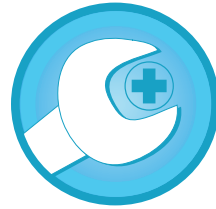


# *Maintenance Explained.*



## maintenance defined.

**Maintenance** is defined as any **action** that keeps something in good working order. For repairable items, maintenance plays a vital role in the life of an item. It affects the item's overall reliability, availability, downtime, cost of operation, etc. Generally, maintenance actions can be divided into three types: corrective maintenance, preventive maintenance and inspections.



## corrective maintenance.

Corrective maintenance consists of the action(s) taken to **restore** a failed system to operational status. This usually involves replacing or repairing the component that is responsible for the failure of the overall system. Corrective maintenance is performed at unpredictable intervals because a component's failure time is not known. The objective of corrective maintenance is to restore the system to satisfactory operation within the shortest possible time. Corrective maintenance is typically carried out in four steps:

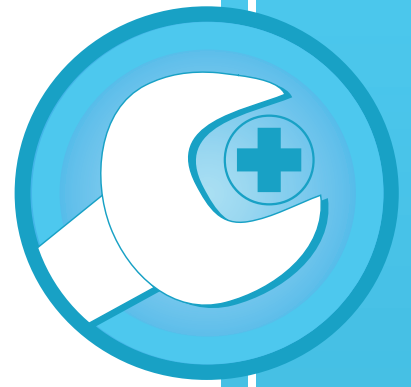


**diagnosis of the problem** The maintenance technician must take time to locate the failed parts or otherwise satisfactorily assess the cause of the system failure.

**repair and/or replacement of faulty component(s)** Once the cause of system failure has been determined, action must be taken to address the cause, usually by replacing or repairing the components that caused the system to fail.

**verification of the repair action** Once the components in question have been repaired or replaced, the maintenance technician must verify that the system is again successfully operating.

**reporting** Registration of the process must be completed by the technician to ensure future data analysis.



## preventive maintenance.

Preventive maintenance, unlike corrective maintenance, is the practice of replacing components or subsystems before they fail in order to promote **continuous** system operation. The schedule for preventive maintenance is based on observation of past system behavior, component wear-out mechanisms and knowledge of which components are vital to continued system operation. Cost is always a factor in the scheduling of preventive maintenance.

Preventive maintenance is a schedule of planned maintenance actions aimed at the prevention of breakdowns and failures. The primary goal of preventive maintenance is to prevent the failure of equipment before it actually occurs. It is designed to preserve and enhance equipment reliability by replacing worn components **before** they actually fail.

## value of preventive maintenance.

There are multiple misconceptions about preventive maintenance. One such misconception is that PM is unduly costly. This logic dictates that it would cost more for regularly scheduled downtime and maintenance than it would normally cost to operate equipment until repair is absolutely necessary. This may be true for some components; however, one should compare not only the costs but the **long-term** benefits and savings associated with preventive maintenance. Without preventive maintenance, for example, costs for lost production time from unscheduled equipment breakdown will be incurred. Also, preventive maintenance will result in savings due to an increase of effective system service life.

Long-term **benefits** of preventive maintenance include:

1. Improved system reliability
2. Decreased cost of replacement
3. Decreased system downtime
4. Better spares inventory management

Long-term effects and cost comparisons usually favor preventive maintenance over performing maintenance actions only when the system fails.

## when does preventive maintenance make sense.

Preventive maintenance is a **logical** choice if, and only if, the following two conditions are met:

**condition #1** The component in question has an increasing failure rate. In other words, the failure rate of the component increases with time, thus implying wear-out. Preventive maintenance of a component that is assumed to have an exponential distribution (which implies a constant failure rate) does not make sense!

**condition #2** The overall cost of the preventive maintenance action must be less than the overall cost of a corrective action. (Note: In the overall cost for a corrective action, one should include ancillary tangible and/or intangible costs, such as downtime costs, loss of production costs, lawsuits over the failure of a safety-critical item, loss of goodwill, etc.)

The objective of a good **preventive maintenance** program is to either minimize the overall costs (or downtime, etc.) or meet a reliability

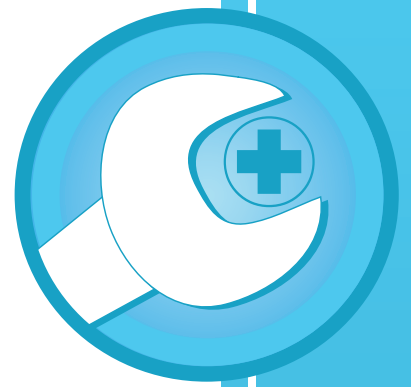


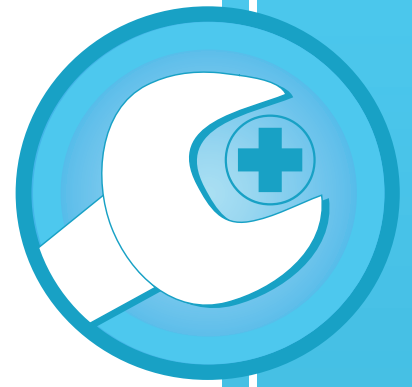
objective. In order to achieve this, an appropriate interval (time) for scheduled maintenance must be determined. One way to do that is to use the optimum age replacement model, as presented next.

The component is exhibiting behavior associated with a wear-out mode. That is, the failure rate of the component is increasing with time. The cost for planned replacements is **significantly less** than the cost for unplanned replacements.

## inspections.

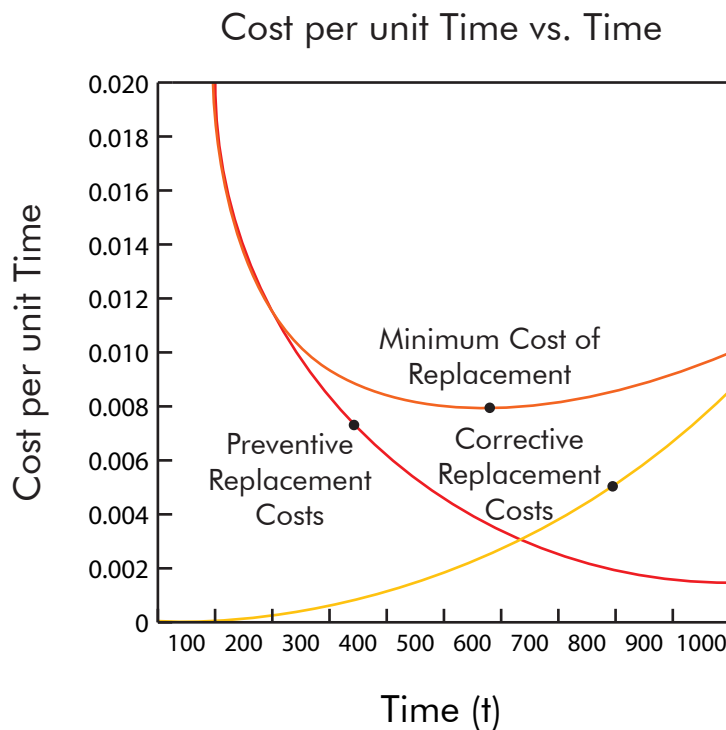
Inspections are used in order to uncover **hidden failures** (also called dormant failures). In general, no maintenance action is performed on the component during an inspection unless the component is found failed, in which case a corrective maintenance action is initiated.





## cost per unit time vs. time.

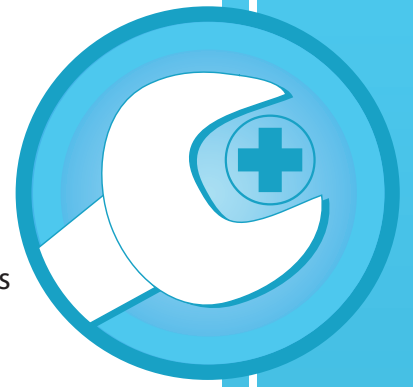
In this figure, it can be seen that the corrective replacement costs increase as the replacement interval increases. In other words, the less often you perform a PM action, the higher your corrective costs will be. Obviously, the longer we let a component operate, its failure rate increases to a point that it is more likely to fail, thus requiring more corrective actions. The opposite is true for the preventive replacement costs. The longer you wait to perform a PM, the less the costs; while if you do PM too often, the higher the costs. If we combine both costs, we can see that there is an optimum point that **minimizes** the costs. In other words, one must strike a balance between the risk (costs) associated with a failure while maximizing the time between PM actions.



## optimum age replacement policy.

To determine the optimum time for such a preventive maintenance action (replacement), we need to mathematically formulate a model that describes the associated costs and risks. Thus, the **optimum** replacement time can be found by minimizing the cost per unit time,  $CPUT(t)$ .

$$CPUT = \frac{\text{TOTAL EXPECTED REPLACEMENT COST CYCLE}}{\text{EXPECTED CYCLE LENGTH}}$$



## downtime distributions.

Maintenance actions (preventive or corrective) are not instantaneous. There is a time associated with each action, i.e. the amount of time it takes to complete the action. This time is usually referred to as downtime and it is defined as the length of time an item is not operational. There are a number of different factors that can affect the length of downtime, such as the physical characteristics of the system, spare part availability, repair crew availability, human factors, environmental factors, etc. Downtime can be divided into two categories based on these factors:

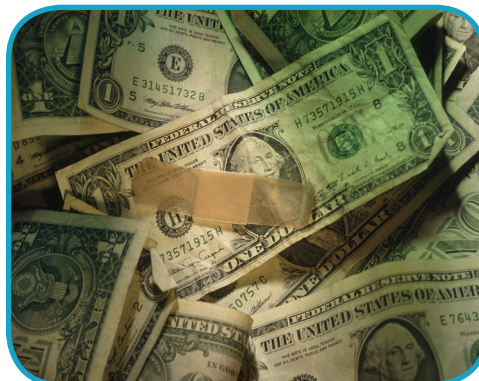
**downtime** This is the time during which the equipment is inoperable but not yet undergoing repair. This could be due to the time it takes for replacement parts to be shipped, administrative processing time, etc.

**active downtime** This is the time during which the equipment is inoperable and actually undergoing repair. In other words, the active downtime is the time it takes repair personnel to perform a repair or replacement. The length of the active downtime is greatly dependent on human factors, as well as on the design of the equipment. For example, the ease of accessibility of components in a system has a direct effect on the active downtime.

## life cycle cost analyses.

A life cycle cost analysis involves the analysis of the **costs** of a system or a component over its entire life span. Typical costs for a system may include:

1. Acquisition costs (or design and development costs)
2. Operating costs
3. Cost of failures
4. Cost of repairs
5. Cost for spares.
6. Downtime costs
7. Loss of production
8. Disposal costs





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