Making the Business Case for Asset Life Extension

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Abstract

This paper describes and illustrates one of the processes being developed by the cross-industry SALVO project for the cost/benefit/risk evaluation of options for extending asset life. It represents one part of the SALVO suite of methods for improved financial decision-making in the management of aging assets. In particular it illustrates the optimisation of a periodic maintenance regime (painting) for the purposes of extending asset life, using the example of a steel bridge in London Underground.

1 Introduction

Many organisations are facing the dual challenge of aging infrastructure and tight financial constraints. So decisions about asset renewal or, if possible, life extension, are increasingly common and increasingly critical. The SALVO Project (www.SALVOproject.org), introduced at the IET/IAM conference in 2010 [1] [2], has now developed some innovative and very flexible methods to evaluate life extension options and optimal renewal timings. Furthermore, field trials have shown that a fully robust business case can be developed in most cases by a combination of

a) Asking the right questions of the right people (structured process)
b) Capture, quantification and correct use of 'tacit' knowledge (including uncertainties)
c) Performing the necessary reliability engineering and financial maths (including sensitivity analysis)
d) Determination of the optimal strategy, and the total business impact of any alternatives
e) Converting the answers into language that the financial world understands.

Key learning points from these studies have included:

- Significant cost, risk and asset lifespan benefits compared to existing methods of planning and decision-making (much bigger than expected)
- Initially counter-intuitive conclusions in some cases – but, with a transparent basis for the outcomes, achieving rapid and full acceptance of the correct strategy.
- Generic nature of the approach – which is proving applicable to a range of asset types and business environments.

2 Options to extend asset life

The SALVO methodology is a 5-step process that starts with clear problem definition and prioritisation. Once the issue is identified and understood (including root cause analysis), the options for addressing the problem are considered. These may range from the familiar RCM options of proactive (e.g. by design change), predictive, preventive, detective (failure finding) and corrective maintenance strategies, to the non-technical options of insurance, outsourcing of asset function and mitigation plans. SALVO work has identified 53 possible options that can be considered, depending upon the nature of the problem. And a range of them are geared to extend the asset life.

For example, if the assets are deteriorating through age or usage, then an enhanced planned maintenance programme may control the degradation process and enable longer life. Alternatively, a 1-off intervention such as refurbishment might possible to 'reset the clock' (at least partially) of asset condition and age. The correct steps and mathematics for cost/benefit/risk evaluation of these options are quite different, so SALVO has developed decision-specific guidance and tools for their evaluation and timing/interval optimisation. This paper explains and illustrates the processes for evaluating one of these options, through a specific case study: *optimising the painting strategy of bridging steelwork.*

This is one of c.500 bridges and other steelwork structures owned by London Underground who, like most organisations, have struggled with justifying a regular painting regime. The last time this bridge was fully prepped and painted was some 10 years ago.

3. Why we paint things

The SALVO evaluation stage requires consideration of all potential benefits of interventions, grouped into five primary methods of quantifying their effects in financial terms. These correspond to the findings of the earlier (1990's) MACRO project [3], which demonstrated how different competing demands can *always* be evaluated through a combination of:

1. Operational **efficiency** effects: the ratio of inputs (e.g. costs, resources) to outputs (volume, quality, service level etc.).
2. Operational **reliability & risk** control: probabilities (or frequencies) x consequences
3. **Sustainability** and **asset lifespan**: the extended usage opportunity and deferment of reinvestments
4. **Compliance** with non-negotiable obligations: the premium necessarily paid for such compliance.
5. **'Shine'** factors of reputation, morale and other human perception motives: the premium chosen to be paid for such 'intangibles'.

In the case of painting structural steel, at least two of these factors are usually involved – the desired extension of asset life, and the 'Shine' factor (especially if the steelwork is highly visible). Additional influences may also exist, however, and must be considered. For example, a painting activity involves surface preparation which may include early detection of minor defects before they grow to become functional defects or asset failures – so 'painting' can also have risk/reliability benefits. And there are cases where a better painted surface has energy efficiency benefits as well.

3.1 How much life extension for how much painting?

The relationship between painting at different intervals or standards, and the longer term degradation rates or ultimate replacement timing of the asset is difficult to determine. In special cases, corrosion rates have been monitored, modelled and extrapolated. But the vast majority of infrastructure is not individually critical enough to justify this level of personal attention. So a generic modelling approach was developed to organise and quantify the key assumptions.

This constructed an S-curve of effects (see figure 1). At the upper extreme, 'perfect' corrosion control could, in theory, deliver infinite asset life. However other factors (such as changed functional demand, or other degradation mechanisms) will generally cut in, so there will be a zone of diminishing benefits for better and better painting before some other consideration takes over as the lifespan-limiting influence. In this case, a horizon of 100-150 years was chosen as an initial assumption for maximal (corrosion-eliminated) life.

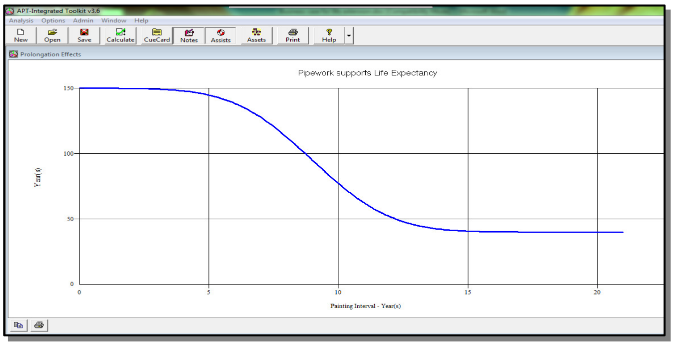


Figure 1. Possible relationship between asset life and painting interval

At the other end of the scale, *inadequate* painting (or even no painting at all) will certainly allow corrosion to be faster, but there will still be a minimum life associated with such a 'do nothing' strategy. In this case study, a 'minimum life' of 30-40 years was initially assumed for (galvanized but unpainted) steelwork. The SALVO process thus focussed on interpolating between such extreme cases, each represented by a range-estimate to reflect their uncertainty, followed by a 'sanity check' of more realistic painting strategies (e.g. 5-yearly) and the credible lifespans that would result (80-100 years).

These assumptions where obviously very uncertain, but the ranges were derived using another of the SALVO processes for capture of realistic 'tacit knowledge' from the assembled multi-disciplined team. This is a bracketing technique that we have called the Sherlock Holmes Method as it involves '*eliminating the impossible - as the remainder must include the truth*'.

3.2 The value of the extended life

The financial value of the longer life is a product of two data items:

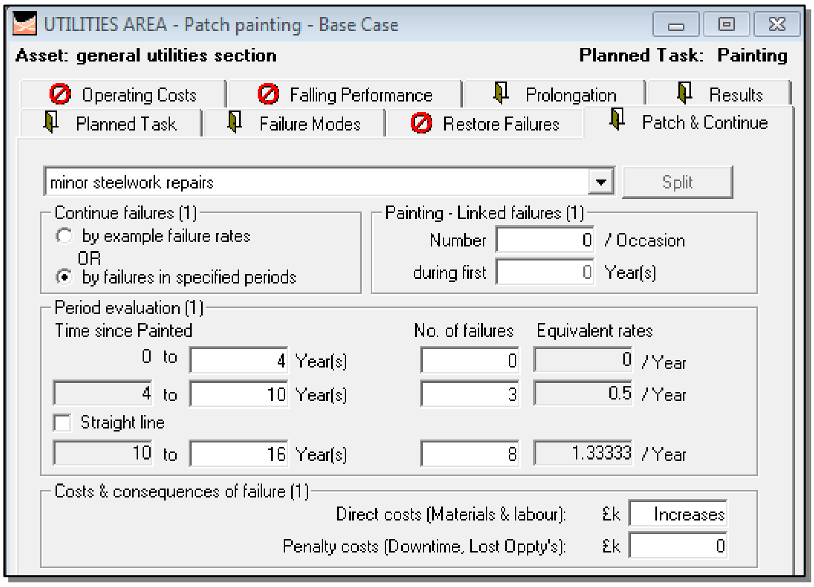
- The action that will occur at the end of life (e.g. replacement or at least major rebuild)
- The 'cost of money' or discount rate, which turns the future expenditure into an equivalent value in today's money.

In this case, the cost of rebuilding the supportive steelwork, on a planned basis, at a point where corrosion concerns would trigger such an action, was estimated at GB£4-5million in present day rates. The discount rate used was 3.5%/year but this was, of course, also tested for sensitivity.

3.2 Quantifying the risk benefits of early detection and failure prevention

This additional benefit from a painting intervention is not always feasible, but the case in study included the opportunistic detection of loose bolts, cracks and other minor structural defects, and their early, condition-based repair. This adds to the motivation for 'painting' and was quantified in terms of the estimated number of defects that would otherwise have propagated to become a special callout repair or an even more significant component failure (see Figure 2). If there had been any painting-induced risks, such as defects actually caused by the planned intervention, then these too would have been introduced at this stage.

In this way, a mix of possible failure modes, their patterns of probability, and a distribution of possible consequences were combined into the overall painting strategy optimisation.



Asset: general utilities section **Planned Task: Painting**

minor steelwork repairs

Continue failures (1)
○ by example failure rates
OR
● by failures in specified periods

Painting - Linked failures (1)
Number 0 / Occasion
during first 0 Year(s)

Period evaluation (1)

Time since Painted	No. of failures	Equivalent rates
0 to 4 Year(s)	0	0 / Year
4 to 10 Year(s)	3	0.5 / Year
☐ Straight line		
10 to 16 Year(s)	8	1.33333 / Year

Costs & consequences of failure (1)
Direct costs (Materials & labour): £k Increases
Penalty costs (Downtime, Lost Oppty's): £k 0

Figure 2. Quantifying the risk pattern for defect elimination effects

3.3 How do we put a price on the 'Shine' factors?

The third business motive for painting in this case was the image or reputation effect of well-painted infrastructure. This is potentially very important, depending upon the visibility of the structure, and can have impact on both employee pride and motivation and external reputation or confidence. But organisations are very inconsistent in their consideration of these factors, and in their budgeting for painting to achieve such benefits.

In the SALVO process, an inference method is used once all the other factors are quantified and the strategy options calculated. By calculating the optimal strategy *without* Shine considerations, then calculating the total cost/risk of a higher, 'desirable' level of painting, a "premium paid for Shine" is quantified (see Figure 4). This has proven to be an excellent way of stimulating more awareness and more consistency in handling reputation and other intangible factors in asset management decisions.

4 The costs of painting

A distinctive feature of a painting intervention is that the scope and cost varies considerably with the degree of preparation required. So longer painting intervals lead to bigger jobs, higher cost per occasion and, if process or system isolation is required, larger downtime 'penalties'. These are quantified in the SALVO process by two elements – the base cost of mobilisation, access, minimum preparation and painting, and the variable element, representing the additional time, effort and costs that are dependent on the degree of deterioration encountered (see Figure 3).

5 Constraints & Opportunities

Finally the evaluation process considered constraints and opportunities that render some strategies impractical, or more/less attractive from an access or alignment viewpoint (considering resources, other tasks, scheduled downtime etc.). Painting, for example, may require system isolation and downtime, or be limited to specific contractual commitments, or there may be 'free' or cheaper timing opportunities due to seasonality or existing shutdown cycles. The generic modelling process is capable of handling a mix of such factors, ranging from discrete, regular alignment opportunities (eliminating the need for, say, special access costs or downtime impact) to partial influences, where the merits of particular strategies have specific attraction or constraint.

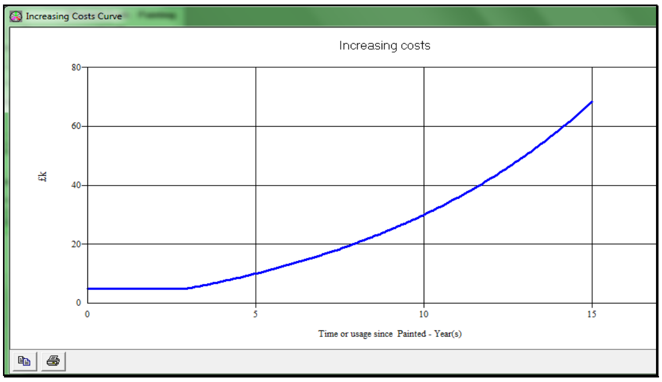


Figure 3. Escalation of painting cost with preparation needs

6 Calculating the optimal strategy

Constructing and quantifying the cost, risks, benefits and constraint/opportunity factors involved a small cross-disciplinary team (comprising operations, maintenance and civil engineering staff) for just 2-3 hours when following the structured process. This developed a 'base case' and extremes of optimistic and pessimistic strategy. It also enabled instant exploration of different assumptions and individual sensitivities. What became clear very rapidly was that a business justification for higher frequency patch-painting strategy, at an interval of 3-4 years, was solid against all reasonable "what if?" challenges (see Figures 5 & 6). Furthermore, despite being the apparent 'primary' reason for the painting, the resulting lifespan of the asset was revealed not to be the main decision-driver at the optimal interval. In fairly equal share, the two biggest influences on the painting interval were the cost-per-occasion of the task itself (escalating time and cost for preparation work) and the 'bonus' effect of spotting and correcting minor structural defects before they developed into discrete call-out repairs.

Not only had the optimal strategy been identified, but also

a) The consequences of ***not*** painting at this interval were clear and quantified (i.e. the cost of being too late)

b) The 'Shine' benefits of painting even more frequently (such as every 2 years) were similarly quantified – and deemed to be not worthwhile.

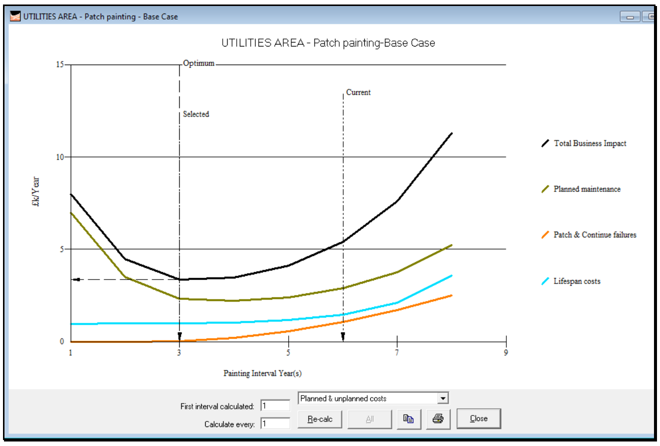
Compared to the historical practices (averaging about 6-10 years between paintings), the optimum of 3-4 yearly represented net benefits of c.£8k/year. If similar findings are achieved for the c.500 structures, this would represent c.£4 million/year of improvement, comprising a combination of more frequent painting at a lower per-occasion cost, reduced minor defects due to early detection/correction and the optimal amount of extension of asset life (amortised renewal expenditures in present day values). This provided the engineering staff with the clear business case for their painting budget – hitherto always a major struggle.

Other observations of note were:

- The cross-disciplinary working team needed just two meetings to resolve this strategy and generate a fully accepted, auditable business case. The resulting template can now be replicated and adapted, in 'batch' mode, across the other c.500 steel structures.

- The extra 'Shine' benefits of 2-yearly painting (instead of 3-4 yearly), would incur a premium of +£1k/year over the optimal strategy (see Figure 4). The marginal extra image improvement was deemed not worthwhile.

Figure 4. Calculated results for different painting strategies



First interval calculated: 1

Calculate every: 1

Planned & unplanned costs

Figure 5. Graph of costs & risks for different painting intervals

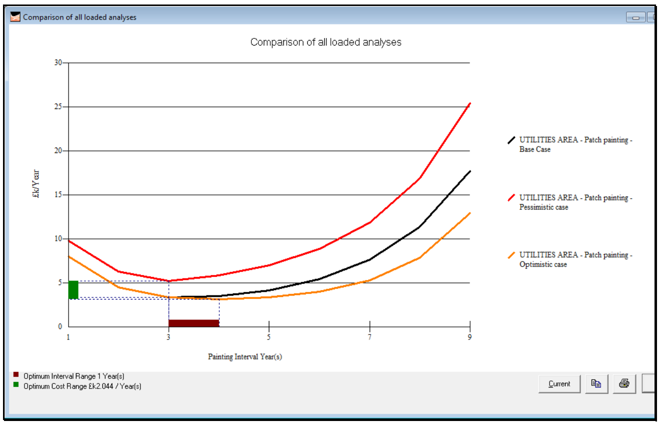
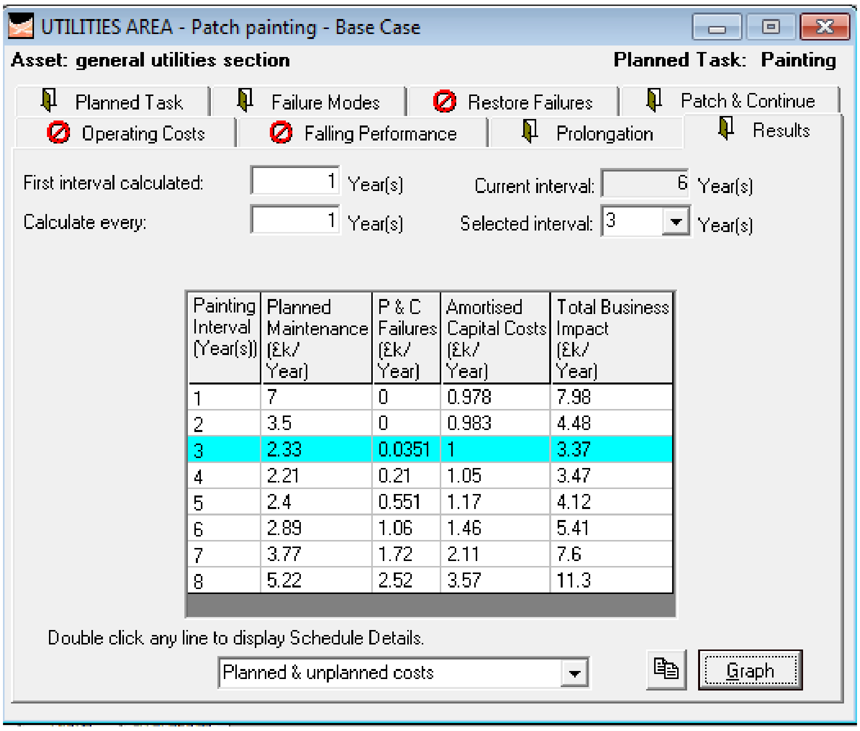


Figure 6. Sensitivity analysis to extremes of assumptions



Asset: general utilities section **Planned Task: Painting**

First interval calculated: 1 Year(s)

Calculate every: 1 Year(s)

Current interval: 6 Year(s)

Selected interval: 3 Year(s)

Painting Interval (Year(s))	Planned Maintenance (£k/ Year)	P & C Failures (£k/ Year)	Amortised Capital Costs (£k/ Year)	Total Business Impact (£k/ Year)
1	7	0	0.978	7.98
2	3.5	0	0.983	4.48
3	2.33	0.0351	1	3.37
4	2.21	0.21	1.05	3.47
5	2.4	0.551	1.17	4.12
6	2.89	1.06	1.46	5.41
7	3.77	1.72	2.11	7.6
8	5.22	2.52	3.57	11.3

Double click any line to display Schedule Details.

Planned & unplanned costs

7 Conclusions

This study illustrated the combination of a structured approach, the capture and quantification of existing expert knowledge, and correct mathematical treatment of the life cycle, reliability and economic impact of asset care strategies for life extension (painting). It showed that current knowledge, if correctly used, is enough to make robust cost/risk/life cycle decisions and that a generic, disciplined approach to such decisions can yield significant business benefits.

Moreover, the resulting strategy was fully agreed and 'owned' by the multi-disciplinary team involved, with the ability to explain and justify it to other stakeholders. A 'batch' version of the above process is already being developed within the SALVO suite, enabling systematic application of this process to large portfolios of similar, but variant, cases.

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Steve Faulkner; Halcrow
Robert Lange, Joshua Graham; DSTL

Note that the above case includes some small numerical changes for company confidentiality purposes. These do not affect the process or the results and conclusions.

References

[1] J.Woodhouse. “Optimal Timing for Replacing Aging or Obsolete Assets”, *IET* Asset Management conference, (2010).

[2] A.Thomson. “The SALVO Project: Innovative approaches to decision-making in the management of aging assets”, *IAM Assets*, (2011). www.SALVOproject.org

[3] Eureka MACRO project EU1488, www.MACROproject.org