Asset Maintenance Policies

Introduction

Current asset maintenance policies are usually based on reactive maintenance where assets are repaired or replaced after they fail rather than on proactive maintenance where assets are maintained to reduce their risk of failure. There is increasing realisation that proactive maintenance has many advantages over reactive maintenance, including much lower costs, higher asset availability, longer asset lifetimes and fewer staff required. All these benefits lead to improved operational and financial performance of the organisation. A key task in implementing a proactive asset maintenance policy is establishing which assets require proactive maintenance – a task that requires detailed analysis and modelling of failure data and other data using predictive analytics. **PAM** offers this predictive functionality (see PAM Introduction and PAM Modules).

Example Maintenance Interventions

Table 1 shows some maintenance interventions for some asset types.

Table 1

Asset Type	Example Maintenance Interventions
Pumps	Investigation, adjustment, lubrication, reset, unblock, repair, refurbish, replace
Valves	Exercise, adjustment, inspection, repair, refurbish, replace
Motors	Change oil, inspect belt, power supply, load, lubrication, repair, refurbish, replace
Generators	Check alignment, adjustment, lubrication, repair, refurbish, replace
Transformers	Check wirings, check operating temperature, repair, refurbish, replace

Asset Management Optimisation

The objective of asset management optimisation is to find the asset management policy that minimises the life-cycle cost of operating, maintaining and replacing assets subject to a set of constraints, for example environmental and safety regulations, and the organisation's maintenance capacity and attitude to the risk of asset failure. Proactive maintenance helps organisations achieve this objective. Asset management policies that are not optimal lead to higher costs and lower asset availability.

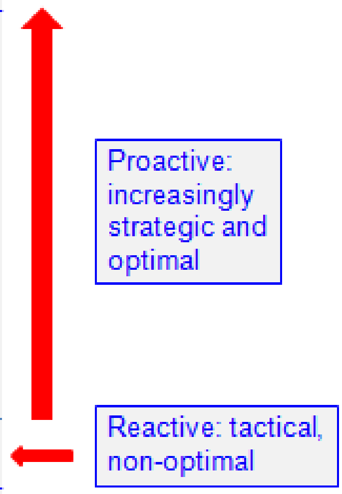
Good proactive asset management policies use predictive analytics to model asset performance and determine the causes of asset failure. Organisations can then act on these findings to reduce the failure rates and improve the performance of assets that are causing concern by, for example, replacing them by assets with different specifications or by changing their maintenance policies.

Maintenance Policies

Asset maintenance policies can be classified as reactive or proactive. Figure 1 shows the key features of five maintenance policies (four proactive and one reactive). The proactive policies are ranked in order of increasing strategic value and optimality (bottom to top).

Figure 1

Maintenance Policy	Key Feature
Risk-based	Part of a comprehensive asset management policy
Predictive	Predicts assets at risk of imminent failure
Condition-based	Uses decision rules to detect when an asset parameter is out of range
Scheduled	Regular maintenance based on manufacturer's schedule
Reactive	Assets run to failure



Organisations usually use a range of asset maintenance policies depending on the cost and criticality of their assets – this is discussed in this paper.

Reactive (Unplanned) Maintenance

This is the simplest and most basic maintenance policy and involves replacing assets after they fail. It is appropriate for cheap non-critical assets and the maintenance cost for the policy is zero.

Reactive maintenance – a run to failure maintenance policy – is not appropriate for expensive or critical assets. It can quickly become very costly for such assets when *all* the costs of asset failure, including consequence costs, for example service interruption and fines from regulators, are considered. Indeed, the total cost of reactive maintenance on such assets can be about six times the cost of proactive maintenance. In general, reactive maintenance for expensive or critical assets can:

- lead to shorter asset lifetimes
- increase asset downtime. leading to a loss in output
- make it harder to return assets to an ‘as good as new’ condition because repeated reactive maintenance degrades asset performance much faster than regular proactive maintenance
- cause planned maintenance to be postponed because of high priority reactive maintenance on other assets, leading to a backlog of maintenance work
- lead to higher energy costs because assets that are not in optimal condition use more energy.

Simple maintenance such as lubrication or changing filters can reduce energy consumption by as much as 15%.

However good a maintenance policy, reactive maintenance will always be required as assets will always fail unexpectedly. A rule of thumb is to aim for 20% of maintenance time to be spent on reactive maintenance.

Preventive Maintenance

The aim of preventive maintenance is to reduce the risk of asset failure, and so reduce asset downtimes and extend asset lifetimes. It requires a strategic approach and is very often the most cost effective maintenance policy. There are two types of preventive maintenance policy, scheduled maintenance and predictive (proactive) maintenance, and they are described below in order of increasing asset management optimality.

Preventive maintenance is suitable for critical assets or assets whose failure rates can be reduced by maintenance. It is not suitable for assets that can fail randomly or whose failures are not related to maintenance, for example electronic components.

Scheduled maintenance involves maintenance at specified frequencies whereas predictive maintenance is carried out on an asset when its risk of imminent failure is sufficiently high for it to have immediate maintenance to reduce its risk of failure. If possible, predictive maintenance and scheduled maintenance should be carried out at the same time to minimise asset downtime.

Even though predictive maintenance is the generally recommended maintenance policy, there may sometimes be a temptation to over-maintain assets. This condition is reached when additional maintenance does not result in increased asset reliability. There is an optimal level of predictive maintenance that can be found by simulating the effects of a range of asset maintenance policies and studying the balance between the costs of the policies and the costs of asset failure.

Scheduled (Cyclic, Planned) Maintenance

Scheduled maintenance is planned maintenance that is carried out regularly on a time basis rather than on a usage basis. An example of time-based scheduled maintenance is annual maintenance on heating systems before the winter and an example of usage-based scheduled maintenance is maintenance on a vehicle based on its mileage. This document considers only time-based scheduled maintenance.

The work required and maintenance frequency for scheduled maintenance are usually specified by the asset manufacturer. If possible, the maintenance should be planned to coincide with periods of low asset use. The maintenance frequency is often based on the failure rate curve with more frequent maintenance during the asset's infant mortality and wear out periods than at other times. The failure rate decreases in the infant mortality period and increases in the wear out period (see *Asset Deterioration Curves Module* in PAM Modules).

If it is thought that maintenance is being carried out too frequently, the maintenance frequency can be reduced. This will reduce the *direct* maintenance cost but may increase the likelihood of asset failure and the costs resulting from asset failure. The use of condition-based maintenance should be considered to compensate for the lower maintenance frequency (see Condition-based Maintenance below).

Predictive (Proactive) Maintenance

Predictive maintenance improves asset performance by calculating the condition or state of the assets and then working out when they should be maintained to prevent failure. It is not appropriate for cheap non-critical assets – reactive maintenance (discussed above) is more suitable for these assets.

PAM (see PAM System) helps organisations change their asset management policies from reactive fail-and-fix to proactive predict-and–prevent. It uses predictive analytics (survival analysis) to model asset failure as a dynamic phenomenon and so gain insight and understanding into the causes of asset failure. This knowledge is then used to improve the assets' maintenance policies and so reduce the risk of their failure. The models in **PAM** optimise asset performance at individual asset level and at the operational, tactical and strategic levels.

Predictive maintenance is more cost effective than scheduled maintenance because maintenance is carried out when required rather than when it is scheduled for based on a calendar. This targeted approach to maintenance leads to increased asset availability, longer asset lifetimes and lower maintenance costs, and so helps prevent reactive maintenance.

Predictive maintenance is particularly suitable for critical assets. It goes further than condition-based maintenance by warning of asset failure much earlier by applying predictive analytics to a range of non-asset and asset data, including sensor data. Additionally, the analytics can help organisations understand the causes of asset failure.

Condition Monitoring

Condition Monitoring (CM) uses real-time data from monitors on assets to detect the onset of performance deterioration or failure. It is carried out before failure in response to observed changes in the condition or performance of an asset. A maintenance intervention is triggered when a parameter that reflects the state of the asset and is a good leading indicator of impending failure reaches a threshold value. The parameters analysed include temperature, pressure, vibration frequency and viscosity. The decision rule for determining if a parameter has reached its threshold value must be very stable and able to be applied at all operating conditions of the asset.

CM is very effective where safety and reliability are paramount concerns, for example in the aircraft, nuclear, oil and gas industries. It allows preventive and corrective maintenance to be scheduled for before failure is likely to occur.

The advantages of CM include:

- potential failures can be identified before they occur
- repairs can be carried out while the asset is in use and with minimal disruption to production
- improved asset reliability
- lower asset maintenance and replacement costs
- reduced likelihood of collateral damage to the system.

The disadvantages of CM include:

- The capital cost and installation cost of CM can be high, possibly greater than the cost of the asset being monitored. They can be higher still for assets already in use.
- Maintenance interventions can be triggered in quick succession. This can lead to inefficient and costly use of maintenance resources and low asset availability.
- the signal may be noisy and so lead to false positives or false negatives
- it requires its own maintenance
- fatigue or uniform wear failures are not easily detected by CM
- the sensors may not be able to operate as designed in the asset's operating environment
- the asset may require modifications to accommodate the sensors
- the maintenance periods are unpredictable.

One way of understanding CM and the failure process is by the P-F curve as shown in Figure 2. The curve, also known as the asset deterioration curve, is characterised by a gradual increase in the rate of deterioration after failure has started. Once failure has started, the condition of the asset deteriorates so increasing the likelihood of failure.

Figure 2

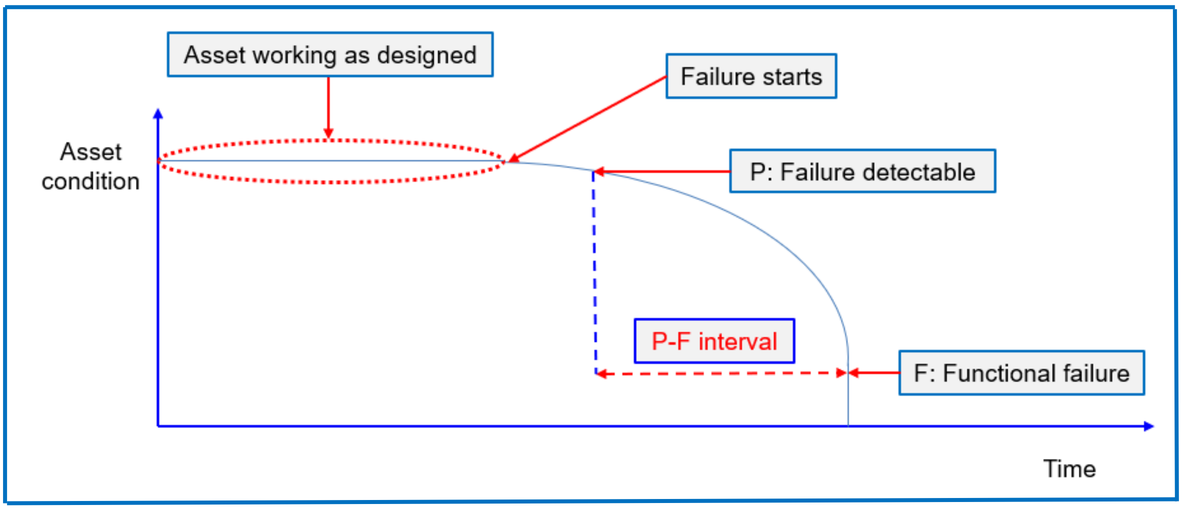


Figure 2 shows that failure may only be detected some time after it has started. The point P is the point at which the potential failure is first detected. The asset is still working but it has not yet suffered a functional failure (point F) when it will no longer be able to perform as expected or desired.

If the cause of the potential failure is not addressed, the asset continues to deteriorate until it fails at F. The interval between P and F, the P-F interval, is the window during which the asset can be inspected and the feasibility of carrying out proactive maintenance established. The time available for carrying out the maintenance can be calculated from an asset deterioration model.

CM must be carried out at a lower frequency than the P-F interval to allow enough time to detect and then correct the potential failure before the consequences of failure become serious and functional failure occurs.

Table 2 shows some of the different types of CM, and how and where they are used.

Table 2

CM Type	Example Uses
Vibration analysis	Rotating equipment (for example pumps and compressors)
Infrared	Electrical and mechanical equipment where thermal anomalies suggest failure
Ultrasonic	Deep water equipment
Acoustic	Gas, liquid and vacuum leaks
Oil analysis	Asset wear
Electrical	Current, power

Other aspects of CM are discussed in *Predictive Asset Management and Condition Monitoring* in PAM System.

Risk-based Maintenance

Risk-based maintenance is a methodology for determining how maintenance resources (staff, time and materials) should be deployed to minimise the risk of asset failure. The ‘pure’ or probability-based risk measure of asset failure can be enhanced by weighting it by the criticality and cost of each asset (**PAM** offers all three risk measures). The assets prioritised for maintenance are calculated either from one measure or by combining two or three measures. The actual assets to be maintained are worked out from the risk measure(s) selected for each asset and domain knowledge.

Figure 3 shows how the asset maintenance policy is influenced by the maintenance frequency and cost of the asset.

Figure 3