Finding the right mix of costs, risks & performance

By John Woodhouse, Managing Director, TWPL

Introduction

Most engineering, maintenance and operating decisions involve some aspect of cost/risk trade-off. Such decisions range from evaluating a proposed design change, determining the optimal maintenance or inspection interval, when to replace an ageing asset, or which and how many spares to hold. The decisions involve deliberate expenditure in order to achieve some hoped-for reliability, performance or other benefit.

We may know the costs involved, but it is often difficult to quantify the potential impact of reduced risks, improved efficiency or safety, or longer equipment life. Historical evidence points to what is allowed to happen – we try not to gather the data about the other side of the coin: what would happen if we did *not* perform maintenance. RCM, TPM and other frameworks inject some common sense into the speculation, and provide some guidance on the questions of "What maintenance/ inspections/ replacements should I do, when?". They do not, however, provide the vital business justification step – how do determine the best combination of costs incurred, risks taken and performance achieved.

A 5-year, GB£2 million collaboration project "MACRO"* has been addressing this issue and has developed a structured set of procedures (to make sure that the right questions are asked), and a suite of "what if?" analysis tools to determine the optimum strategies specifically. Specifically designed to be used where hard data is poor, and engineering judgement or range-estimates comprise the main raw material, these optimization techniques recovery project design, purchasing, maintenance, condition monitoring, replacement and inventory decisions.

What is "Optimization"?

The first concept that needs clarifying is the meaning of "optimum". The word is often used very loosely in phrases such as "the optimum maintenance strategy" or "the optimum performance". In areas where there are *conflicting interests*, such as pressures to reduce costs at the same time as the desire to increase reliability/performance/safety, an optimum represents some sort of compromise.

It is clearly impossible to achieve the component ideals - zero costs at the same time as total (100%) reliability/safety etc. Higher reliability, performance or quality costs money or, to put it the other way around, to reduce expenditure we must choose what *not* to do or achieve. The inevitable trade-off is often drawn as a graph (see figure 1 for simplified version), but the optimum strategy is sometimes mis-labelled as the crossing point of the conflicting components.

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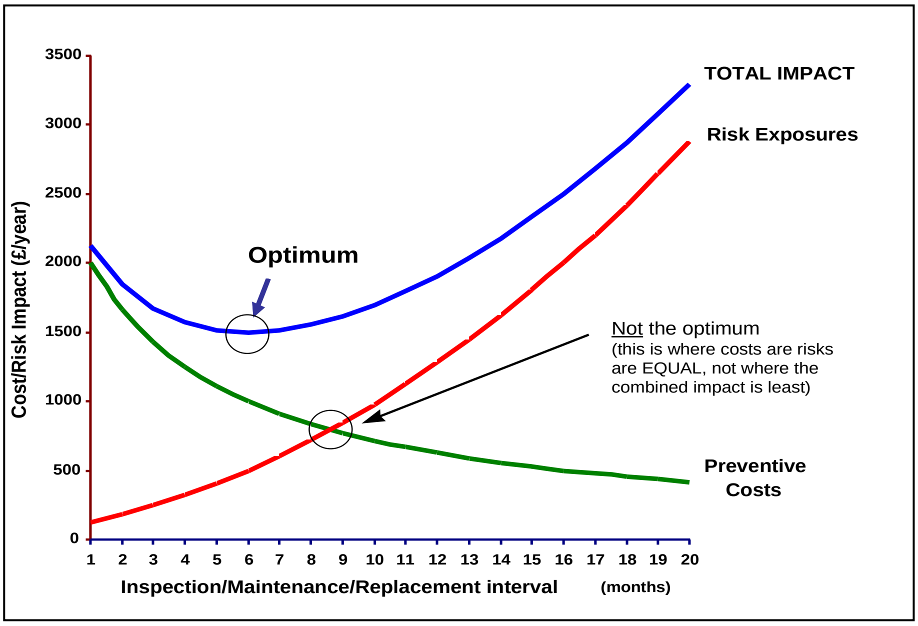

Figure 1 Optimum is defined as minimal Total Business Impact

Why this is difficult to find?

There are two specific barriers to identifying where the optimum lies:

- **lack, or poor quality, of relevant hard data** (what are the risks, and how would they vary with more/less preventive action)
- **how we would use any information that is available** (the commercial calculation of introduced and residual risks, planned costs incurred, performance impact, downtime, quality etc).

The first of these problems divides us into two camps – those who feel that more data (better, quicker, more accessible) is the answer, and those who have tried that route and found it a false horizon (what is "enough"?, "data swamping is just as big a danger", "what about all the engineering knowledge we have already?"). Both factions have some merit, and the need for better (not necessarily more) data is unarguable –

but what is 'better'? To determine what data is needed, the second problem has to be considered, namely how the information would be used to arrive at a commercial decision. This step determines what data is appropriate, and whether greater accuracy or collection effort is worthwhile.

Range-estimated engineering judgement may well be enough for a robust decision – or detailed statistical analysis may be warranted. Until we can test assumptions for sensitivity, it is nearly impossible to pre-judge whether current knowledge is adequate or not.

Fortunately, the nasty maths of maintenance, reliability and economics can now be handled by computers, leaving us to concentrate on asking the right questions in the first place. The findings of the MACRO project include separation of key decision drivers into 5 distinct families:

- Reliability & Risk: where estimates are needed for event likelihood and consequence, and deterioration represents changes in either of these elements.

- Operational Efficiency: quantified by the levels of operating costs and outputs (volumes, quality etc).
- Lifespan: deferment of capital re-investment or similar timescale-related effects
- Compliance: external obligations, for which specific premiums are paid, over and above self-interest in, say, risk/safety.
- "Shine" factors: public image, customer impression, employee morale, environmental and social conscience etc. whose value must be quantified by indirect means.

Under each of these headings, it is possible to structure a comprehensive 'checklist' of questions that need to be asked to range-estimate their significance. Such range estimates are adequate as starting material for the commercial evaluation, to find out if more detail is needed. In fact such sensitivity testing also reveals the *cost of uncertainty* – the potential impact of errors if the optimistic or pessimistic extremes prove true.

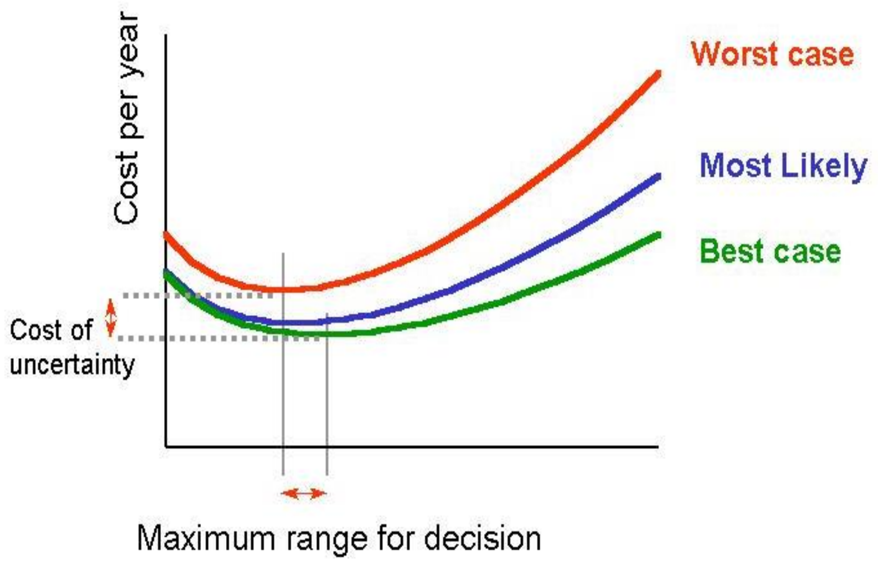

Figure 2 Using range estimates to locate optimum strategy

Example: Equipment maintenance decision

If the performance of a large pump deteriorates as deposits build up, its components wear, tolerances drift or efficiency falls, then there must be an optimum time to address the deterioration.

To determine the best maintenance strategy, we need to estimate how the performance falls with time or use, the economic effect of the losses (perhaps the machine has to operate harder or longer to deliver the required output, or maybe the quality rejects increase). We also need the cost of maintenance (including any operational downtime to do it). Some of this information may be known if there is some operational experience, but or maybe the quality rejects increase).

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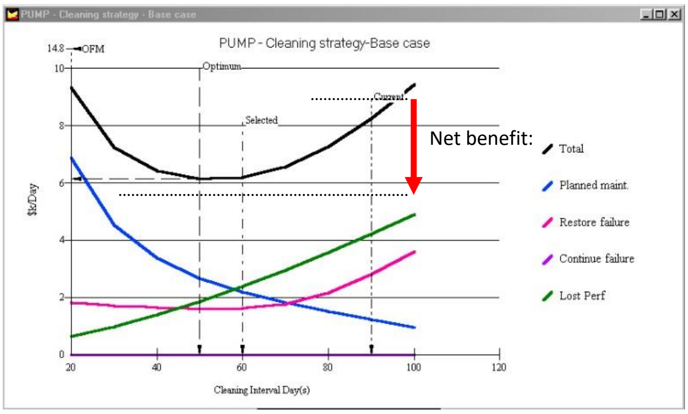
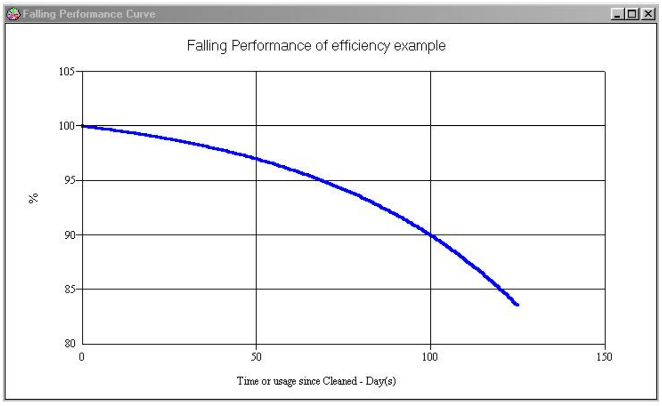
Structured description of the problem:

- By 6 months of operation, pump performance is 5-15% down, and this is likely to accelerate if left further.
- 1% lost performance is worth about $1500/day in production impact or additional operating costs.
- The costs of maintenance are $50-70k in labour and materials, and 6-8 hours downtime (needing overtime catch-up).

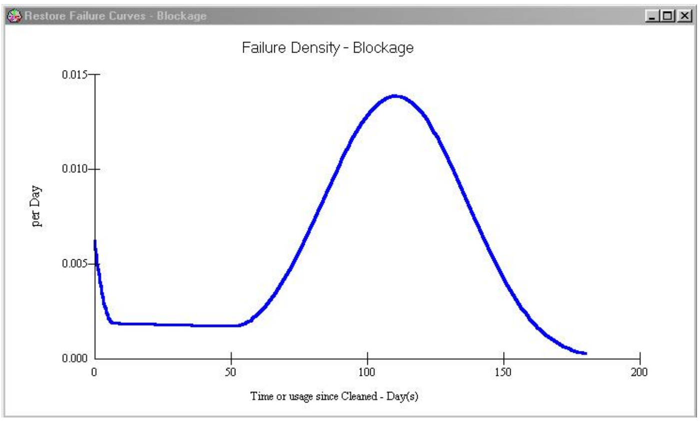


Calculating the impact

The first step involves 'fitting' a performance curve to the examples given:

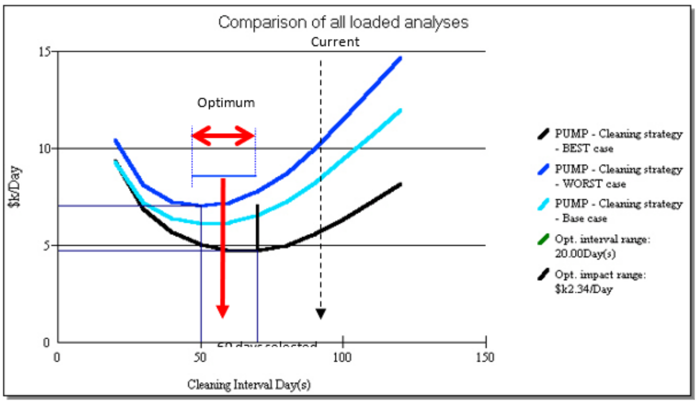


Then, a series of calculations can show the Total Impact of performance losses, cleaning costs and equipment downtime for various maintenance intervals:



Sensitivity testing

The "pessimistic" and "optimistic" interpretations combine the extremes of all the range-estimates. The total impact curves show that the maintenance interval must lie between 50 and 60 days. Yet the current strategy for this case was an overhaul after 90 days (3 months). A total improvement of approximately $2000/day is achievable by increased planned maintenance budget and reduced efficiency losses and unplanned blockage clearances.

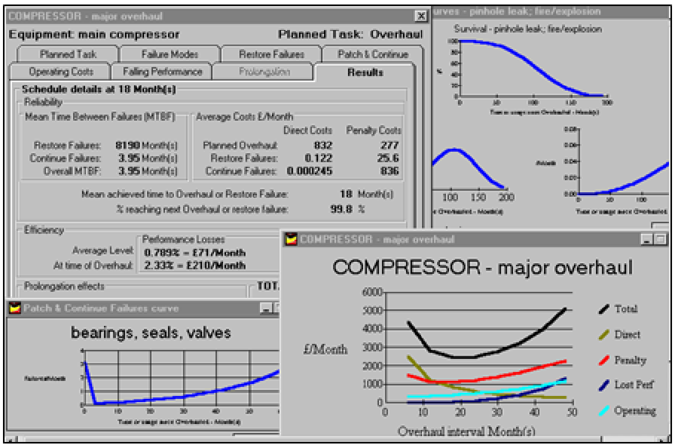


Extensions to include complex reliability characteristics

The subject gets substantially more complex with reliability and risk profiles. Failure modes interact (one risk affects the vulnerability to others, and planned maintenance introduces some risks while addressing/preventing others).

The correct mathematics is extremely complex (that's why we need a computer), however the principles and range-estimating disciplines remain the same, and the "what if?" approach to data uncertainty allows us to identify the key assumptions.

The following is an example of a complex, *multiple-failure mode* analysis of a major equipment overhaul, with wide ranges of uncertainty about failure probabilities, consequences and downtime impact. Such as study takes about 2 hours with the appropriate small team of engineers, operators and maintainers.



Other cost/risk optimization areas

The same essential process applies to a wide range of decisions and the MACRO project has developed six sets of procedures, training courses and analysis tools to cope with the variety of "what if?" investigations that are necessary. These are

- Project cost/benefit and risk evaluation: 1-off investments, change proposals, modifications or procedural changes.
- Asset replacement and Life Cycle Costing: repair versus replace options, life extension projects, alternative cost/performance designs etc.
- Planned maintenance strategy: preventive versus on-failure, preventive versus predictive, optimal maintenance intervals, impact of different designs, maintenance procedures, quality etc.
- Inspection, testing and condition monitoring: optimal inspection or testing intervals, condition reaction points, alternative monitoring methods.
- Shutdowns and work grouping: optimal combinations of work content and timing, opportunities and alignment, shutdown intervals.
- Spares and materials strategies: stockholding, purchasing and supply options, spares 'pooling', centralised versus distributed warehousing, min/max and reorder quantities.

Case studies and examples

The following is a sample of real-life application of Cost/Risk Optimization methods in different industries:

- Minor projects and technology changes: 400 proposals screened in 6-week period. GB£2.5million of unjustifiable expenditure avoided.
- Utility services: maintenance intervals and safety testing strategy for borehole pumping and chlorination plant. Pump maintenance and electricity consumption optimised, saving over US$500,000/year.

- Electrical distribution company: high voltage protection equipment showed justifiable reduction in testing by 50%.
- Manufacturing company: the corrosion monitoring of critical storage vessels and pipework needed to be doubled, with net risk reduction worth £'00,000s per year.
- Industry materials stockist: 60% reduction in slow-moving inventory without impact on risk exposures

For more information

The Woodhouse Partnership Ltd

Kingsclere Park

Kingsclere

Newbury

RG20 4SW

United Kingdom

T: + 44 (0) 1635 298800

www.twpl.com