PAM Asset Survival Simulations Module

Introduction

The Asset Survival Simulations module uses the asset survival models and discrete event simulation to optimise asset performance at the strategic level with respect to the assets' maintenance and replacement costs, and any consequence costs that may result from asset failure subject to operational constraints, for example the organisation's maintenance capacity and attitude to the risk of asset failure. The optimisation is carried out by simulating the effects of a range of asset maintenance and replacement policies subject to the constraints to identify the most cost effective policy.

The simulation can be viewed as a penalty risk simulation where the penalty is the total cost of asset failure and the risk is the risk of asset failure in consecutive periods, which will ultimately lead to asset replacement. The optimisation requires minimisation of the penalty subject to the constraints.

The Simulation Model

There is one simulation model for each functional equipment class or similar asset classification variable because each classification has its own asset survival model (the asset survival model is described in *Asset Survival Models Module* in PAM Modules). The simulation model is formed by combining the asset survival model with discrete event simulation.

Discrete event simulation is used to simulate the effects of maintenance interventions by injecting interventions on defined assets at defined times as discrete events. The assets that will have the simulated interventions at each time are calculated from the state of the assets at that time and the input data. The effect of a maintenance intervention on an asset manifests itself on the asset's subsequent risk of failure by virtue of the structure of the asset's survival model.

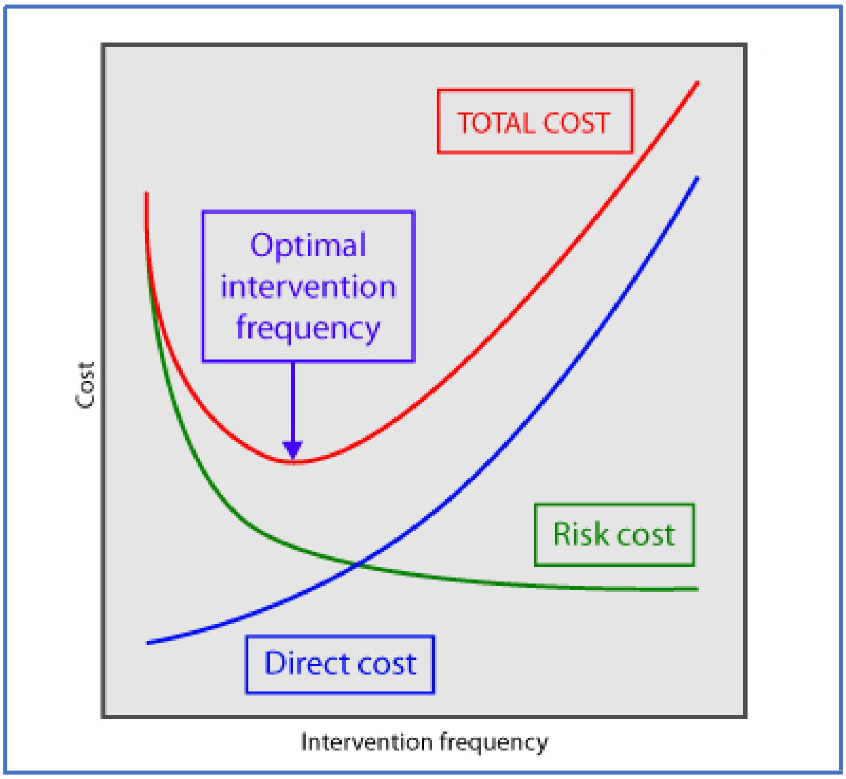
The simulation considers the:

- assets' maintenance costs by asset type and maintenance type
- costs of replacement assets
- consequence costs due to flooding, pollution, service interruption, etc. following asset failure
- balance between proactive maintenance and reactive maintenance
- maintenance capacity of the organisation (constraint)
- organisation's attitude to the risk of asset failure (constraint).

The Optimal Intervention Frequency

Figure 1 shows how the direct cost of asset management (maintenance cost and replacement cost) and the risk cost (cost of downtime and consequence cost) depend on the intervention frequency.

Figure 1



The total cost is the sum of the direct cost and the risk cost. As the intervention frequency increases, the direct cost increases and the risk cost decreases. The Asset Survival Simulations module finds the optimal intervention frequency, i.e. the frequency at which the total cost is a minimum. There is one graph for each combination of risk tolerance and maintenance capacity.

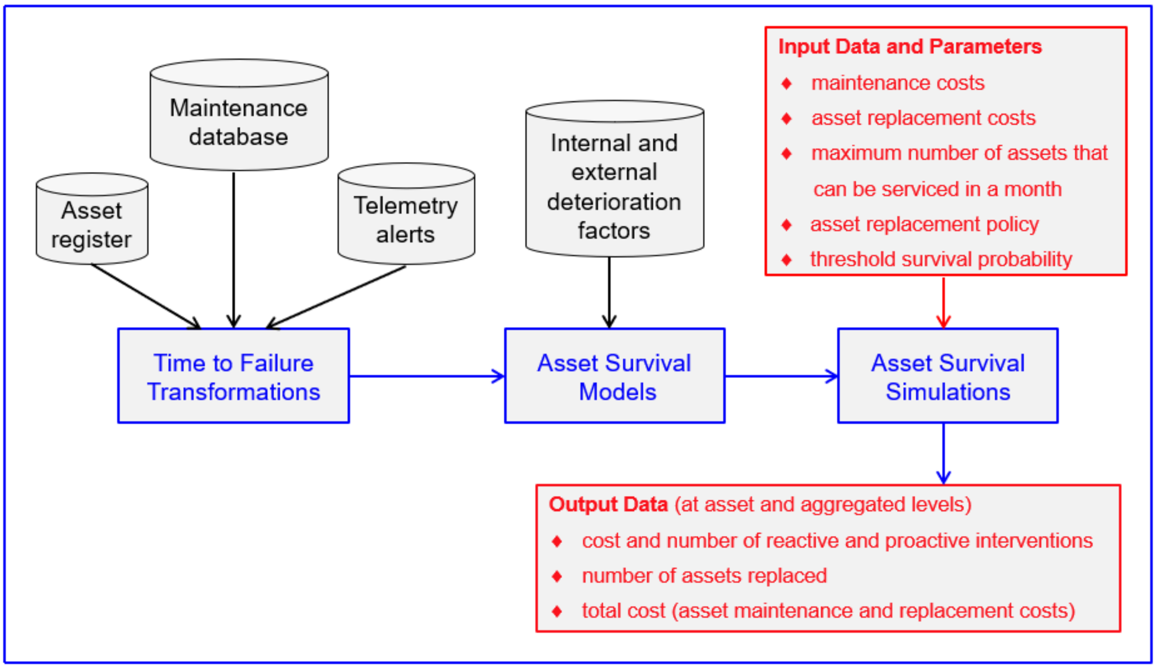
Risk Tolerance

Risk tolerance is a very important concept in the Asset Survival Simulations module. It is the maximum acceptable level of repeated asset failure and defined as the number of consecutive monthly reactive terminal interventions (see *Time to Transformations Module* in PAM Modules) an asset can have before it is replaced. It is measured on a 5 point scale, ranging from risk averse (1) to risk tolerant (5). Even though risk tolerant asset management policies result in lower asset management costs than risk averse policies, they are much more likely to result in higher consequence costs and so to much higher total costs than risk averse polices. These costs must be considered when working out the optimal asset management policy and may result in a more risk averse policy being appropriate (**PAM** considers all the costs).

Schema

Figure 2 shows the schema for the module.

Figure 2



Output Files

The output is graphs and tables of the simulation results that are accessed from the module's visualisation component.

Figures 3, 4 and 5 show simulation results for 2,250 pumps in waste water pumping stations in 800 locations based on 12 years of maintenance and failure data, and other data for maintenance capacities of 20, 60 and 100 interventions a month. The results are the pumps' maintenance and replacement costs (the penalty) for the 5 years after the 12 years (the consequence costs of pump failure are not included). The figures show how these costs vary with the percentage of proactive interventions (the percentage of interventions that are proactive as opposed to reactive) for each risk tolerance.

Figure 3 (20 interventions a month [low maintenance capacity])

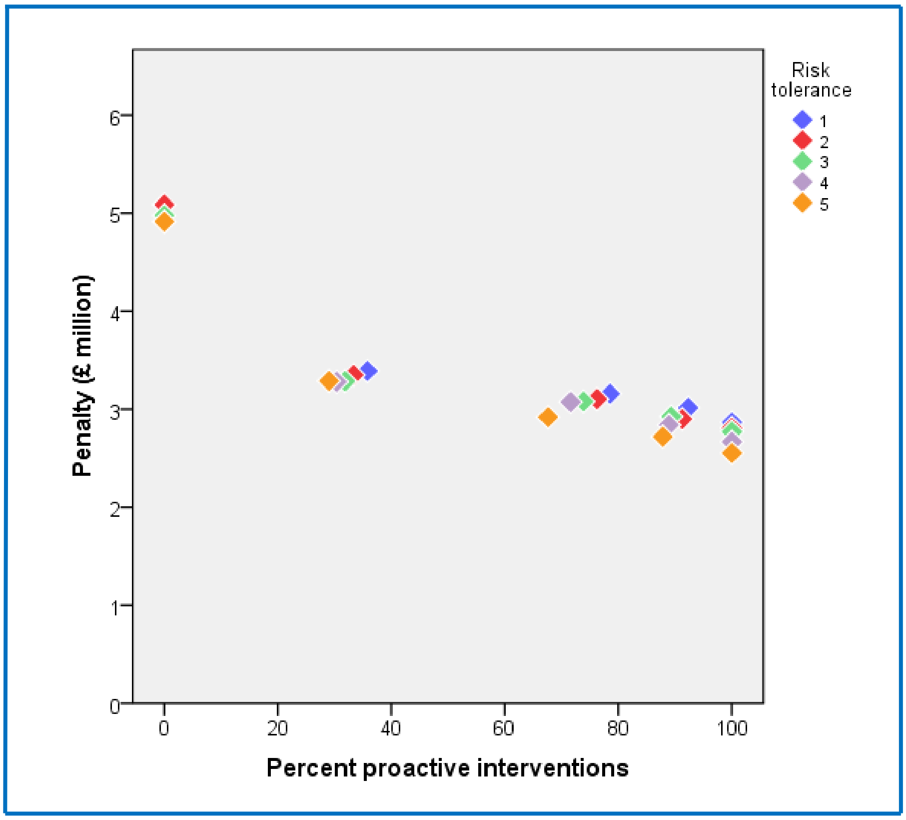


Figure 4 (60 interventions a month [medium maintenance capacity])

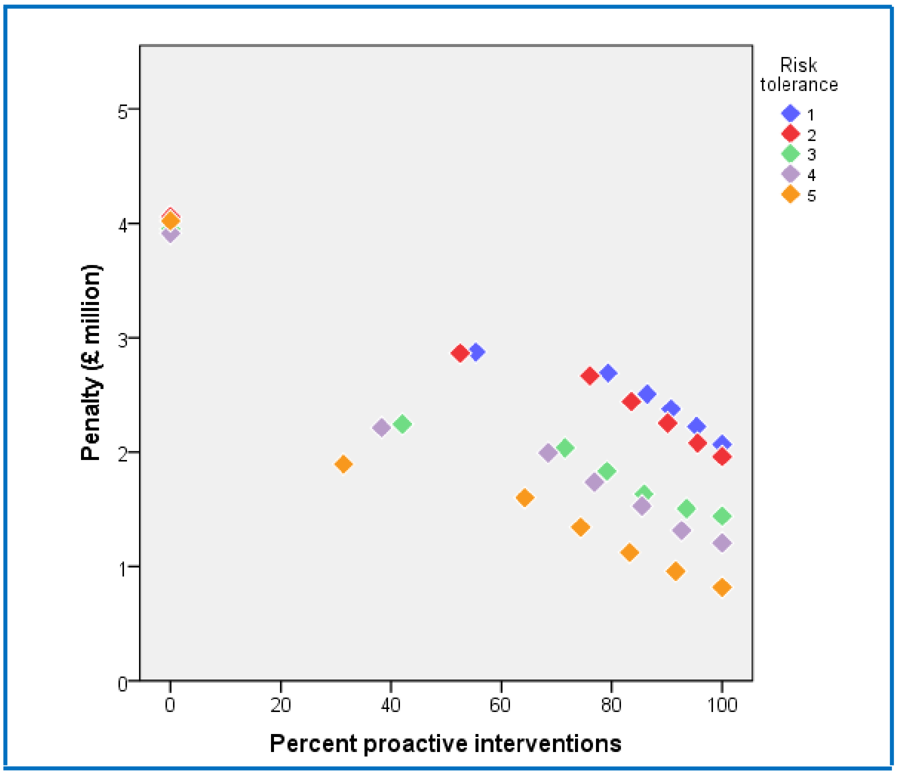
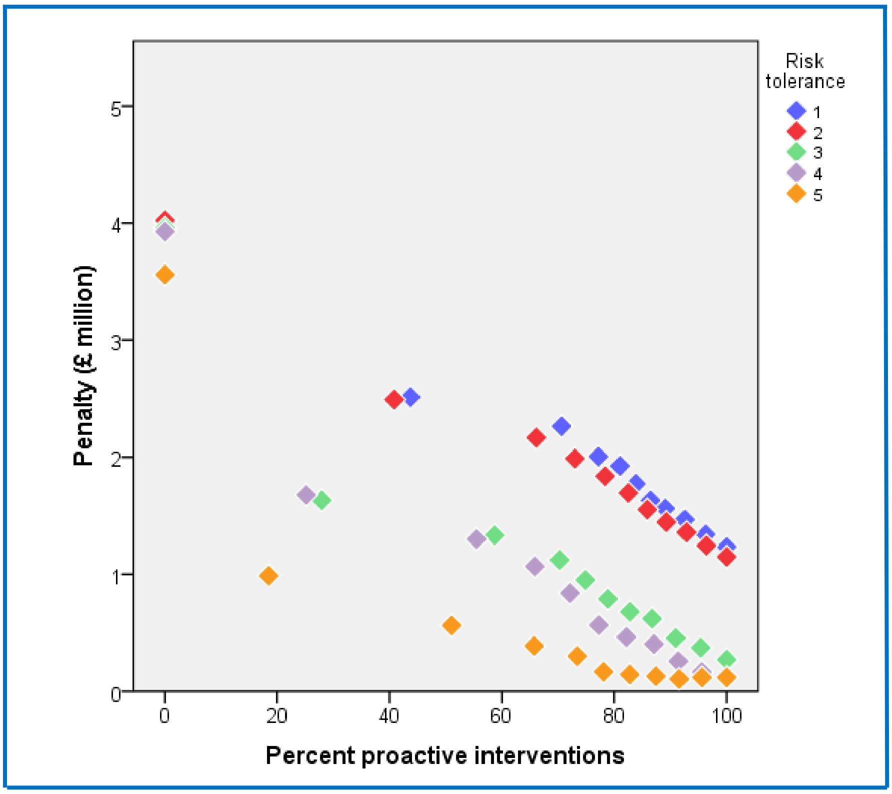


Figure 5 (100 interventions a month [high maintenance capacity])



When analysing Figures 3, 4 and 5, the point made in the section 'Risk Tolerance' above about how risk tolerant asset management policies can lead to very high consequence costs must be considered. Since these costs are not included in the penalty figures, the total cost of risk tolerant polices can be significantly greater than the costs shown in the figures. Risk averse policies can also lead to consequence costs but they are likely to be smaller than the consequence costs of risk tolerant policies.

All the figures show that the penalties of maintenance policies that consist only of reactive maintenance are much greater than the penalties of maintenance policies that are proactive, even to a small extent. They show that for all risk tolerances the penalty decreases as the proportion of proactive maintenance increases except at high maintenance capacities and very risk tolerant policies, the extent of the decrease depending on the maintenance capacity.

If the optimal asset management policy is the policy that minimises the assets' maintenance and replacement costs, Figures 3, 4 and 5 show that (consequence costs are not considered):

- If the maintenance capacity of the organisation is very low, the optimal asset management policy cannot be achieved.

- ♦ If the maintenance capacity of the organisation is very high, the risk tolerance is high and the maintenance policy is almost exclusively proactive:
  - the penalty increases from its optimal, i.e. minimum, value
  - the optimal asset management policy does not require all the maintenance capacity. Too much maintenance is being carried out and unnecessary costs are incurred. This result is shown in Figure 2 in *Asset Key Performance Indicators Module* in PAM Modules.
- ♦ For all other maintenance capacities, the optimal asset management policy is achieved at high levels of proactive maintenance. The reduction in the penalty becomes progressively smaller as the level of proactive maintenance increases. When other costs such as lower consequence costs associated with high levels of proactive maintenance are included, the curves become steeper and then flatten out, making the optimal point or region clearer.

