that applies to the period of successful operation of a particular product. Since time is a common measure of life, life data points are often called "times-to-failure" and product life will be described in terms of time throughout the rest of this guide. There are different types of life data and because each type provides different information about the life of the product, the analysis method will vary depending on the data type. With complete data, the exact time-to-failure for the unit is known (e.g. the unit failed at 100 hours of operation). With suspended or right censored data, the unit operated successfully for a known period of time and then continued (or could have continued) to operate for an additional unknown period of time (e.g. the unit was still operating at 100 hours of operation). With interval and left censored data, the exact-time-to failure is unknown but it falls within a known time range. For example, the unit failed between 100 hours and 150 hours (interval censored) or between 0 hours and 100 hours (left censored). In this paper we will concerned with the number of failures in a given period. (e.g. the number of failures of the unit for period of 30 days of operation)

Mean Time Between Failures (MTBF)



For each observation, downtime is the instantaneous time it went down, which is after (i.e. greater than) the moment it went up, uptime. The difference (downtime - uptime) is the amount of time it was operating between these two events.

MTBF is usually expressed in hours or days or any lifetime measurement. Of a system, over a long performance measurement period, the measurement period divided by the number of failures that have occurred during the measurement period.

Theoretical background

Since the failure time of an item may be any positive number, the distribution of failure times is continuous. Thus it can be described either by its probability density function, $f(t)$, or by its cumulative distribution function, $F(t)$. Then the probability that an item will fail in the time interval from t to $t+\Delta t$ is given by $f(t)\Delta t$. Also the probability that an item will fail at any time up to t is given by

$$F(t) = \int_0^t f(u)du$$

It is also convenient to introduce a function R(t) called the reliability function which gives the probability that an item will survive until time t. Thus we have

$$R(t) = 1-F(t)$$

One method of measuring the reliability of a product is to test a batch of items over an extended period of time and to note the failure times.
After testing a sample of items, we will have a series of observed failure times denoted by

$$0 \le t_1 \le t_2 \le \ldots \le t_n$$

Thus it appears that our problem is to estimate the related functions $f(t)$, F(t) and $R(t)$ from the observed failure times. However if the type of mathematical distribution is unknown it is often expedient to estimate another function called the conditional failure rate function (or hazard function or instantaneous failure rate function) which is given by

$$Z(t) = \frac{f(t)}{R(t)}$$

Then the probability that an item will fail in the interval from t to $t+\Delta t$, given that it has survived until time t, is given by $Z(t)\ \Delta t$. It is most important to realize that this is a conditional probability and that $Z(t)$ is always larger than $f(t)$, because $R(t)$ is always less than 1. For example, the proportion of cars which fail between fifteen and sixteen years is very small because few cars last as long as fifteen years. But of the cars which do last fifteen years a substantial proportion will fail in the following year. In fact the function $Z(t)$ describes the distribution of failure times just as completely as $f(t)$ or $F(f)$, and is perhaps the most basic measure of reliability.
It is useful to establish a direct relation between $Z(t)$ and $R(t)$. This is done in the following way.
The functions $f(t)$ and $F(t)$ are related by the equation

$$f(t) = \frac{dF(t)}{dt} \quad \text{and} \quad R(t) = 1 - F(t)$$

$$f(t) = -\frac{dR(t)}{dt}$$

$$\textit{Thus} \quad Z(t) = \frac{f(t)}{R(t)} = \frac{-[dR(t)]/dt}{R(t)}$$

$$\therefore R(t) = \exp\left[-\int_0^t Z(u)du\right]$$

In a given system, failures due to the occurrence of fault(s) take place at a given rate. A failure rate of a system, l, is defined as the expected number of failures of the system per unit time.The *Reliability*, R(t), of a system is defined as the conditional probability that the system operates correctly throughout the interval $[t_0, t]$ given that it was operating correctly at t_0. A relationship between reliability and time that has been widely accepted is the exponential function, i.e., $R(t) = e^{-\lambda t}$. The *mean-time-to-failure* (*MTTF*) of a system is defined as the expected time that a system will operate before the *first* failure occurs. The relationship between the *MTTF* of a system and its failure rate l can be expressed as

$$\text{MTTF} = \frac{1}{\lambda}$$

Whenever a given system fails, it may be possible to bring it back to function through a process called system repair. Repair of a system requires the use of a workshop characterized by a repair rate, μ. The repair rate is defined as the average number of repairs that can be performed per unit time. The mean-time-to-repair (MTTR) of a system is defined as the expected time that the system will take while in repair (being unavailable). The relationship between the MTTR of a system and the repair rate μ can be expressed as

$$\text{MTTR} = \frac{1}{\mu}$$

Assumption & Decision Making

Assume that each failure means cost (Cost of repairing the failure).

Let :

CF_1 = The Cost of repairing 1st. failure.

CF_2 = The Cost of repairing 2nd. failure.

CF_n = The Cost of repairing n-th. failure.

The Total Cost of the Period-j

$(TCPj) = \sum_{1}^{n} CF_i$, i=1...n , j=1 2 . . m

m = number of periods.

n = is the number of failures in each period.

Mean Total Cost of the Period (MTCP).

$$MTCP = \frac{\sum_{1}^{m} TCP_j}{m}$$

The Price of New one = PN

The Bank Rate Loan = BR

If MTCP > PN * BR then it is worth to buy new one.

Case study

First of all we need the failures and its cost of repairing for at least 6-months periods, each period one month to take the decision.

Month	No. of Failures	Total Cost of Repairing in each month
1	3	975 $
2	4	1050 $
3	3	980 $
4	3	957 $
5	5	1200 $
6	5	910 $

m = 6 months

If the Price of New one = PN, PN = 25000 $

And the Bank Rate Loan = BR, BR = 0.04

$$MTCP = \frac{\sum_{1}^{m} TCP_j}{m}, \qquad \sum_{1}^{6} TCP_j = 6072\ \$$$

$$MTCP = \frac{\sum_{1}^{6} TCP_j}{6} = 1012\ \$$$

PN * BR = 25000 * 0.04 = 1000 $

MTCP > PN * BR,

The decision is to buy new one.

Conclusion

Sometimes people stay repairing their automobiles and spend money for some thing not worth. It is better to buy new one. For this reason I tried to investigate this paper. We can take a decision to buy new, or keep the old one. It needs to supply at least 6-months data and doing some calculations to take the decision.

References

1. Chatfield C. (1983), "Statistics for Technology", Chapman and Hall.
2. Menezes F. S. de, Mario J. Ferrua Vivanco (2005), "Determination of Prediction Intervals for a Future Number of Failures", Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil.
3. Martz H. F. & Waller R. A. (1982), "Bayesian Reliability Analysis", Wiley, New York.
4. Jacob D. & Amari S.V. (2005), "Analysis of Complex Repairable Systems", Reliability and Maintainability Symposium, 2005, Proceedings, Annual Volume, Jan, 24-27.
5. Guo R. & Love C. E. (2003), "Statistical Modeling of System Ages", International Conference on Industrial Engineering - Theory Applications and Practice, Las Vegas, USA, Nov.