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Program : **B.E**

Subject Name: **Maintenance Management**

Subject Code: **ME-8004**

Semester: **8th**

# Maintenance Management, ME – 8004 (3)
## Unit – 1: Introduction

**MAINTENANCE MANAGEMENT:**

Maintenance of facilities and equipment in good working condition is essential to achieve specified level of quality and reliability and efficient working. Plant maintenance is an important service function of an efficient production system. It helps in maintaining and increasing the operational efficiency of plant facilities and thus contributes to revenue by reducing the operating costs and increasing the effectiveness of production.

**Maintenance Objectives:**

Maintenance in any activity is designed to keep the resources in good working condition or restore them to operating status.



The objectives of plant maintenance are:

1. To increase functional reliability of production facilities.

2. To enable product or service quality to be achieved through correctly adjusted, serviced and operated equipment.

3. To maximize the useful life of the equipment.

4. To minimize the total production or operating costs directly attributed to equipment service and repair.

5. To minimize the frequency of interruptions to production by reducing breakdowns.

6. To maximize the production capacity from the given equipment resources.

7. To enhance the safety of manpower.

**Maintenance Costs:**

Breakdown of equipment makes the workers and the machines idle resulting in loss of production, delay in schedules and expensive emergency repairs. These downtime costs usually exceed the preventive maintenance costs of inspection, service and scheduled repairs up to the point M shown in figure:

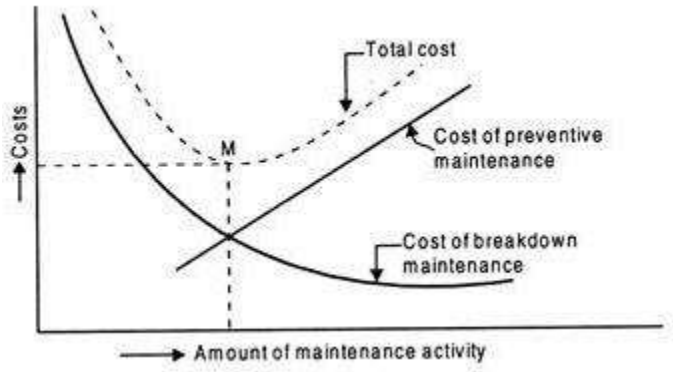



Figure: Maintenance Costs

Beyond this optimal point an increasingly higher level of preventive maintenance is not economically justified and it is economical to adopt breakdown maintenance policy. The optimal level of maintenance activity M, is easily identified on a theoretical basis, to do this the details of the costs associated with breakdown and preventive maintenance must be known.

**Costs associated with maintenance are:**

1. Down time (Idle time cost) cost due to equipment breakdown.

2. Cost of spares or other material used for repairs.

3. Cost of maintenance labor and overheads of maintenance departments.

4. Losses due to inefficient operations of machines.

5. Capital requirements required for replacement of machines.

**Maintenance Policies:**

1. Breakdown (repair) maintenance

2. Preventive maintenance

Breakdown maintenance is emergency based policy in which the plant or equipment is operated until it fails and then it is brought back into running condition by repair. The maintenance staffs locate any mechanical, electrical and any other fault to correct it immediately. Preventive maintenance policy prevents the probable breakdown and it ensures smooth and uninterrupted production by anticipating the breakdowns (failures) and taking corrective actions:

The preventive maintenance policy has four forms:

**(a) Time based:**

Which means doing maintenance at regular intervals? It is time dependent rather than usage dependent.



**(b) Work based:**

Maintenance after a set of operating hours of volume of work produced.

**(c) Opportunity based:**

Where repair and replacement takes place when the equipment or system is available.

**(d) Condition based:**

Which often relies on planned inspection to reveal when maintenance is required?

Preventive maintenance is used to delays or prevents the breakdown of equipment and also to reduce the seventy of any breakdowns that occur.

**Two aspects of preventive maintenance are:**

1. Inspection:

Inspection of critical parts will indicate the need for replacement or repair well in advance of probable breakdown. Regular inspection conducted by either by equipment or operator or by maintenance department is the most important direct means of increasing equipment reliability.

2. Servicing:

Routine cleaning, lubrication and adjustment may significantly reduce wear and hence prevent breakdowns. Frequently such duties are carried out by equipment operator or may be carried out by maintenance department.

***Preventive versus Breakdown Maintenance:***

Preventive maintenance is the routine inspection and service activities designed to detect potential failure conditions and make minor adjustments or repairs that will help prevent major operating problems.



Breakdown maintenance is the emergency repair and it involves higher cost of facilities and equipment that have been used until they fail to operate.

Effective preventive maintenance programs for equipment requires properly trained personnel, regular inspection and service and has to maintain regular records.

Preventive maintenance is planned in such a way that it will not disturb the normal operations hence no down time cost of equipment.

Breakdown maintenance stops the normal activities and the machines and the operators are rendered idle till the equipment is brought back to normal condition of working.

**Maintenance Performance:**

The following criteria can be used for measuring the effectiveness of maintenance function:

1. $\text{Productivity of Maintenance} = \dfrac{\text{Output (Product)}}{\text{Maintenance cost (Product)}}$

2. $\text{Down time index} = \dfrac{\text{Downtime hours}}{\text{Production hours}} \times 100$

3. $\text{Maintenance cost index} = \dfrac{\text{Maintenance cost}}{\text{Capital cost}} \times 100$

**NECESSITY OF MAINTENANCE MANAGEMENT:**

Maintenance activities are related with repair, replacement and service of components or some identifiable group of components in a manufacturing plant so that it may continue to operate at a specified 'availability' for a specified period.

Thus maintenance management is associated with the direction and organization of various resources so as to control the availability and performance of the industrial unit to some specified level.

Thus maintenance management may be treated as a restorative function of production management which is entrusted with the task of keeping equipment/machines and plant services ever available in proper operating condition.

The minimization of machine breakdowns and down time has been the main objective of maintenance but the strategies adopted by maintenance management to achieve this aim have undergone great changes in the past.

Maintenance has been considered just to repair the faulty equipment and put them back in order in minimum possible time.

In view of the utilization of mostly general purpose/conventional machines with low production output, the demands on maintenance function were not very high. But with fast developments

in the design, development and mechanisms of control such as electronic, NC and CNC in machine tools the manufacturing scenario has changed a lot.

The stringent control of dimensional tolerances and surface finish of the product have increased the tendency to adopt standardization and interchange-ability of parts/components of machines.

In the current production setups even a minor down time leads to serious production problems both technological as well as economical. All this is due to tough competition in the industrial market. Under the present circumstances effective and objectively designed efforts to update maintenance management has become a necessity.

**IMPORTANCE OF MAINTENANCE MANAGEMENT:**

Maintenance management is responsible for the smooth and efficient working of the industrial plant and helps in improving the productivity.

It also helps to keep the machines/equipment in their optimum operating conditions. Thus plant maintenance is an important and inevitable service function of an efficient production system.

It also helps in maintaining and improving the operational efficiency of the plant facilities and hence contributes towards revenue by decreasing the operating cost and improving the quality and quantity of the product being manufactured.

As a service function it is related with the incurrence of certain costs. The important component of such costs are — employment of maintenance staff, other minor administrative expenses, investment in maintenance equipment and inventory of repair components/ parts and maintenance materials.

Absence of plant maintenance may lead to frequent machine breakdown and failure of certain productive centres/services which in turn would result in stoppages of production activities, idle man and machine time, dislocation of the subsequent operations, poor quality of production, failure to meet delivery dates of product supply, industrial accidents endangering the life of workers/ operators and allied costs etc.

However, the importance of plant maintenance varies with the type of plant and its production but it plays a prominent role in production management because plant breakdown creates problems such as:

- Loss of production.
- Rescheduling of production.
- Materials wastage (due to sudden stoppage of process damages in process materials).
- Need for overtimes,
- Need for work subcontracting.
- For maximum manpower utilization workers may need alternative work due to temporary work shortages.

Hence, the absence of planned maintenance service proves costlier. So it should be provided in the light of cost benefit analysis. Since plant maintenance is a service function, it should be provided at the least possible cost but it is very important as discussed above.



**OBJECTIVES OF MAINTENANCE MANAGEMENT:**

The purpose of maintenance management is to optimize the performance of productive facilities of an organization by ensuring that these facilities function regularly and efficiently. This can be achieved by preventing the failures or breakdowns if any, as far as possible and by minimizing the production loss due to failures.

***The main objectives of maintenance management are as follows:***

(1) Minimizing the loss of productive time because of equipment failure to maximize the availability of plant, equipment and machinery for productive utilization through planned maintenance.

(2) To extend the useful life of the plant, machinery and other facilities by minimizing their wear and tear.

(3) Minimizing the loss due to production stoppages.

(4) To ensure operational readiness of all equipment's needed for emergency purposes at all times such as fire-fighting equipment.

(5) Efficient use of maintenance equipment's and personnel.

(6) To ensure safety of personnel through regular inspection and maintenance of facilities such as boilers, compressors and material handling equipment etc.

(7) To maximize efficiency and economy in production through optimum utilization of available facilities.

(8) To improve the quality of products and to improve the productivity of the plant.

(9) To minimize the total maintenance cost which may consist of cost of repairs, cost of preventive maintenance and inventory costs associated with spare parts/materials required for maintenance.

(10) To improve reliability, availability and maintainability.



**Functions of Maintenance Management:**

The important functions of maintenance can be summarized as follows:

(1) To develop maintenance policies, procedures and standards for the plant maintenance system.

(2) To schedule the maintenance work after due consultation with the concerned production departments.

(3) To carry out repairs and rectify or overhaul planned equipment/facilities for achieving the required level of availability and optimum operational efficiency.

(4) To ensure scheduled inspection, lubrication oil checking, and adjustment of plant machinery and equipment.

(5) To document and maintain record of each maintenance activity (i.e., repairs, replacement, overhauls, modifications and lubrication etc.).

(6) To maintain and carry out repairs of buildings, utilities, material handling equipment's and other service facilities such as electrical installations, sewers, central stores and roadways etc.

(7) To carry out and facilitate periodic inspections of equipment and facilities to know their conditions related to their failure and stoppage of production.

(8) To prepare inventory list of spare parts and materials required for maintenance.

(9) To ensure cost effective maintenance.

(10) To forecast the maintenance expenditure and prepare a budget and to ensure that maintenance expenditure is as per planned budget.

(11) To recruit and train personnel to prepare the maintenance workforce for effective and efficient plant maintenance.



(12) To implement safety standards as required for the use of specific equipment or certain categories of equipment such as boilers, overhead cranes and chemical plants etc.

(13) To develop management information systems, to provide information to top management regarding the maintenance activities.

(14) To monitor the equipment condition at regular intervals.

(15) To ensure proper inventory control of spare parts and other materials required.

***In terms of plants operations the functions of maintenance are:***

(a) The plant must be available as and when required.

(b) The plant must not breakdown during actual operation state.

(c) The plant must operate in an efficient manner at required level of plant operation.

(d) The down time must not interfere with production runs.

(e) The down time due to breakdown should be a minimum.

To accomplish these conditions there must be complete cooperation and mutual understanding between maintenance and production departments. There must be an effective maintenance policy for planning, controlling and directing all maintenance activities.

The plant maintenance department must be well organized, adequately staffed sufficiently experienced and adequate in number to carry out corrective and timely maintenance with the efforts in minimizing breakdowns.



## PREVENTIVE MAINTENANCE

Preventive maintenance attempts to prevent any probable failures/breakdowns resulting in production stoppages. It is said that Preventive maintenance is a stich in time that saves time. So it follows a slogan that “prevention is better than cure”.

Preventive maintenance refers to maintenance action performed to keep or retain a machine/equipment or asset in a satisfactory operating condition through periodic inspections, lubrication, calibration, replacements and overhauls.

***Preventive Maintenance Involves:***

- Periodic inspection of equipment/machinery to uncover condition that lead to production breakdown and harmful depreciation. Upkeeps of plant machinery to correct such conditions while they are still in a minor stage.
- The key to all good preventive maintenance programs, however is inspection.

- Regular cleaning, greasing and oiling of moving parts.
- Replacement of worn out parts before they fail to operate,
- Periodic overhauling of the entire machine.
- Machines or equipment's which are liable to sudden failures should be installed in duplicate e.g. motors, pumps, transformers and compressors etc.

**Features of Preventive Maintenance:**

A well-conceived preventive maintenance program should possess the following features:

(1) Proper identification of all items to be included in the maintenance program.

(2) Adequate records covering, volume of work, associated costs etc.

(3) Inspection with a definite schedule with standing order on specific assignments.

(4) Use of checklists by inspectors.



(5) An inspection frequency schedule

(6) A crew of well qualified inspectors with competency of simple repairs, as and when small trouble is noticed.

(7) Administrative procedures which provide necessary fulfilment as well as follow up on program.

**Objectives of Preventive Maintenance:**

(1) To minimize the possibility of unanticipated production interruption or major breakdown by uncovering any condition which may lead to it?

(2) To make plant, equipment and machinery always available and ready for use.

(3) To maintain the value of equipment and machinery by periodic inspections, repairs, overhauls etc.

(4) To reduce the work content of maintenance jobs.

(5) To maintain the optimum productive efficiency of the plant equipment and machinery.

(6) To maintain the operational accuracy of the plant equipment.

(7) To achieve maximum production at minimum repair cost.

(8) To ensure safety of life and limbs of the workmen along with plant equipment and machines etc.

(9) To maintain the operational ability of the plant as a whole.

**Procedure of Preventive Maintenance:**

There is no readymade, on the shelf, preventive maintenance procedure for any industry or enterprise involved in manufacturing activities. In view of the fact that all industries differ in size, location, layout, construction, resources, machinery and its age so as to suit the requirements of an individual industrial plant, the preventive maintenance programs are specifically framed.

A well-conceived preventive maintenance program has the following elements, features or steps to be adhered to in general:



(1) Who should perform preventive maintenance?

(2) Where to start preventive maintenance?

(3) What to inspect regarding preventive maintenance?

(4) What to Inspect for?

(5) What should be the frequency of Inspection?

(6) When to inspect or inspection schedules?

(7) What are preventive maintenance stages?

(8) Training of Maintenance staff.

(9) Motivation Techniques.

(10) Maintenance of Records of Preventive Maintenance.

(11) Material Management for Maintenance.

(12) Control and Evaluation of Preventive maintenance.

In view of the elements of PM mentioned above for establishing a sound preventive maintenance system in a manufacturing enterprise, we require extra manpower, maintenance facilities, testing equipment's and spare parts etc. to start with but in the long run it provides a lot of benefits by way of reduction in production losses, down time and repair costs etc.

***Thus the essential requirements for a sound preventive maintenance can be listed as follows:***

(1) Proper identification of machines/equipment's and tools:

Every item must be uniquely identified by a prominent serial/identity number.

(2) Adequate past records must be available for all equipment's being utilized. It should furnish complete details regarding previous maintenance operations/activities.



(3) Breakdown/Failures Data:

Sufficient breakdown information regarding criticality and frequency of failures must be available for all machines. This would be needed for the purpose of failure identification, failure diagnostics, analysis as well as final rectification.

(4) Secondary data:

In fact it is a sort of experienced data for similar equipment being utilized.

(5) Manufacturer's utilization recommendations:

Regarding the use of a particular machine i.e. how to utilize and provide P.M.

(6) Service manuals, instruction and maintenance sheets.

(7) Consumables and replaceable parts/components should be available as and when needed.

(8) Availability of requisite skilled manpower may be engineers, inspectors and technicians.

(9) Availability/provision of test rigs/equipment's i.e., test rigs, sensors etc.

(10) Clear instructions with a check list regarding preventive and corrective measures must be available to ensure proper functioning of the system.

(11) Users feedback and cooperation:

The user of the equipment/machine must provide feedback to the manufacturer regarding actual functioning of the equipment.

(12) Management Support:

For establishing a preventive maintenance system, the commitment of top management is very essential for the implementation of preventive maintenance policy of the organization.

**Applications of Preventive Maintenance:**

(1) This system of maintenance is applicable for automated or continuous production process e.g., steel mills, chemical plants and automobile industries.

(2) In some of the abovementioned practical situations the cost of lost production due to a failure/breakdown can be extremely high. Besides, such heavy cost of failures, the breakdowns may be totally destructive in nature i.e., the failure of a small equipment may lead to complete breakdown of the system. Hence preventive maintenance system is essential in such situations to ensure continuous and failure free plant operation.

(3) In the failure of equipment's such as boilers, turbines, pressure vessels and lifting devices the results may be fatal sometimes. Thus in order to avoid any loss of human life and health hazards, a proper preventive maintenance system must be adopted.

(4) Some common examples where preventive maintenance is adopted are as follows:

- P.M. of machine tools.
- P.M. of pressure vessels or boilers.
- P.M. of steam and gas turbines.

- P.M. of heat exchangers,
- P.M. of mobile compressors and generators.
- Overhead cranes.
- Small power plants.
- Elevators.
- Vehicles.

**Preventive maintenance is subdivided into following two categories:**

I. ***Running.***

II. ***Shut down.***

Running maintenance means that maintenance work carried out even when machine or equipment is in service, while shut down maintenance is concerned with maintenance work carried out only when the machine/ equipment is not in operation.

**Advantages of Preventive Maintenance:**



(1) Reduction in breakdown time and associated breakdown elements.

(2) Reduces the odd time repairs and over time to the maintenance staff.

(3) Fewer large scale and repetitive repairs.

(4) Less member of standby equipment and spare parts required.

(5) Greater safety to work force/employees due to reduced breakdowns.

(6) Increased life of equipment and machines.

(7) The work load of the maintenance staff can be properly planned.

(8) It improves the availability of facilities.

(9) Optimum production efficiency can be achieved by employing preventive maintenance.

(10) Maintenance and repair cost reduce heavily.

(11) It improves the quality of product and reduces rejections.

(12) Production cost goes down by adopting RM.

(13) Regular planned servicing and adjustment maintains and provides a high level of plant output, better equipment performance and better product quality.

(14) Healthy, hygienic, safe and an accident free work environment can be achieved with the application of scientific preventive maintenance. This would promote industrial relations since workers do not loose any type of incentive due to breakdowns or accidents.

(15) Reduction in inventory of spare parts.

**Limitations of Preventive Maintenance:**

(1) When the cost of failure prevention is always greater than cost of failure rectification the process of P.M is very costly e.g., batch production-bridge construction.

(2) The type of maintenance requires extra facilities and lead to under/poor utilization of basic facilities for RM.

(3) For small scale manufacturing units which are mainly undertaking job and batch production, the P.M system is not suited and economically justified.



## CORRECTIVE MAINTENANCE

**DEFINITION OF CORRECTIVE MAINTENANCE:**

- ***A maintenance work carried out to restore the equipment/machine to a satisfactory condition after the failure has occurred.***

- ***It may be defined as a specific maintenance operation which is well organized and performed with some prior planning, forethoughts and control activity.***

Actually corrective maintenance is a special type of maintenance activity carried out to restore an item/machine when it has failed to meet an acceptable condition. Further it is basically a rectification process which is always adopted after the occurrence of a breakdown.

**It may be executed in the form of:**

- *Repair may be minor or major.*
- *Replacement may be partial or total.*

In fact, down time due to breakdown may consist not only of time taken to complete the repair work but also delays caused by lack of resources or information.

Repair time is a function of management technique so, engineering techniques and maintainability. Corrective or planned maintenance is required not only when the asset/machine item fails but also when indicated by condition based criteria.

**Characteristics of Corrective Maintenance:**

(1) A correction maintenance activity is generally planned.

(2) A planned or unplanned corrective maintenance operation depends on the nature of break-down and type of equipment/machine.

(3) The maintenance work is taken up after the occurrence of a breakdown and with some permissible time lag.

(4) Breakdown maintenance should not be very serious in nature as far as production losses, down time, loss of human life etc. are concerned.

(5) Breakdown of individual equipment should not affect considerably the overall production loss.

In general breakdown maintenances are predictable and expected failures and hence they may be rectified over a long period of time without any time constraints.

**Objectives of Corrective Maintenance:**

(1) To get equipment/machine back into operation as quickly as possible in order to minimize the interruption to production. These objectives are directly related with production capacity, costs of production, product quality and consumer satisfaction.

(2) To control the cost of the operation of repair shops.

(3) To keep the cost of repair crew under control, including regular and overtime of labour costs.

(4) To control the investment in replacement of parts/components that are used/required when machines are repaired.

(5) To control the investment required for back up machines. These replace manufacturing machines are needed until the repairs are completed.

(6) To perform the appropriate amount of repairs at each malfunction of the asset/equipment.

(7) To restore an asset in working order.

(8) To maintain the operation availability of the plant and infrastructural facilities

(9) To avoid any sudden and heavy failure (breakdown) in future.



**TYPICAL CAUSES OF EQUIPMENT BREAKDOWN:**

**The causes of equipment breakdown may be as follows:**

- Failure to replace worn out components/parts.
- Lack of lubrication.
- Neglected cooling arrangement/system.
- Indifference towards minor faults.
- External factors such as wrong fuel, too low or too high line voltage etc.
- Indifference towards equipment vibrations, unusual sounds coming out of the rotating parts and equipment getting too much heated up.

**Advantages of Corrective Maintenance:**

(1) Emergency maintenance requirements are reduced.

(2) Heavy down time losses are reduced.

(3) Plant availability is increased.

(4) Results in better utilization of plant facilities.

(5) Safety level is improved and hence there are less chances of accidents.

(6) Provides sufficient information concerning the maintenance replacement and repair.

**Limitations of Breakdown Maintenance:**

(1) Breakdowns generally occur at inappropriate times. It may lead to a poor hurried maintenance and excessive delays in production schedules.

(2) It involves prolonged down time due to non-availability of requisite manpower and spare parts, they may lead to overtime practice also.

(3) It becomes impossible to plan workload and distribution of maintenance workforce for balanced and proper attention of all equipment's.



(4) Reduction in production output.

(5) There are increased chances of accidents and less safety for workforce.

(6) It leads to faster plant deterioration.

(7) Corrective maintenance cannot be employed for those industrial plants/enterprises which are regulated by statutory provisions for example boilers and cranes.

(8) The maintenance of product quality is difficult.

(9) Loss of direct profits.

## MAINTENANCE MANAGEMENT IN SAFETY

Maintenance is an important factor in quality assurance, which is another basis for the successful competitive edge. Inconsistencies in equipment lead to variability in product characteristics and result in defective parts that fail to meet the established specifications. Beyond just preventing break downs, it is necessary to keep equipment operating within specifications (i.e. process capability) that will produce high level of quality.

Good maintenance management is important for the company's cost control. As companies go in for automation to become more competitive, they increasingly rely on equipment to produce a greater percentage of their output. It becomes more important that, equipment operate reliably within specifications. The cost of idle time is higher as equipment becomes more high-tech and expensive e.g. NC/CNC machines and robots.

Dependability of service is one of the performance measures by which a company can distinguish itself from others. To establish a competitive edge and to provide good customer service, companies must have reliable equipment that will respond to customer demands when needed. Equipment must be kept in reliable condition without costly work stoppage and down time due to repairs, if the company is to remain productive and competitive.

Many manufacturing organizations, particularly those with JIT (Just-In-Time) programs are operating with inventories so low that, they offer no protection in the event of a lengthy equipment failure. Beyond the cost of idle equipment, idle labor, and lost ales that can result from a breakdown, there is a danger of permanently losing market shares to companies that are more reliable. Maintenance function can help prevent such as occurrence.

Organizations like airlines and oil refineries have huge investments in the equipment. Equipment failure will be disastrous for such companies. They need proper maintenance to keep the equipment in good condition.

## DESIGN OUT MAINTENANCE

The Maintenance tactic whereby changes or modifications are done to the equipment to remove a failure cause, or to allow other maintenance strategies to be applicable in managing the consequence of the failure. The elimination of maintenance through the creation of reliability by design.

The eradication of a cause of failure from a component by a reliability creating engineering design change. Design-out is used to engineer high reliability parts into machines, plant and equipment because the risks associated with the failure are too expensive to accept.

Design-out Maintenance cannot mean both re-engineering to remove the cause of failure, and at the same time allow failure in a better-managed, less-costly fashion.

To manage the consequences of failure and 'allow failure in a better-managed, less-costly fashion' is merely a change in maintenance strategy and/or operating strategy to those actions that deliver lower maintenance costs. In other words, you change your maintenance and/or operating practices and methods to reduce stress in your equipment components. Any time you reduce stress in machinery and equipment parts you will increase the time to a component's failure. You have not actually designed-out the causes of failure.

In Reliability Centered Maintenance (RCM), design-out is a necessary final solution when maintenance and/or operating strategy is ineffective in sufficiently reducing risk. In RCM, design-out is where parts are re-engineered to prevent a failure mode(s). This is evidence that 'design-out' really means reliability improvement by an engineering design change, and does not include in its meaning a change in maintenance or operating strategy (which are actually business process changes).

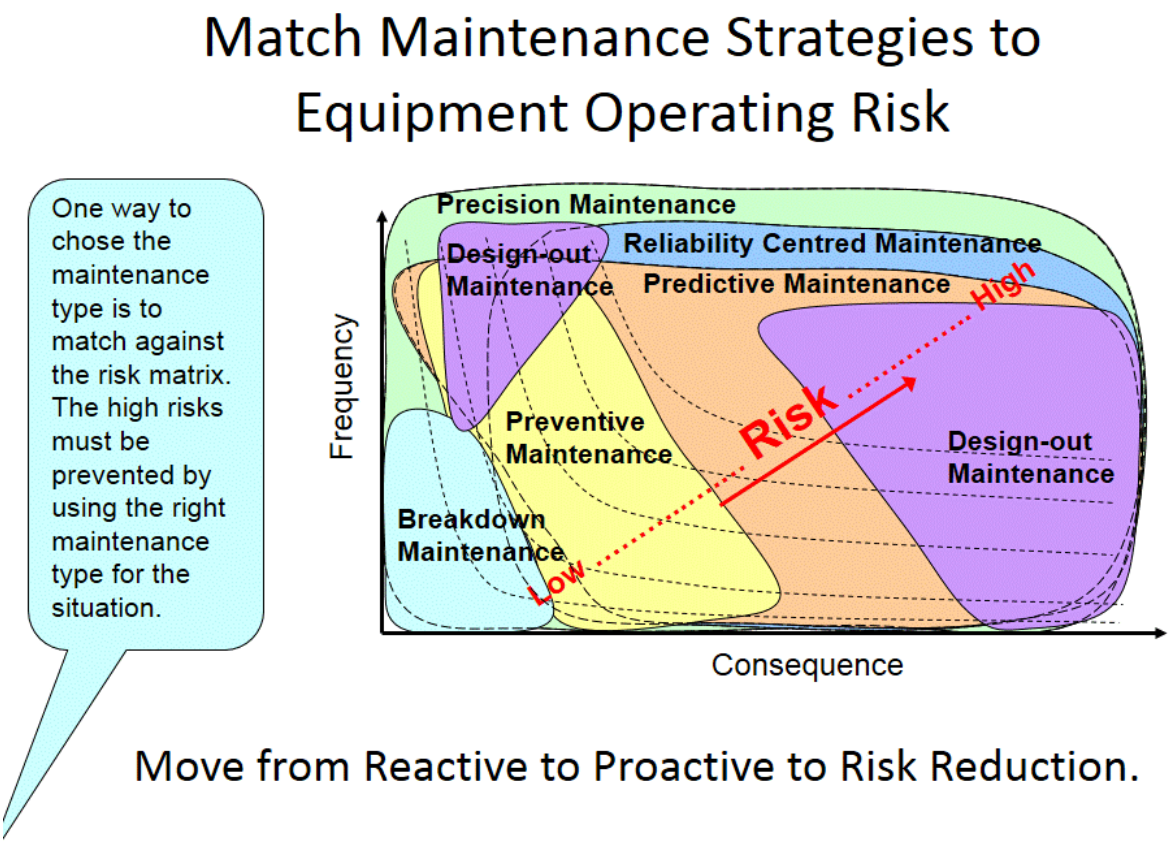
Proactive reliability-creating, design-out solutions include the likes of: Failure Mode Effects Analysis FMEA, Physics of Failure Analysis PoFA, Highly Accelerated Life Testing HALT, Highly Accelerated Stress Screening HASS, and more. In these design-out methodologies you remove opportunities for failure through component design changes. In a new design you prototype it and intentionally make it fail, while looking for failure modes to design-out. In an existing design you re-engineer it so that there are fewer failure modes when in service.

Finite Element Analysis FEA is a useful computer modelling tool to 'virtually prototype' component designs. Before making the part you model it digitally and apply computer-generated stresses to it. The stresses simulate what might happen in service and you can see the component's weaknesses as it distorts and distresses from the virtual loads and forces. But you

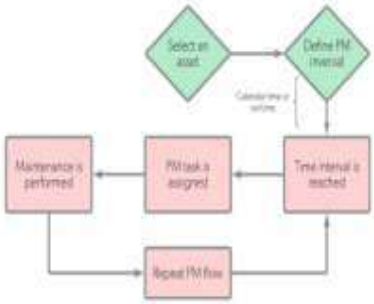
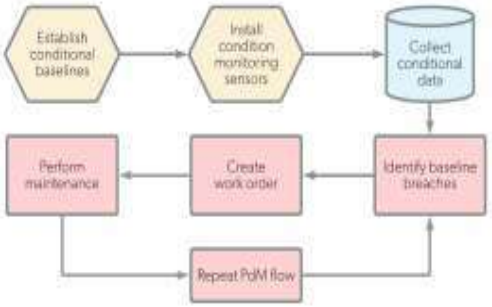
should also make a real component and put it in a real machine and stress it through failure testing trials to identify failure modes.

There must be economic value from having a better design. You would only make changes to a design because it is less costly than not doing so. This immediately implies that operating risk drives the need for a design change. In the figure below you can see when design-out maintenance becomes viable—if the consequence of a single event is unacceptable, and also when you have many repetitive failures.

With design-out reliability improvement you make better engineered designs. You create high reliability components that do not fail as often. You eliminate failure causes so parts do not fail from current failure modes. Design-out gives you a powerful methodology for defect removal and failure cause elimination so maintenance is not required.



Difference between PREVENTIVE and PREDICTIVE Maintenance.

| | **Preventive maintenance** | **Predictive maintenance** |
|---|---|---|
| **Definition** | Preventive maintenance (PM) is work that is scheduled based on calendar time, asset runtime, or some other period of time. | Predictive maintenance (PdM) is work that is scheduled as-needed based on real time conditions of assets. |
| Workflow |  |  |
| Trigger | Time | Condition |
| Cost | Low | Medium/High |
| Cost Savings | 12% to 18% | 25% to 30% |
| Resources Needed | Maintenance software for scheduling<br>Maintenance scheduler (for larger organizations) | Maintenance software for scheduling<br>Maintenance scheduler (for larger organizations)<br>Condition monitoring software<br>Condition monitoring tools and sensors<br>PdM training |
| Pros | Better than reactive maintenance<br>Relatively easy to implement | Maintenance is performed as needed<br>Reduces maximum amount of downtime |
| Cons | Risk of over-maintaining (e.g. over-lubrication can damage asset)<br>Labor intensive (not performed as needed) | Expensive technology needs purchased<br>Time-intensive to implement correctly |

**OFFLINE and ONLINE Condition Based Maintenance**

Online condition monitoring is where plant item/s have/has permanently mounted transducers and a wired or wireless system to convey signals to a central processing/logging point. Sampling of data may be continuous or at decided intervals. A plant may have many transducers used for

operation with outputs conveyed to the control room. Some CM can be done using these outputs and is helped if a computer-based system is fitted.

In online monitoring sensors are being permanently mounted on the machine. We can see the data over wider range of time. We usually use online monitoring for those machinery which are more critical in the process like in Cement Industry.

Many Turbo machineries are also being monitored and it is a better option for the OEM to remotely access all the parameters and do the analysis while being far away for the site.

Online monitoring is also preferable for those areas which are more critical and hazardous. Wind turbine main bearing also being monitored using CMS.

Offline condition monitoring to be when someone takes data in person at a plant item for some immediate interpretation and/or noting or taking away to the office for logging/trending/interpretation, usually using a computer.

Offline Condition monitoring refers to as Portable analyzers either Vibration analyzers, Acoustic emissions or Oil analysis. Person would go the machine take the data on that very instant to see the machinery fault. So data should've to be collected on daily basis in order to see any fault developing onto the machinery.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