

Maintainability & Availability

Maintainability Definition



Maintainability

Maintainability implies a built in characteristics of the equipment design which imparts to the cell **an inherent ability to be maintained** so as to keep the equipment productively operating by employing a **minimum** number of maintenance man-hour, skill levels, and maintenance costs.

Maintainability Functions

Examples

Maintainability



Maintainability

Maintainability
Functions

Examples

- Various measures are used in maintainability analysis:
 - ❑ Mean Time To Repair (MTTR)
 - ❑ Mean Preventive Maintenance Time (MPMT)
 - ❑ Mean Maintenance Downtime (MMD)

- In addition to these measures, maintainability functions are used to predict the probability that a repair, starting at time $t = 0$, will be completed in a time t .

Maintainability



Maintainability

It measures the elapsed time required to perform a given maintenance activity.

MTTR is expressed by:

$$MTTR = (\sum \lambda_i CMT_i) / \sum \lambda_i$$

Where:

k = number of units or parts

λ_i = failure rate of unit/part i , for $i= 1, 2, 3, \dots, k$

CMT_i = Corrective Maintenance or repair Time required to repair unit or part i , for $i= 1, 2, 3, \dots, k$

Maintainability
Functions

Examples

Usually, times to repair follow exponential, lognormal, and normal probability distributions

Maintainability

The mean preventive maintenance time is defined by:

$$MPMT = (\sum FPM_i \times ETPMT_i) / \sum FPM_i$$

Where:

MPMT = Mean Preventive Maintenance Time

m = total number of preventive maintenance tasks

FPM_i = Frequency of Preventive Maintenance task *i*,
for *i* = 1, 2, 3,, *m*

ETPMT_i = Elapsed Time for Mreventive Maintenance
Task *i*, for *i* = 1, 2, 3,, *m*

Note that if the frequencies *FPM_i* are given in maintenance task per hour, then *ETPMT_i* should also be given in hours.

Maintainability

Maintainability
Functions

Examples

Maintainability



Maintainability

- **Mean maintenance downtime** (MMD) is described as the total time required either to restore system to a given performance level or to keep it at that level of performance.

Maintainability Functions

- It is composed of corrective maintenance, preventive maintenance, administrative delay, and logistic delay times.

- **The administrative delay time** is the system or item downtime due to administrative constraints.

Examples

- **Logistic delay time** is the time spent waiting for a required resource such as spare part, a specific test, or a facility



Maintainability

$$MMD = MAMT + LDT + ADT$$

Where:

ADT = Administrative Delay Time

LDT = Logistic Delay Time

MAMT = Mean Active Maintenance Time or mean time needed to perform preventive and corrective maintenance associated tasks.

Maintainability
Functions

Examples

Maintainability Functions

Maintainability functions predict the probability that a repair, starting at time $t = 0$, will be completed in a time t .

The maintainability function for any distribution is defined by:

$$M(t) = \int fr(t) dt$$

Where:

t = time

$M(t)$ = maintainability function (probability that a repair action will be finished at time t)

$fr(t)$ = probability density function of the repair time

Maintainability Functions

Maintainability

Exponential p.d.f:

Exponential p.d.f is widely used in maintainability work to represent repair times. It is expressed by:

$$fr(t) = (1/MTTR) \exp (-t/MTTR)$$

Maintainability
Functions

The maintainability function in this case is:

Examples

$$M(t) = \int (1/MTTR) \exp (- t/ MTTR) dt$$
$$= 1- \exp (- t/ MTTR)$$

Maintainability Functions



Maintainability

Weibull p.d.f:

Weibull p.d.f can also be used to represent times to repair. It is defined by:

$$f_r(t) = (\beta/\theta) t \exp(-t/\theta)$$

where:

β = shape parameter θ = scale parameter

The maintainability function in this case is:

$$\begin{aligned} M(t) &= \int (\beta/\theta) t \exp(-t/\theta) dt \\ &= 1 - \exp(-t/\theta) \end{aligned}$$

Examples

When $\beta=1$ and $\theta=MTTR$, the $M(t)$ reduces to the $M(t)$ in the case of exponential distribution

Maintainability Functions

Normal p.d.f:

Normal p.d.f can also be used to represent times to repair. It is defined by:

$$f_r(t) = 1/\sigma \sqrt{2\pi} \exp(-1/2(t - \theta/\sigma)^2)$$

where:

σ = standard deviation of the variable maintenance time t around the mean value θ

θ = mean of maintenance times

The maintainability function in this case is:

$$M(t) = 1/\sigma \sqrt{2\pi} \int \exp(-1/2(t - \theta/\sigma)^2) dt$$

Maintainability Functions

The mean of the maintenance times is:

$$\theta = \sum t_i / k$$

where:

k = total number of maintenance tasks performed

t_i = i th maintenance time, for $i= 1, 2, 3, \dots, K$

The standard deviation is :

$$\sigma = [\sum (t_i - \theta)^2 / (k - 1)]^{1/2}$$

Availability

Availability is the probability that a facility scheduled for service will be operating at any point in time.

System availability predicts the actual running or uptime in terms of ratio of actual operating time to the scheduled operating time:

$$\text{Availability} = \text{Actual operating time} / \text{Standard Operating Time}$$

Availability



Maintainability

$$\text{Availability} = \text{MTBF or MTTF} / (\text{MTBF or MTTF} + \text{MFOT or MTTR})$$

Maintainability
Functions

Availability

Availability

- ❑ This means an increase in maintainability (results in small MTTR) or reliability (results in a high MTBF or MTTF) or **both** increases the availability of the system.
- ❑ Therefore, **sound design** provides both high reliability and maintainability.

Maintainability

Maintainability
Functions

Availability

Example



Maintainability

A mechanical machine has three important subsystems. The first subsystem has failure rate of 0.003 failures per hour and repair time of 1 hour. The second and the third subsystems have failure rates of 0.005 and 0.004 failures per hour and repair times of 4 hours and 3 hours respectively. The times to repair of this machine are exponentially distributed. Find:

Maintainability
Functions

1. The probability that a repair on this machine will be performed in 5 hours.
2. The MTTR of this machine
3. The MMD of this machine, if the authorization of the maintenance work order takes 12 min and the time to get the required materials and spare parts from the store is 20 min

Examples