Reactive and Proactive Maintenance - The Best Mix

Introduction

The amount of proactive maintenance and reactive maintenance, and the balance between them for a given maintenance capacity have significant effects on an asset's maintenance and replacement costs, and availability, and any consequence costs resulting from its failure due to, for example, flooding, pollution, service interruption and damage to the organisation's reputation.

Asset Life Cycle Costing

Before proactive maintenance and reactive maintenance are discussed, it is worthwhile considering briefly how decisions about if and when assets should be repaired or replaced are made – decisions that can have important financial implications for organisations. The decisions are based on analysing changes in the life cycle costs of assets as the assets are used, maintained and repaired. The life cycle cost of an asset is made up of a number of costs, some of which are listed below. When working out an asset's life cycle costs, its maintenance and repair costs are allocated to operational expenditure and its replacement costs are allocated to capital expenditure.

It is usually more economic to maintain and repair an asset to extend its life for as long as can be justified than to replace it. Some of the factors to consider when calculating an asset's life cycle cost and so decide if it should be repaired or replaced are:

- is the asset near the end of or beyond its expected life
- do the asset's expected reliability and consequences of failure pose unacceptable risks, for example security, health and safety risks, and is the cost of mitigating them greater than the cost of replacing the asset
- do the asset's current and expected repair costs exceed the cost of replacing it
- will maintaining the asset improve its performance sufficiently
- has the existing asset been superseded by a much better version and are spare parts for it expensive and hard to obtain.

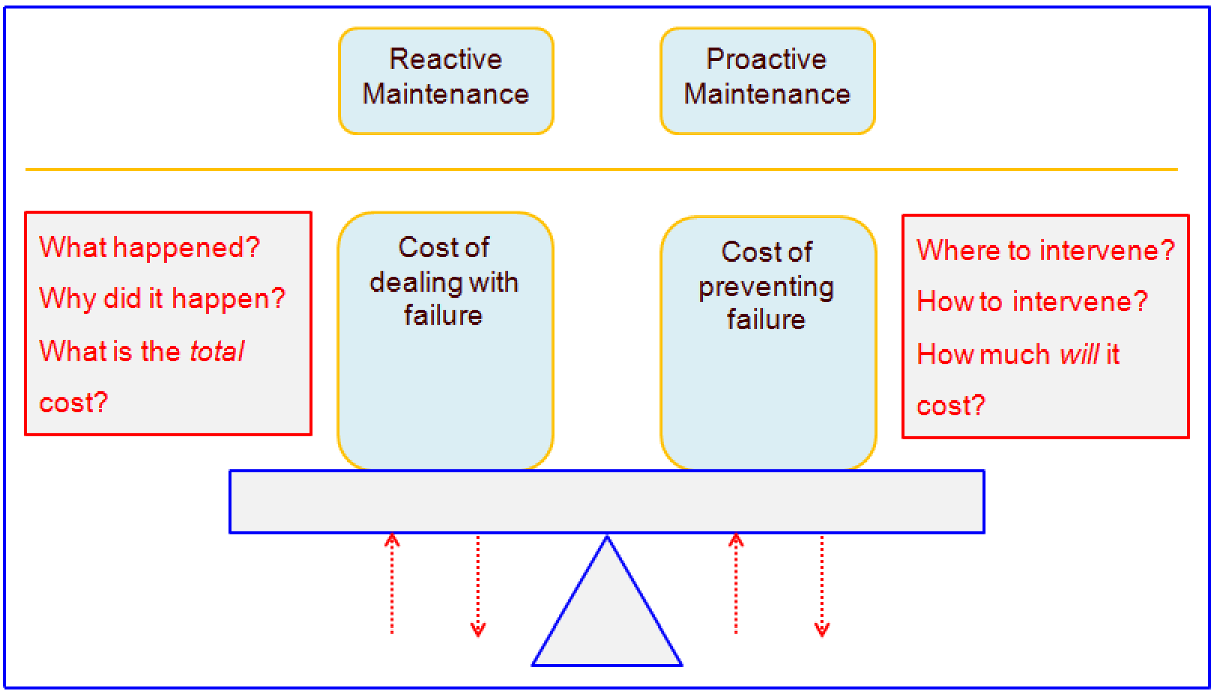
During its life time, an asset's maintenance costs can become many times its initial cost. Although assets can and do last longer than their design lives, it becomes increasingly important to consider the trade-off between their projected maintenance costs and their replacement cost as they get older. Eventually, a time will come when it will be more economic to replace the asset than to continue maintaining and repairing it. The life cycle cost profile can be used to determine this time.

Proactive Maintenance and Reactive Maintenance

A purely proactive maintenance policy is the ideal policy but unachievable because assets will always fail unexpectedly however good the maintenance policy and so require reactive maintenance. A proactive maintenance policy based on predictive analytics to determine which assets should be scheduled for maintenance should be the aim. This approach will not remove totally the need for reactive maintenance but it will minimise the occurrence of reactive failures. The minimisation is subject to operational and other constraints, for example the organisation's maintenance capacity and attitude to the risk of asset failure. The Asset Survival Simulations module in **PAM** (see *Asset Survival Simulations Module* in PAM Modules) considers these and other factors when working out the optimal asset management policy.

Figure 1 summarises the trade-off between proactive maintenance and reactive maintenance. The key difference between them is that reactive maintenance asks questions about the past whereas proactive maintenance asks questions about the future.

Figure 1



The analysis presented in this paper shows that as the proportion of proactive maintenance increases, the total asset maintenance and replacement cost decreases. Before considering maintenance policies that involve both types of policy, it is best to first consider each maintenance policy alone.

For simplicity, all the analyses use average asset maintenance costs rather than differentiating them by asset type, etc.

Reactive Maintenance Only

In a purely reactive maintenance policy assets are repaired or replaced after they fail. In effect, the policy looks backwards rather than forwards – ‘after the event’ maintenance. A purely reactive maintenance policy has the following features:

- maintenance prioritisation is rule-based, for example on the severity of the consequences of asset failure, but does not consider the current risks of asset failure
- very high asset maintenance costs
- very high asset replacement costs
- very high consequence costs due to, for example, pollution, flooding and service interruption, and fines from regulators for breaching environmental limits or service targets
- takes much longer than proactive maintenance.

Let:

- *no_asset_failures* be the number of assets that failed in a particular month
- *max_capacity* be the maximum number of assets that can have reactive maintenance in a month
- *cost_reactive_maintenance* be the average asset reactive maintenance cost.

IF *no_asset_failures* <= *max_capacity*:

cost_of_asset_failure = (*no_asset_failures* × *cost_reactive_maintenance*) + *consequence_costs*.

IF *no_asset_failures* > *max_capacity*:

cost_of_asset_failure = (*max_capacity* × *cost_reactive_maintenance*) + *costs due to work that is not carried out in the current month and work that was not carried in previous months*.

It is clear that if the maintenance capacity is too low, a reactive only maintenance policy can quickly lead to an ever increasing work load and costs.

Proactive Maintenance Based on Predictive Analytics

In a purely proactive maintenance policy assets are maintained to reduce their risk of failure. Predictive analytics can be used to optimise this type of policy by identifying the assets at greatest risk of imminent failure as the assets are used. The predictive analytics method used in **PAM** (survival analysis) allows the risk of asset failure to be modelled as a dynamic phenomenon so that increases in the risk of failure as assets are used can be monitored (maintenance reduces the risk of failure).

A proactive maintenance policy based on predictive analytics has the following features:

- the maintenance schedule can be prioritised by the risk of failure or by the risk of failure adjusted by asset cost or by the risk of failure adjusted by asset criticality
- it minimises the total cost of asset management
- it establishes the factors that contribute to asset failure, so providing insight into and understanding of asset failure
- consequence costs do not occur because assets are maintained before they fail (ideally).

Let:

- *no_assets_proactive* be the number of assets that need proactive maintenance
- *cost_proactive_maintenance* be the average asset proactive maintenance cost.

Assuming there are no failures and there is always sufficient maintenance capacity
cost_of_asset_maintenance = *no_assets_proactive* × *cost_proactive_maintenance*.

Reactive Maintenance and Proactive Maintenance

Assume that, subject to maintenance capacity constraints, proactive maintenance and reactive maintenance are carried out each month.

For any month let:

- *no_assets_proactive* be the number of assets that need proactive maintenance
- *no_assets_reactive* be the number of assets that fail unexpectedly
- *max_no_assets_proactive* be the maximum number of assets that can have proactive maintenance
- *max_no_assets_reactive* be the maximum number of assets that can have reactive maintenance.

Table 1 shows the four combinations of proactive maintenance and reactive maintenance that must be considered. The first combination is the simplest to analyse and the last combination is the hardest to analyse.

Table 1

Proactive Maintenance	Reactive Maintenance
no_assets_proactive < *max_no_assets_proactive*	*no_assets_reactive* < *max_no_assets_reactive*
no_assets_proactive < *max_no_assets_proactive*	*no_assets_reactive* > *max_no_assets_reactive*
no_assets_proactive > *max_no_assets_proactive*	*no_assets_reactive* < *max_no_assets_reactive*
no_assets_proactive > *max_no_assets_proactive*	*no_assets_reactive* > *max_no_assets_reactive*

Consider the first and third scenarios in Table 1.

First Scenario

cost_of_asset_failure = (*no_assets_proactive* × *cost_proactive_maintenance*) +
(*no_assets_reactive* × *cost_reactive_maintenance*) + *consequence_costs*.

Third Scenario

This scenario assumes that all the maintenance (proactive and reactive) is carried out in the current and next maintenance periods. The analysis allows for some of the assets whose proactive maintenance was postponed to the next period to fail before this period.

cost_of_asset_failure =
(*max_no_assets_proactive* × *cost_proactive_maintenance*) +
{SUM OVER[*assets_requiring_proactive_maintenance_next_maintenance_period*]
(PROB(*asset_surviving_to_next_period*) × *cost_proactive_maintenance*) +
(PROB(*asset_failing_before_next_period*) × *cost_reactive_maintenance*) +
consequence_costs} +
[(*no_assets_reactive* × *cost_reactive_maintenance*) + *consequence_costs*].

This analysis can be generalised to cases where the required maintenance is postponed by at least two maintenance periods. In practice, it may have to be postponed for at least two periods due to, for example, limited maintenance capacity and other priorities. This will lead to a lengthening backlog of maintenance, with some of the assets failing before they have the planned proactive maintenance. The reactive maintenance then carried out on these assets will cost more, take longer than the originally planned proactive maintenance, and lead to higher consequence costs and lower asset availability.

The Asset Survival Simulations module in **PAM** (see *Asset Survival Simulations Module* in PAM Modules) shows that if the maintenance capacity is below a threshold value, increasing the proportion of proactive maintenance has only a marginal effect on the assets' maintenance and replacement costs. If the maintenance capacity of the organisation is above the threshold value, the assets' maintenance and replacement costs decrease as the proportion of proactive maintenance increases.

Summary Comparison of Reactive Maintenance and Proactive Maintenance

Reactive maintenance:

- looks backwards, i.e. 'after the event' maintenance, rather than forwards
- costs much more and takes much longer than proactive maintenance.

Proactive maintenance based on predictive analytics:

- looks forwards to minimise the occurrence of asset failure
- asset maintenance is prioritised on the current risk of failure of each asset so that the risk of subsequent asset failure is reduced significantly
- is based on an analytical model and so identifies assets at greatest risk of imminent failure.

PAM helps organisations change their asset management policies from **reactive fail-and-fix** to **proactive predict-and-prevent**, so saving them very large sums of money in maintenance costs (because proactive maintenance costs much less than reactive maintenance), replacement costs (because the number of assets requiring replacement is reduced) and any consequence costs.