Extending SALVO decision-making disciplines into procurement, spares & inventory strategies

by John Woodhouse

Abstract

This paper summarises the best practices in decision-making developed by the international SALVO consortium, recently extended to address the optimisation of spares, supply chain and inventory strategies. The paper outlines the problems encountered in such decisions and the disciplines/process that can be used to ensure that the right spares are held in the right numbers. It identifies the factors that need to be taken into account, the cost/risk trade-offs involved, and the process for such decision-making even when available data is limited or unreliable.

Applications of these processes have already shown multi-million ££ financial benefits and service level improvements. They have also been successfully used to evaluate alternative supply chain options, the effect of obsolescence on spares strategies, deterioration in storage (‘shelf life’) and options for distributed or centralised stock holding.

Introduction

There is a long history of quantitative analysis of materials and procurement strategies. Yet most decisions about what to buy and how many to hold are still based on inconsistent subjective judgement. Finance directors put pressure on the minimisation of inventory, while technical staff want at least one spare for everything (and plenty of spares for higher risk items). Depending upon viewpoint, different parts of the organisation have very filtered views, of both the true cost of holding spares, and the real risk of not having enough. And the underlying information is almost always very uncertain (especially for ‘slow moving’ or strategic spares).

This paper explores we need to do in order to put spares, procurement and inventory decisions on a more disciplined basis. It represents the extension of SALVO Process (best practices in asset management decision-making) into the cost/risk trade-offs and optimisation of such decisions, to enable a transparent business case to be make for buying/holding the right items in the right numbers.

The nature of the problem

Most Enterprise Asset Management (EAM), Enterprise Resource Planning (ERP) and materials management systems offer some sort of simple ‘Economic Order Quantity’ (EOQ) calculation. And some tools exist for simulation of demand patterns and purchasing options to explore procurement strategies such as Min/Max stock levels, Re-order Cycles to meet a subjectively-chosen target Service Level (the availability of spares when needed). Some of these methods are even described as ‘optimisation’ techniques.

However most of them are incomplete in their consideration of the costs and consequences of different inventory strategies and none of them helps to answer ‘*What is the <u>right</u> service level’?* It is easy to state, for example “We want 95% confidence of spares being available when required” - but why 95%? Why not 99%, or 85%? This obviously depends upon the consequences of stock-out (*not* having the right spare available when needed). And this varies widely, with operational flexibility, contingency plans, suppler lead-times for replacements and other factors. It also depends on the costs of holding the spares, which in turn includes the capital tied up (e.g. lost earnings or interest rate), the storage and possible in-storage maintenance requirements, and various other potential factors such as depreciation, shelf-life and potential write-off due to future technical obsolescence.

So how do we identify the *optimal combination* of all the costs of buying and holding spares, and the risks of not having them (or enough) when needed?

The SALVO Process

A core part of all asset management decision-making is determination of optimal combinations of costs, risks, performance and sustainability. This was the subject of a rigorous 4-year R&D programme, the SALVO Project [1], involving leading organisations in power and water utilities, transport, process, petrochemicals, manufacturing and service sectors. In particular, this collaboration programme considered trade-off decisions where there is a high level of uncertainty in the necessary information i.e. it addressed both the underlying discipline of 'forcing the right questions to be asked' and the real-life issues of having to work with range-estimates, conflicting expert opinion, 'what if?' scenarios etc.

The 6-step SALVO *Process* was developed to guide and support asset management decisions, including most typical interventions considered in each life phase, up to and including optimal time to replace or decommission.

A recent extension, has developed the corresponding disciplines and evaluation methods for spares, procurement and inventory decision-making. This is an area of widespread need and great opportunity: initial findings have already shown that it is a big 'quick win' area for the SALVO disciplines and better decision-making.

In particular, the cases of slow-moving, 'critical' or 'strategic' spares, are both critical and difficult to decide. This is because such items:

- Tend to be **expensive** (up to 80% of inventory value, represented by just 20% of the spares held)
- Procurement **lead-times can be long** (it might take 18-24 months to obtain a replacement)
- The **consequences of unavailability**, if a failure occurred, can be severe or even catastrophic
- The probability/frequency of needing the spare may be low but it is also **very uncertain**.

The factors that need to be considered

Step 4 of SALVO is the evaluation step for such decisions – it provides the 'storyboard' to ensure that all the factors are considered, the cost/risk/benefit calculations are correct, that uncertain assumptions are explored and that alternative scenarios evaluated and compared on a level playing field. In the case of spares and inventory decisions, we found 27 potential influences or factors that may need to be considered. Yet organisations typically consider just 4 or 5 of them when deciding if, or how many, spares to hold. Factors often overlooked in many decisions include, among others, the repairability of failed units to become serviceable spares, potentially limited shelf life (deterioration in storage) or vulnerability to technology overtake (obsolescence). Constructing a Storyboard, with step-by-step consideration of all the factors, provides us with greater rigour and consistency. It also reveals surprises: forcing the right questions to be asked can sometimes trigger 'lateral thinking' solutions that avoid the need for the spares, or reduce the risk by other means.

SALVO Storyboards are necessarily specific for each decision type, since they are prompting only the relevant questions and factors to be considered. Over 40 of these have now been developed, ranging across new asset selection (based on life cycle costs and value), optimal inspection or maintenance intervals, project yes/no decisions, life extension options, asset refurbish/renewal justification and optimal timings etc. For inventory decisions, two families of storyboard were developed: one for medium/fast-moving consumables, for which purchasing quantity, min/max stock and other turnover-related options can then be evaluated. The other Storyboard covers the slow-moving, contingency planning or strategic spares cases. This is illustrated in Figure 1, showing the major areas (pages) of decision influence in left hand panel, and the specific factors to be considered and estimated in each page (right hand panel).

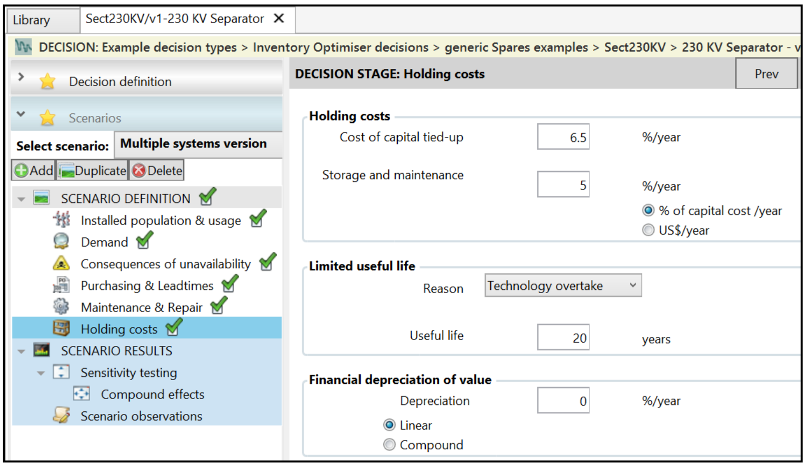

Figure 1: Example storyboard, showing factors to consider in spares 'holding costs' stage.

Summary of factors that need at least to be considered in a slow-moving spares decision:

Installed population & usage

- Items in use (for which the spare is interchangeable)
- Installed redundancy (tolerance of failure with reduced impact)
- Multi-location differences (in numbers installed, usage, redundancy)
- Operational usage profile (e.g. hours per year, affecting the proportion of calendar leadtime that corresponds to how much functional system downtime)
- Inter-location 'robbing' possibilities and timescales required

Demand

- Unit failure rates requiring a spare to be used
- Multi-location differences in failure/demand rates
- Planned maintenance usage of spares for 'hot-swapping'
- Numbers of units needed on each occasion

Consequences of unavailability

- 'per occasion' direct and indirect consequences of failure *irrespective of spares held* (e.g. minimum downtime to swap equipment, direct damage repairs, clean-up etc)
- 'per occasion' consequences incurred *if no spare available* (mitigation costs, expediting of replacement etc)
- 'time-dependent' impacts (e.g. system downtime consequences *while awaiting a spare*)

Purchasing and leadtimes

- Unit costs of spares
- Delivery, logistics and overhead costs of procurement
- Emergency delivery costs (if system downtime being incurred)
- Normal procurement and emergency leadtimes (and their variability)

Maintenance and repair

- Repairability of failed items to become serviceable spares
- Repair period (duration of unavailability for such purpose)
- Planned maintenance interval if using spare for interchange (rotables or hot-swapping)
- Number of units per occasion needed in such cases
- Duration of unavailability while PM is being performed

Holding costs

- Cost of capital tied-up (lost earnings or alternative usage)
- Storage and in-storage maintenance costs of spares
- Shelf life (in-storage deterioration)
- Finite horizon of demand (system life)
- Technology obsolescence horizon
- Depreciation and taxation impact (book life)

Data sources

The Storyboard 'wish list' of information reveals how such decisions require inputs from multiple sources and affected parties. A spares decision needs information from the supply chain (purchase costs, lead-times etc.), operations (consequences of failure and unavailability), maintenance (frequency of failures, repairability, deterioration), warehousing (storage and maintenance of spares) and finance (cost of capital, depreciation). And the credibility of the resulting decision also depends, in part, on the visible participation, inputs and endorsement of results by these different interest groups. So, while *some* information can sometimes be obtained from data systems (e.g. EAM or materials management tools), the usually varied quantity and quality mean that the audit trail needs also to include *who* provided or endorsed the input data. In the case of slow-moving spares the data availability is, by definition, sparse: there are very few examples of usage or procurement. This means that 'data analytics' cannot help much: we are estimating a future without the benefit of recordable experience. This is especially true when determining spares needed for assets at the beginning of their lives, before we have *any* experience of their performance, deterioration and reliability.

Uncertain information

Uncertain assumptions and an incomplete picture form part of almost all asset management decisions. The SALVO work therefore invested heavily in understanding how to safely capture, quantify and explore expert opinion and 'tacit' knowledge to compensate for deficiencies in available hard data. This yielded a range of techniques such as the Sherlock Holmes method for '*eliminating the impossible, so what remains <u>must</u> include the truth*' (as introduced in a previous IET Asset Management paper [2]). The slow-moving spares cases are excellent examples of the need for such methods. Estimating the low probability of needing such a spare, or the potential consequences of not having one when needed, are inherently uncertain forecasts or assumptions. So we use range-estimates and optimistic/pessimistic extremes, followed by sensitivity testing to discover if such 'fuzzy' information has an effect upon the decision. When this is done systematically, it is surprising how often the uncertainty does **not** have a decision-changing effect. And, in the cases where it does, we can now demonstrate the financial impact of such uncertainty – which translates directly into the budget worth spending to improve our knowledge (the 'payback' for better data).

The cost/risk trade-off mathematics

The next key part of the decision-making is the correct handling of the trade-offs and determination of the optimal mix of costs, risks etc. The maths, in the case of critical spares decisions, is fairly well established. It is a product of probability distributions and 'queuing theory', representing and using the natural clustering or spread of even independent events. An average failure rate of 1in 5 years thus allows for a finite chance of, say, 2 failures in the same year, or a gap of 10 years between such events.

The existence of an available spare does eliminate risk – there is always some residual risk of another failure occurring before the previously failed item has been repaired or replaced. The calculations need to calculate all the permutations of possible coincident events, and the financial risk exposures that they represent, for each option of holding different numbers of spares.

When combined with all the holding costs for such spares, we can then see the 'total business impact' of the different strategies (see Figure 2). And when this can be done almost instantly, this evaluation becomes a real-time exploration of options, assumptions and scenario comparisons.

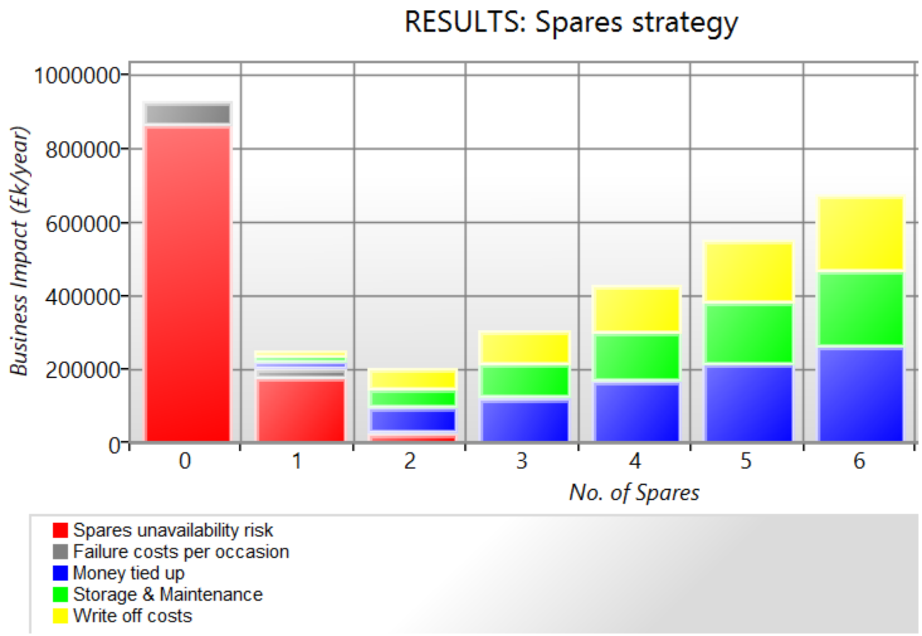

Figure 2: Combining costs and risks for different numbers spares held

Drawing the right conclusions

Just collating the best available information, doing the right maths, and showing the results in a consolidated 'business impact' view, is not enough. The full process involves active consideration of ways to avoid the need for such spares, and other scenarios, such as pooling spares with other users, negotiating alternatives with vendors etc. SALVO obliges us to think laterally, not just accept the first option presented. This has revealed some remarkably ingenious ideas and solutions; once we know what one strategy costs (such as the costs & risks of an optimal spares strategy), we have also quantified the available 'scope for improvement' through design improvements, operational changes or other innovations. Thus the optimal total life cycle strategy needs to combine design choices, operating and maintenance strategies, spares and contingency plans, life extension and renewal/decommissioning decisions. This is handled in Step 5 of the SALVO process – the blending and bundling of component decisions.

Industrial applications and case studies

These methods have now been used in a range of real-life environments, and have proven to both effectively identify the optimal strategy and, perhaps more importantly, to achieve consensus about such conclusions. By bringing together the technical, commercial and financial viewpoints, and exploring the impact of these interests in real time, the participants have seen how *and why* the optimal decision is what it is, and the impact of suboptimal alternatives. The following is a typical case from an electrical utility.

25-11KV Transformers: 20 units installed with an estimated total failure rate (demand for spares) of 1 in 5 (pessimistic) to 1 in 50 years (optimistic). Spares cost £500k, with normal leadtime of 2 years (and, in emergency, perhaps obtainable within 3-6 months). Failure consequences were estimated as £20k per occasion plus forced outage impacts of £100-200k/day. The organisation currently held 4 spares.

Figure 3 below shows the costs and risks of holding different numbers of spares, identifying that just 1 spare is justifiable. Reducing to this level represents net benefits of £135k/year comprising the combined effect of financial savings and (very slight) increase in risk of unavailability.

No of spares	Service level %	Spares unavailability downtime %	Spares unavailability risk £k/year	Failure costs per occasion £k/year	Money tied up £k/year	Storage & Maintenance £k/year	Write-offs & depreciation £k/year	Total Impact £k/year
0	0	0.757	331.9	0.988	0	0	0	332.9
1	95.31	0.033	14.49	0.523	23.74	23.65	0	62.4
2	99.82	0.001	0.494	0.505	48.82	48.73	0	98.55
3	100	0	0	0.505	73.84	73.74	0	148.1
4	100	0	0	0.505	98.82	98.73	0	198.1
5	100	0	0	0.505	123.8	123.7	0	248
6	100	0	0	0.505	148.8	148.7	0	298
7	100	0	0	0.505	173.8	173.7	0	348
8	100	0	0	0.505	198.8	198.7	0	397.9

Figure 3: results table for different spares strategies

Batch studies of large numbers of decisions

The SALVO work has also explored how to organise systematic reviews of strategy and the optimisation of large portfolios of cases. The largest example to date has been the c.38,000 spares items reviewed in this way for Royal Navy submarines – with the result of 40% total inventory reduction and c.8% increase in service level. The Sasol programme is incorporating the techniques into the core materials and procurement systems, using a combination of direct SAP data and a multi-disciplined review process. With over 1 million stocked items, ranging from slow-moving to daily consumables, this promises to be fascinating example of systematic review and optimisation. And, given the cases evaluated so far, the results are going to surprise many and deliver very significant cost and risk reductions.

Conclusions

The SALVO process obviously and easily applies to procurement, spares and inventory decisions. Moreover it appears to be particularly well-suited, given the mix of competing interests, high costs, criticalities and great uncertainties. The cases explored have shown the very great benefit of bringing the right people together, helping them to articulate their knowledge in a structured way, and enabling 'what if'?' studies in real time. The current inventory levels have often been revealed to be wrong, and there is a big 'quick win' from the financial impact and system availability effects of either buying spares that are justifiable, or selling/not replacing surplus spares,

Acknowledgements

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References

[1] SALVO Project, www.SALVOproject.org

[2] J Woodhouse, "Making the business case for asset life extension", IET *Asset Management Conference proceedings* (2012).