Condition-based Maintenance

In this case, the proper time for performing corrective maintenance is determinable by monitoring condition and/or performance, provided a readily monitorable parameter of deterioration can be found. The probabilistic element in failure prediction is therefore reduced, the item life maximised and the effect of failure minimised. Condition-based maintenance can however be costly in time and instrumentation. The desirability of this policy, monitoring technique used and its periodicity

will depend on the deterioration characteristics of the equipment studied and the costs involved.

Opportunity Maintenance

Opportunity maintenance is used for actions taken after failure or during fixed-time or condition-based repair, but directed at items other than those responsible for primary cause of the repair. The policy is suitable for complex replaceable or continuously operating items of high shutdown or unavailability costs and might take the form of operation to failure and specification of critical items to be dealt with at that time.

Operation to Failure and Corrective Maintenance

No predetermined action is taken to prevent failure. The emphasis might well be on efficient corrective maintenance. Corrective maintenance arises not only when an item fails but also when indicated by condition-based criteria. The primary aim is to restore the unit to an acceptable condition economically.

Many factors influence the repair-replace choice, cost of unavailability, time of repair compared with that of replacement, availability and cost of resources. Such factors are continually changing and this, together with many possible causes for the defect and the many possible methods of repair, means that a corrective maintenance plan can only provide a framework to assist decision-making. Being the important feature of maintenance decision-making, it cannot be tackled without an information system (illustrated in Fig. 11.7) being available to the right people at the right time. This can be used effectively if the decision-makers have a thorough understanding of the plant for which they are responsible.

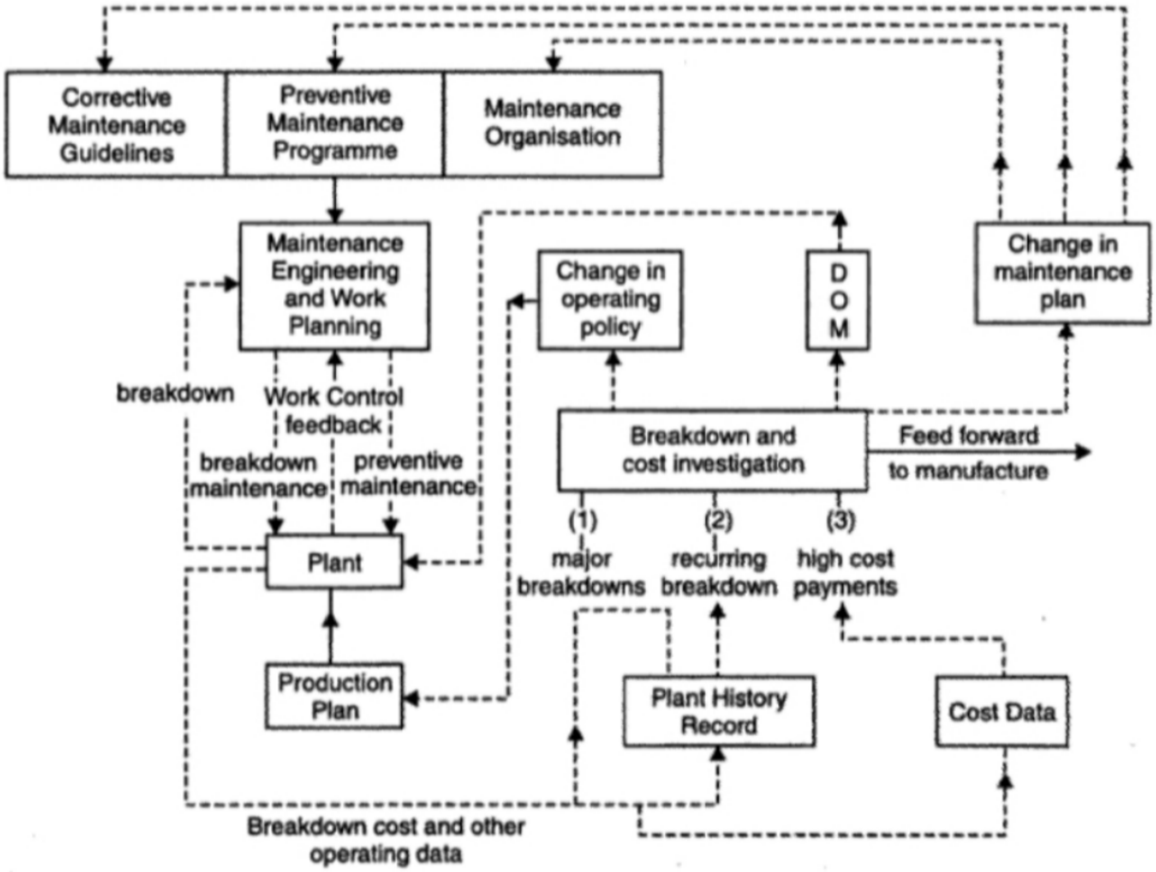

FIGURE 11.7 **Maintenance control model**

Design-out Maintenance

Design-out maintenance is yet another policy which is practised frequently in developed countries. The policy here aims at minimising the effect of failure and at eliminating the cause of maintenance. In essence, an attempt is made to pinpoint the defects in the design of the equipment. Poor design of many an equipment leads to frequent breakdowns. Also, an appropriate choice of tribological materials might eliminate the need for subsequent lubrication frequencies.

A plant-condition control system of the type outlined in Fig. 11.8 will enable such areas to be identified, and the choice is then between the cost of re-design or the cost of recurring maintenance.

Maintenance Planning

The maintenance plan for a plant should be built up by selecting for each unit, the best combination of policies outlined in Fig. 11.5 and then coordinating these policies in order to make optimum use of resources and time.

Preventive and corrective actions for each unit of plant should be specified in detail by the manufacturers. Usually this is the case for simple replacement items where maintenance is inexpensive and deterministic but it is extremely difficult for complex replaceable items where maintenance is costly and probabilistic. Non-replaceable items need no predetermined maintenance action since their expected life should exceed that of the plant. However, some critical items may benefit from periodic condition-based maintenance.

PREVENTIVE MAINTENANCE

Preventive maintenance essentially includes periodic lubrication and calibration of plant and machinery, replacement of wearing parts and capital items, overhaul of equipment and machinery and equipment inspection, and prevention of incipient or random failures. It covers the scope of **what to do** and **when to do.** The ultimate aim is to find out a strategy of maintenance practice which can minimise the component downtime. This practice is known as the preventive maintenance practice. It is based on the principle of carrying out some pre-determined activities to maintain the health of the equipment/component by (*a*) carrying out some maintenance activities at regular intervals, and (*b*) inspection at pre-determined intervals and carrying out the maintenance as per the inspection report.

Planning for preventive maintenance is the most vital activity to improve performance. It is based on speculation, experience and even assumption. Any mistake in planning may misguide the execution crew and thus lead to increase of downtime. Therefore, planning should be done carefully following well laid down procedures so that even minor aspects are not overlooked.

The total preventive maintenance planning can be represented in a cyclic form as shown in Fig. 11.17.

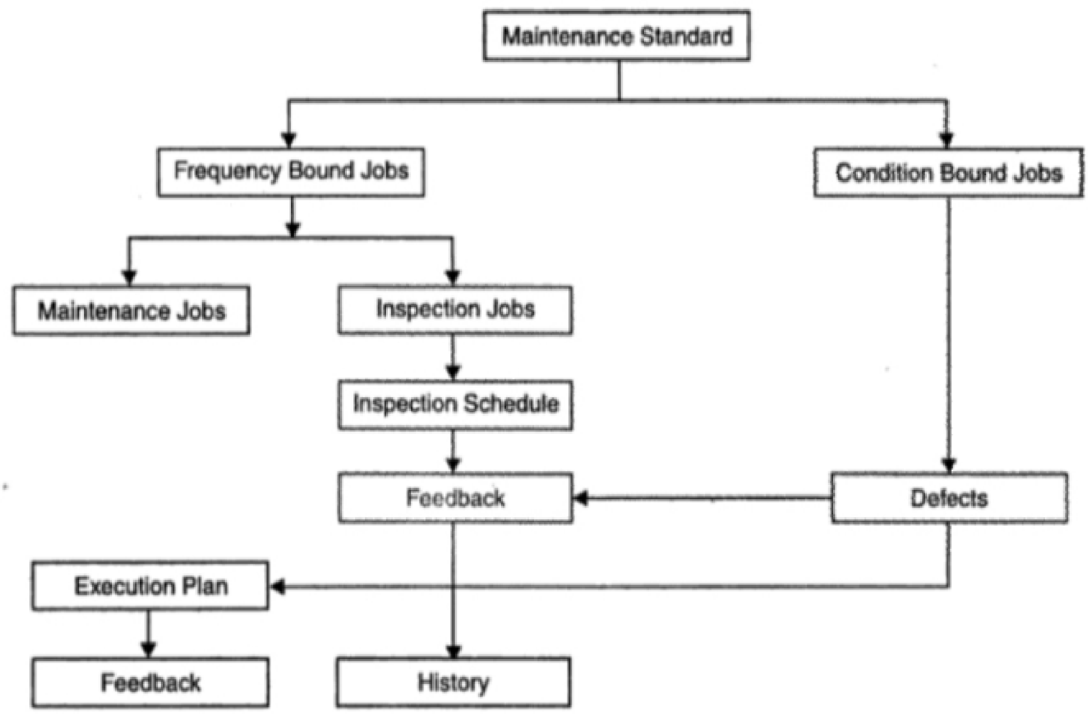

FIGURE 11.17 **Preventive maintenance planning**

Following steps are recommended for total maintenance planning functions:

1. Fixing the maintenance standards for every equipment.
2. Drawing an inspection schedule on a pre-determined frequency (based on experience and history) for all equipments.
3. Recording of defects detected.
4. Fixing time periods for execution of maintenance jobs.
5. Listing the jobs to be done in time periods based on maintenance standards and defects generated.
6. Recording of actual job done on each equipment or maintaining history of jobs done on the equipment.
7. Analysis and evaluation of equipment availability and maintenance performance as a measure for better standard fixation and better plan.

Here opportunity maintenance decisions are also discussed. If the plant is stopped for any reason whatsoever, there is an opportunity to carry out preventive maintenance work which cannot be performed while the plant is running. The plant can be stopped for non-maintenance, *i.e.*, production, reasons such as lack at work/orders, lack of raw materials/stock, etc, and these stoppages are referred to as **production windows.** The important type of opportunity maintenance is the maintenance work carried out during a failure, or planned corrective maintenance shutdown period, but which is not directed at the primary cause of failure/shutdown.

Replacement Decisions

Machinery and equipment require increased maintenance and running cost with time. By replacing these with new ones at frequent intervals, maintenance and other overhead costs can be reduced. However, such replacements would increase capital costs. Thus, some replacement policy is required to be evolved to minimise the total costs, which include capital cost, cost of maintenance and running costs. Replacement problems are also experienced in systems where machines, men or capital assets are the job performing units.

There is another class of problems in which failure is sudden instead of gradual. Also, the time of failure is not predictable for individual items. Thus, items have to be replaced only after the breakdown. However, it may be economical to replace or repair such items before their failure on a scheduled basis. In such cases, it is necessary to keep the record of probabilities of failures. The replacement policy should balance between the wasted life of an item replaced before failure and costs incurred when the item fails completely during service.

In this section, the following types of replacement problems are discussed:

(*a*) Replacement of equipment whose efficiency deteriorates with age such as machines, vehicles, tyres, etc.

(*b*) Replacement of equipment which do not deteriorate but are rendered completely useless such as electric light bulbs, radio or TV parts, etc.; and

(*c*) Replacement of equipment which become obsolete due to research and development.

Replacement Strategy for Equipment which Deteriorates Gradually

To determine the optimal replacement period, the period after which an equipment/machine should be appropriately replaced, it is required to proceed in the following manner. *Initially* it is *assumed* that *there is no time value of money*, that is, a rupee received at the end of a period, say 5 years, is regarded as good as a rupee received now.

The cost of a piece of equipment over a given time period, say n years, has three elements :

Purchase price – value remaining after n years + Maintenance cost for n years

The total cost, $T(n)$, of owning and maintaining the equipment for n years would be

$$T(n) = C - S + \sum_{t=1}^{n} M_t$$

where C is the purchase price of the equipment ; S, the scrap value of the equipment at the end of n years; and M_t, the maintenance cost of the equipment in year t.

Correspondingly, the average cost, $A(n)$, would be defined as

$$A(n) = \frac{1}{n}\left[C - S + \sum_{t=1}^{n} M_t\right]$$