The SALVO Project

Innovative approaches to decision-making for the management of aging physical assets

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Abstract

Aging assets and how to manage them is perhaps the most important issue facing Infrastructure Asset Managers across the world, with hundreds of billions of dollars of infrastructure re-investment estimated in the next 5-15 years.

Making decisions on what to do and when, often with limited information, whilst optimizing the trade-off between costs risks and benefits presents a major challenge. Combine this challenge with constraints around funding resources and time to execute the projected workload and the problem would appear to be insurmountable.

The SALVO project is an international cross industry R&D project, which sees a combination of leading-edge asset owners and practitioners working together to establish best practice approaches to address this key Infrastructure Asset Management issue.

This paper explores the issues, reports on progress to date, and draws some early conclusions regarding the next steps. What is clear now however, is that the prizes for getting these decisions right are huge whereas the penalties for getting it wrong are severe. prizes for getting these decisions right are huge whereas the penalties for getting it wrong are severe.

Introduction

The management of aging assets is one of the most critical issues facing infrastructure asset managers today. With over £25Bn of identified infrastructure re-investment required in the UK and over $200Bn each across Europe and USA during the next 5-15 years.

Furthermore evidence shows that up to *30% of total life cycle costs* can be avoided by better decision-making, it is clear that managing aging assets is one of the most challenging issues facing infrastructure asset managers across the globe today.

This, coupled with constraints on resources, funds and the time available to execute project workload etc, emphasises the requirement for innovative approaches.

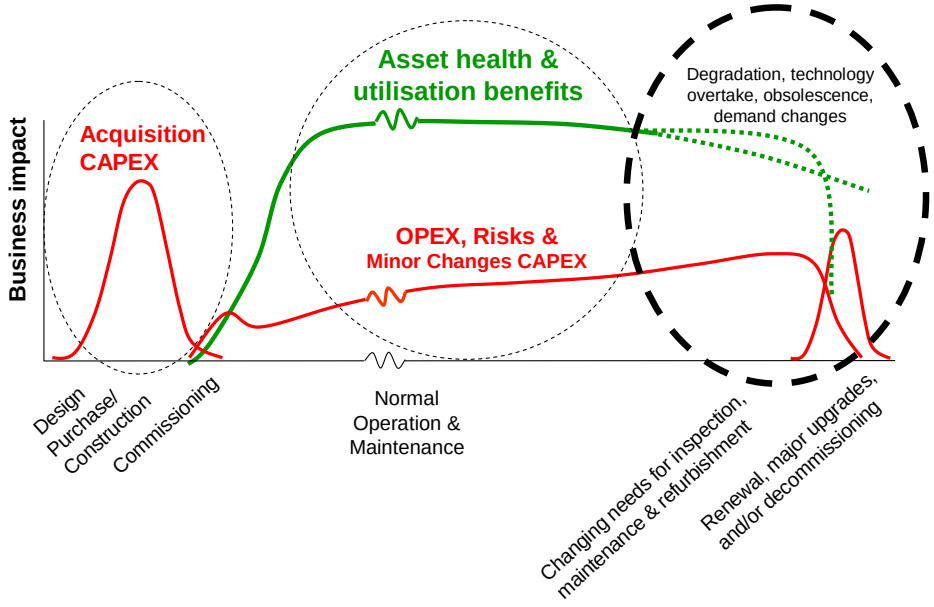


Figure 1 Challenges faced with aging assets – in context of whole life cycle management

This paper describes the international cross-sector project to research and develop innovative approaches to asset management decision-making in equipment replacement, maintenance, modifications, refurbishments and disposals. It is being run by a small, elite consortium of leading edge industrial partners, taking forward previous component work in these areas into a joined-up approach, that will deliver better value-for-money and auditable, risk-based justification for critical investment decisions. SALVO aims to develop simple, flexible and practical guidance, and tools for determining what to spend and when.

It is the natural 'next stage' to the R&D groundwork generated by the European Eureka MACRO Project (EU1488)[1]. MACRO covered several niche instances of asset management decision-making, particularly when hard data is limited or unavailable. It produced a combination of short training courses and free-standing analytical software tools (APT) that have been very successfully applied, but only in a relatively small number of large organisations.

With some of the most experienced practitioners and leading-edge R&D resources, the SALVO consortium intends to collate existing best practice from a wide range of industries, develop innovative methods for applying them to different asset classes and business environments, and deliver clear, practical guidance on how to make the right decisions about what is worth spending and when. This need is particularly acute in the management of aging assets, when deterioration, obsolescence, replacement or life extension activities need to be considered (see figure 1).

Decisions about 'aging' assets: the options

Great concerns are being expressed about aging infrastructure in several industry sectors, and the massive growth in required capital investment that is inferred to be on the horizon. However, decision-making methods in the management of such aging assets (for example, 'what is the optimal timing to replace or upgrade

[1] See www.MACROproject.org.

equipment?') are still generally highly subjective and inconsistent, often based on short term affordability rather than whole life cycle cost/performance criteria. Similarly, the business impact (risk, performance etc) of *deferring* expenditure or different projects is rarely quantified, yet is essential to demonstrate and manage systematically the different priorities for competing investment options.

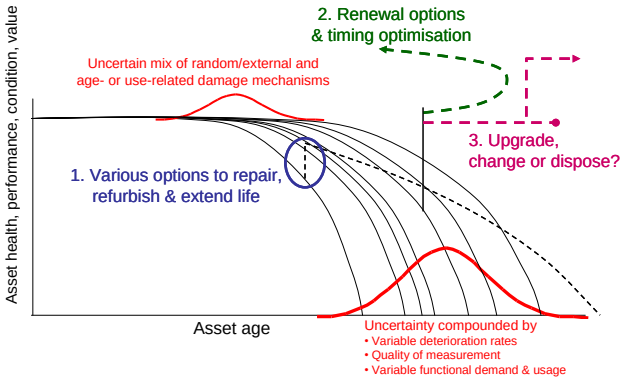


Figure 2 Example decision options faced with aging assets

Demonstrating optimal value-for-money

Risk and whole life cost-based decision-making is increasingly recognised as a key requirement for delivering and demonstrating value-for-money. There is a rapidly growing demand for skills and tools to assist in optimization between conflicting business drivers: between capital and operating expenditures, between short and long-term impacts and between costs, risks and performance. Regulators, shareholders, customers and other stakeholders also increasingly demanding much greater *transparency* in how expenditure decisions are made, particularly about what is worth spending, when and why. In simple terms, we need to demonstrate *what* is worth doing, *why* and *when*.

Furthermore, the BSI PAS 55:2008 standard for optimized management of physical assets (now accepted as the basis for the forthcoming ISO standard for asset management) *requires* organisations to actively and auditably optimize their asset management plans. These requirements exist at three levels of 'granularity':

1. Individual activities on individual assets (*Is this job worth doing, and if so, when*?) - this is where the MACRO project tools (APT) already help significantly but greater integration with business data & processes is needed and more simplified, 'wizard' guidance would help the adoption and usage by a wider range of personnel.

2. Integrated optimization of an asset's life cycle management (*What is the best* combination *of capital investment, utilization, maintenance and life expectancy*?) - this is where the SALVO project will set new standards and provide new solutions for modelling whole life cycle decisions, including determination of the optimal life cycles/replacement timings.

3. Total activity programme coordination and delivery of multiple activities across multiple assets (How do we optimally programme the conflicting urgencies of different activities a) to exploit 'bundling' opportunities and/or b) to smooth resource requirements/performance effects?).

SALVO approach & deliverables

This total process has been broken up into a number of technical and process working groups. In each workgroup, the objectives will be to:

i. Collate existing best practice processes and available tools
ii. Flowchart the realistic range of scenarios, options, decision types, data, information & assumption requirements, cost/risk/benefit evaluations and calculations, results interpretation, decision-making and conclusions implementation processes
iii. Develop a series of decision templates or guidance 'wizards' that force the right questions to be asked, including relevant data sources and knowledge capture aspects. These may be industry sector- and/or asset type-specific to reflect language and asset attributes (e.g. long-life civil structures versus high volume manufacturing systems).
iv. Update and integrate suitable decision-support tools for the cost/benefit/risk quantification and optimisation steps, including generic interface design for different data sources, and facilities for export of results into work planning/management systems.
v. Develop and publish a series of worked case studies of the application of these processes and tools.

Generic principles applied:

Wherever possible, a *quantitative, risk-based* approach will be taken, this includes providing methods for handling uncertain assumptions and the quantification of 'intangibles'. A *criticality-proportionate* approach will be applied, the rigour and sophistication of method must be appropriate to the criticality/complexity of the decision being addressed. Just having the technically correct solution is not enough, *process integration* methods are recognised as a vital part of the deliverables.

The nature of the problem

The biggest challenge for optimizing decisions about mature assets is the objectivity *and integration* of:

a) Step 1: Detecting which assets, in which functional locations represent greatest urgency of attention (health & criticality analysis) Identifying and quantifying asset deterioration patterns (e.g. risk or performance patterns, obsolescence, operating costs, remaining life etc) & their uncertainties
b) Step 2: Determining what options exist for refurbishment/life extension, replacement, upgrade, modification, disposal etc.
c) Step 3: Evaluating and optimizing the individual option timings and cost/benefit/risks
d) Step 4: Aggregating & optimizing the combined programmes for multiple activities across multiple assets (portfolio-level)
e) Step 5: Projecting forwards the asset portfolio costs, performance, risks and other attributes.

The project is developing a 5-step 'top-down to bottom-up' systematic approach (see figure 4) below.

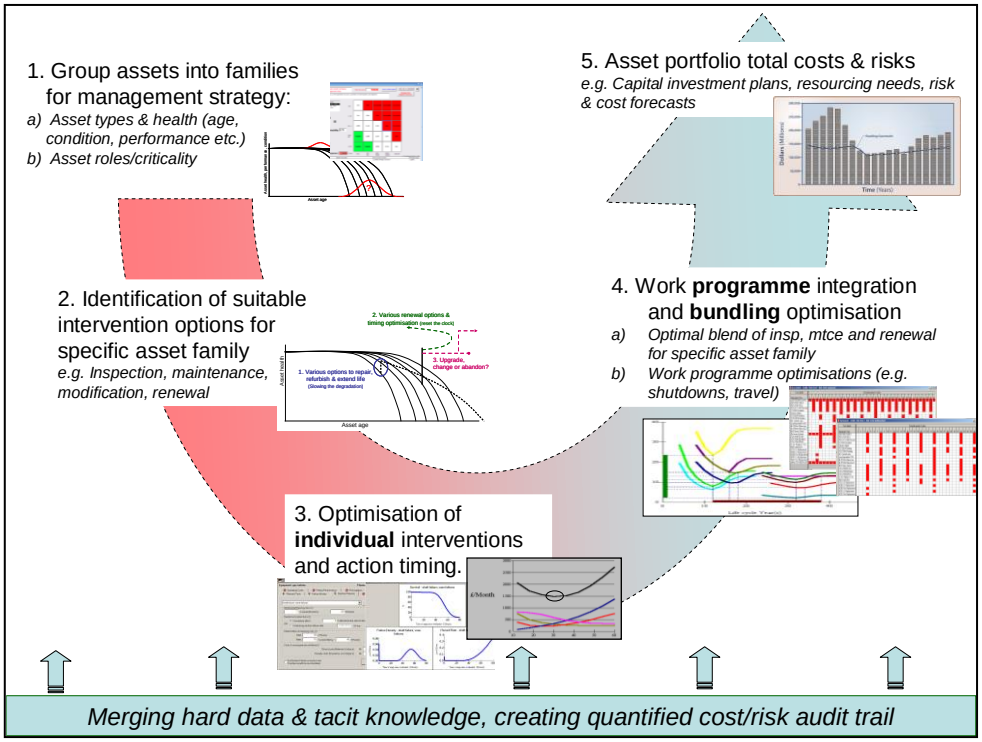


Figure 3 SALVO stages & issues to be addressed: Top-down & Bottom-up

Existing (partial) methods exist for each of the individual steps (a-e above) but these also suffer from some specific weaknesses that will need to be addressed.

form the respective industry sectors to catalyse improvements and develop the approach modelled below:

Progress to date

Work has commenced on many of the workstreams with the following results

Step 1 Grouping assets

Categorising assets into groups or classes with common factors driving the urgency with which to address the issue is a key element in asset decision making. It allows one to focus on critical assets and asset groupings thus making analysis effective i.e. focusing on the correct issue and efficient i.e. optimizing the return for effort deployed. The SALVO team has collated best practice

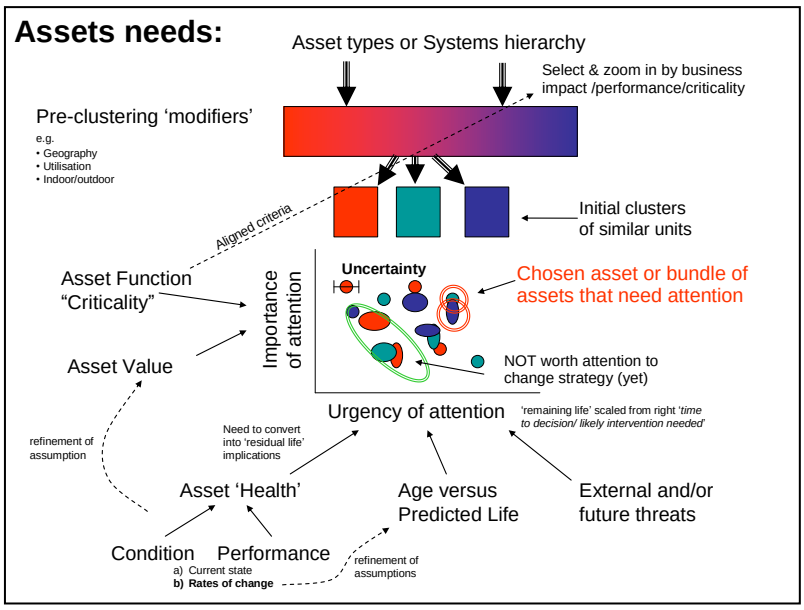


Figure 4 Grouping assets

This approach recognises that there are a number of pre clustering modifiers which allow us to group assets together. The SALVO team have identified 14 of these modifiers. These groups are further refined by urgency drivers of which three classes and 45 discrete drivers have been identified. The classes and example discrete drivers are shown in Table 1 below:

Urgency Driver	Example Description
Asset Health	Condition Monitoring
Asset Health	Performance
External and/or future threats	Demand/forecasts
External and/or future threats	Technology Obsolescence
Criticality/Importance Drivers	Safety
Criticality/Importance Drivers	Environmental responsibility

Table 1 Urgency Drivers

Step 2: Identifying intervention options

When assessing the possible intervention actions which might address the issues identified in Step 1, the project team considered all possible options. A particular feature of this approach was the acknowledgment that a TECHNICAL or ENGINEERING intervention was not always required. In total 53 discrete interventions were identified and these were classified into 13 "*Intervention types*". The types and example interventions are listed in Table 2 below.

Intervention Type	Description
Replace	Like for like
Replace	Like for like
Invest in Contingency	Buy a spare
Invest in Contingency	Competency
Decommission	Mothball
Modify Asset/System Capex	Refurbish include repair
Modify Asset/System Opex	Refurbish include repair
Modify	Operational strategy
Monitoring/Inspection	On Line CM
Sampling (1 off information capture)	Intrusive Inspection
Manage Stakeholder Expectations	Modify risk appetite
Planned Maintenance	Enhanced prolongation
Planned Maintenance	Run to Failure
Alternative Finance/Service Provision	Purchase asset function instead
Re engineer	Mitigate obsolescence
Competency Management	Retirement and succession planning
Quality Control System	Revise standards

Table 2 Intervention types and example interventions

Step 3: Evaluating and optimizing interventions

The MACRO project contributions

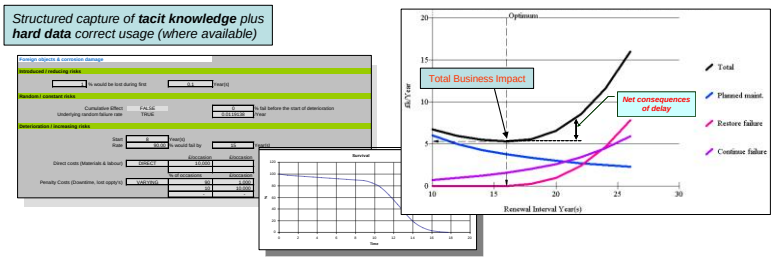
The original MACRO project addressed over 40 different types of discrete decisions, including the capital investment, project appraisals, asset renewals and refurbishments.

Therefore significant pre-consideration of these topics is already available and resulting decision support tools have been developed as listed below to address specific decision types. These tools now need to be better integrated and process clarified in the circumstances where such decisions are encountered.

- **APT-PROJECT:**
  Cost/Benefit/Risk Evaluation of Projects & Changes
- **APT-MAINTENANCE:**
  Risk/Performance/Cost Optimization of PM tasks
- **APT-INSPECTION:**
  Inspection, Condition Monitoring & Safety Testing
- **APT-LIFESPAN:**
  Life Cycle Costing, Renewal & Upgrade timing
- **APT-SCHEDULE:**
  Shutdown Work Content & Timing, Work Bundles

These tools robustly address specific areas of the decision however further improvements are possible.

- Individual asset **replacements (justification & optimal timing)**
- 1-off interventions (e.g. **refurbishments or modifications)**
- Enhanced **inspection, condition monitoring & maintenance**



Individual asset life cycle modelling and cost optimization

This module of MACRO, incorporated into the APT-LIFESPAN tool, addressed a wide range of life cycle cost-based decisions such as new asset purchase choices/comparisons, evaluation of existing asset modification projects, life extension/refurbishments and optimal asset replacement timing. It handles any combination of failure risks (including repairable events and/or forced replacement/life-terminating events), plus performance attributes and cashflows (smooth trends and/or 'lumpy' expenditures). APT-LIFESPAN uses Equivalent Annual Cost (annualised NPV) to enable fair comparisons of options with different life cycles or time horizons.

A key area of development already started is the life cycle modelling of specific assets and assessment of refurbishment options to defer asset replacement. This represents a significant mathematical challenge for which responses have already been developed.

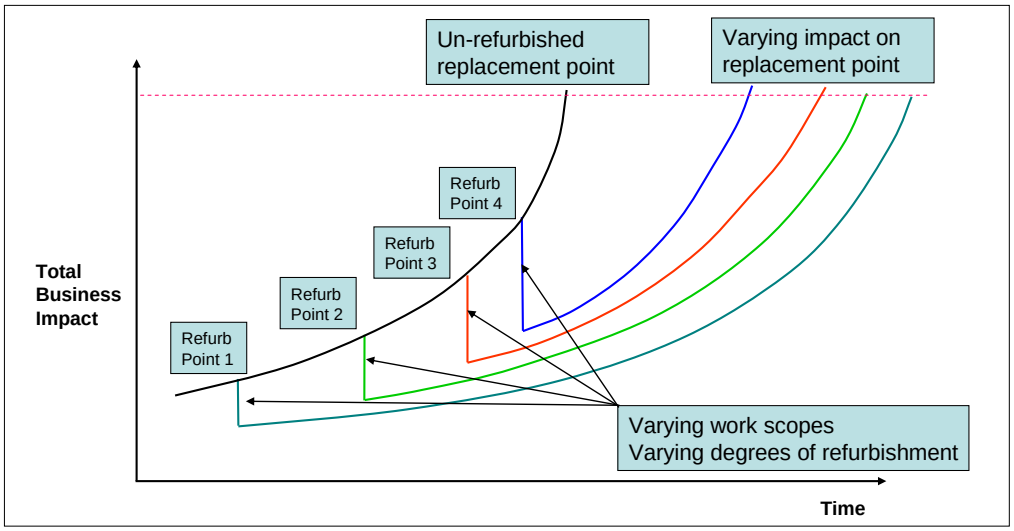


Figure 6 Optimizing one-off refurbishments

Selecting the optimum time to perform a one-off refurbishment is complex and is dependent upon a number of variables e.g. the required workscope and benefits obtained will change as the refurbishment is delayed. Whilst it is possible to develop mathematical models utilising simulation techniques this leads to a "black box" mentality. The SALVO approach is to avoid this issue and as such a combination of robust process and mathematical modelling will be developed to optimise the one off refurbishment decisions. The nature of the problem is shown in figure 6.

Step 4: Work bundling, alignment and shutdown strategies

This area is where individual tasks (projects, maintenance or inspection activities) are combined in the optimal way to share system downtime opportunities or some overheads such as travel logistics costs etc. APT-SCHEDULE is the MACRO model for this, and it goes part-way to the required programme integration requirements. It does not, however, explore resource constraints adequately, neither does it 'close the loop' by integration with the wide range of work management systems and planning tools that different organisations use. Work is yet to commence on the development of this element

Step 5: Total capital investment or opex plan optimization

The full picture, with budget forecasting and global 'what if?' capability is addressed in some organisations by a major simulation/modelling approach. Various service providers and commercial tools are available in this area, which aggregate the asset population characteristics (e.g. types, ages, condition and performance distributions), applies some assumed patterns for degradation, risk and intervention points or options, then performs a very large number of simulated work programmes to identify the "optimum" such programme. This approach can be excellent for the global work forecasting, (indeed, the oil & gas sector have been doing this routinely for all major investment projects for over 20 years), however, it has a number of weaknesses. SALVO addresses these weaknesses by providing the (criticality proportional) "feeder" information about cost/risk implications of *individual* interventions and their timing sensitivities. In summary, SALVO is aiming to create the best of both worlds – the *global*

problem description and navigation (inputs), the *individual* actions optimized to individual needs, and then the *global* coordination and cost/risk/performance optimization (outputs).

Lessons learned

The main challenge is one of navigable processes and mathematical integration – between global scale of asset portfolio problems/risks etc, the evaluation/optimisation of individual interventions, and the correct assembly (without double-counting!) and optimisation of combined work programmes and their global or portfolio implications.

The intellectual understanding of strategic asset management investment planning, decision-making and delivery is still fragmented and confusing and requires much greater assistance. This can be addressed by developing more specific 'wizard' guides and templates for the decision types and circumstances, and will also yield more educational material (e.g. "*how to*…" guides) incorporating industrial case studies

Business process & data integration

The second area of requirement is the total process understanding and better linkages from problem *identification* (e.g. aging assets, or new functional demands) to *option selection* and *evaluation*, intervention *timing optimization*, *programme integration*/optimization and *programme delivery* (including decision gates/review triggers). This 'source to solution' approach is needed for each of the main problems or decision types, (e.g. asset renewals, new demand asset investments, refurbishment or upgrade projects), as the final stages will involve a merger of all activities, whatever their provenance.

Hard data and tacit knowledge incorporation

This is a critical, core element of the proposed advances. The project should improve the understanding of *what* information is needed, *in what form*, and *how it should be used* for each decision type, and clearly show how any available hard data can, and must be supplemented by tacit knowledge (appropriately captured and qualified for inherent uncertainties), in order to build the best composite picture of current and proposed scenarios. This could be taken as far as development of generic standards for required inputs, enabling better systems integration and interchangeability.

A further deliverable should be clarification of required decision *outputs*. This might include, for example, the differential cost/performance/risk impact of any alternative options, task timings or the 'carbon cost' of different plans. It should also consider the impact of uncertainty and risk – the degree of confidence in the chosen option, the variability or sensitivity to key assumptions, and the specific data items that have the greatest impact on the conclusion.

Conclusion

The SALVO project represents an important development in decision making in Infrastructure Asset Management, in particular the management of aging assets. It takes existing knowledge and tools, and develops them to provide improved business processes supported by leading edge mathematical optimization tools.

The project reinforces the key concept that "black box" modelling tools are not the answer, any tool must be deployed within a set of robust processes which allows a clear understanding of the problem, the solution and how that solution is derived.

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