Flexible Supply

the Next Step in the Evolution of Sparing Strategies

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1. Background

As long as large technical systems have existed, the problem of spares support or supply has interested logistics managers responsible for the maintenance of such systems. With time, the techniques and tools available for addressing the problem have improved. Alongside, the scope of the problem has increased from a single-item single-site setting to the complete supply chain and the full support system.

Our view on the evolution of tools and methods is in broad terms as follows:

1. Engineering judgement – subjective methods based on the knowledge and experience of experts
2. Single-item, single-site techniques – analytical methods based on local information and performance targets
3. Systems-oriented techniques – analytical methods based on global information, cost and performance targets (state-*independent* supply strategy)
4. Flexible supply or support – the systems-oriented approach with the addition of more flexible, state-*dependent* supply

This paper will comment upon the pros and cons of all these techniques. We believe that this is appropriate since, occasionally, techniques 1 and 2 are sometimes applied although exceedingly inferior to method 3. Today, there are readily available and sophisticated models that can aid the logistics manager to implement step 3. In doing so he/she will:

– Create a platform for advanced systems and logistics analysis (ILS/LSA)
– Save money by optimizing the spares investment, typically 20-30%

Furthermore, we will concentrate on what can be achieved when from step 3 to 4. We believe that allowing and implementing more flexible supply strategies is the next step forward. Therefore, models, methods and techniques must be developed and adopted to fit this trend. In allowing flexible supply we will show that the logistics manager can:

– Save more money, typically 20-30% compared to step 3

2. Engineering judgement

Of course, engineering judgement does give valuable contributions to the spares provisioning process. It can, for example, contribute to criticality assessments and guarantee the correctness and validity of data. However, it is not appropriate to base the spares investment solely on judgement. The

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complexity of the problem makes it practically impossible to generate / propose reasonable sparing solutions. Other significant drawbacks are:

1. Lack of formality and tractability - 2 logistics managers will probably propose different solutions, and there is no formal way to deduce their suggestions
2. There are no effectiveness (performance) measures associated with the solutions

Figure 1 below illustrates the consequence of these weaknesses [Bec90]. It shows how 5 different spares assessors succeeded in proposing spares requirements in a very simple situation with only four different items at one store. The line depicts the cost/effective-curve generated by OPUS10 [Sys99]. It shows the maximum/optimum effectiveness obtainable for a given spares investment or, equivalent, the minimum cost for reaching an effectiveness requirement. The five squares place the five proposed spares allocations within the same diagram.

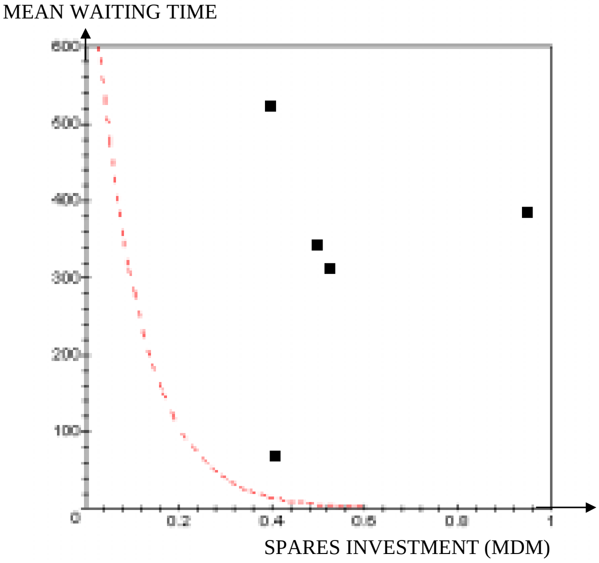

Figure 1: *Five different spares assortments compared to optimum*

The conclusion to draw is fairly obvious. When relying solely on engineering judgement you:

– Do not have any estimate of effectiveness, which also implies that have you trouble comparing solutions with different associated costs
– Have trouble finding optimal or even good solutions

3. Single-item single-site techniques

The first analytical techniques that were developed were primarily single-item single-site (SISS) techniques. They rely primarily on one piece of information, the demand for spares at the different sites in the support organization. Given this information and item/site-dependent performance targets, the objective is to determine the minimum stock required to meet the target. Targets are often expressed in terms of fill rates (confidence levels) or, conversely, stock-out probabilities.

The SISS techniques lack systems orientation. Items are not tied together into systems through a systems breakdown (no indenture information is used). Similarly, the location of the site in the supply chain is not considered (no echelon information is used). It is up to the decision-maker to set the individual item/site target levels taking these and other factors such as cost and criticality into account. This is of course a cumbersome task, and hence constant confidence (the same performance target for all items at all sites) is often applied. Clearly, such a technique is in general non-optimal from a systems perspective. Some of the drawbacks with SISS techniques are illustrated in the next chapter. One benefit, compared to engineering judgement, is of course the objectivity and tractability of the approach.

4. Systems-oriented techniques - the systems approach

With the development of the METRIC [She68] model, the first OPUS models (1970) and MOD-METRIC [Muc73] a fundamental step was taken. These models adopted a systems-oriented approach. They facilitated sparing strategies (stock levels) to be evaluated against a global systems performance, for example, availability. In doing so they took the indenture level of the item and the location of the site into account. Furthermore, the cost of an item was considered when optimizing against the global performance target.

With the introduction of the system-oriented approach and sophisticated spares optimization tools (OPUS10), the burden on the decision-maker is greatly alleviated. He/she can rely on OPUS10 generating the optimal sparing while he/she can focus on setting appropriate targets and doing what-if or sensitivity analyses. Of course, compared to the approach of engineering judgement, the data requirements do tend to increase.

The systems approach and the models and techniques derived to enable it are somewhat incorrectly perceived to concern spares requirements and modeling only. On the contrary, they are essential for analyses on a higher level such as:

– System analysis (ILS, life-cycle costing)
– Logistic support analysis (LSA)

The reason is that when applying the systems approach we (are forced to) consider both the technical system and the support system intended to support it. The approach and associated models have a global scope.

Roughly speaking, system analysis (ILS) concerns making the technical system well adapted to the support system. Conversely, logistic support analysis (LSA) concerns the adaptation of the support system to a technical system. Keep one part constant and vary (seek to optimize) the other. Of course, the process ought to be iterative in nature. Consequently, the systems approach, and sparing models based upon it, does provide a necessary bridge between:

– the technical system and the logistic support system
– effectiveness and cost

The bridge between effectiveness and cost is illustrated by the cost/effectiveness curve, see Figure 2. This curve is perhaps the most central result obtain by the OPUS10 model, which is based on the systems approach. Spares are used to glue an otherwise fixed support system to a given technical system. The higher the investment in spares the better the effectiveness performance of the technical system, but also the higher the life-support cost. The curve shows how much spares “glue” must be added to fit the technical system and the support organization.

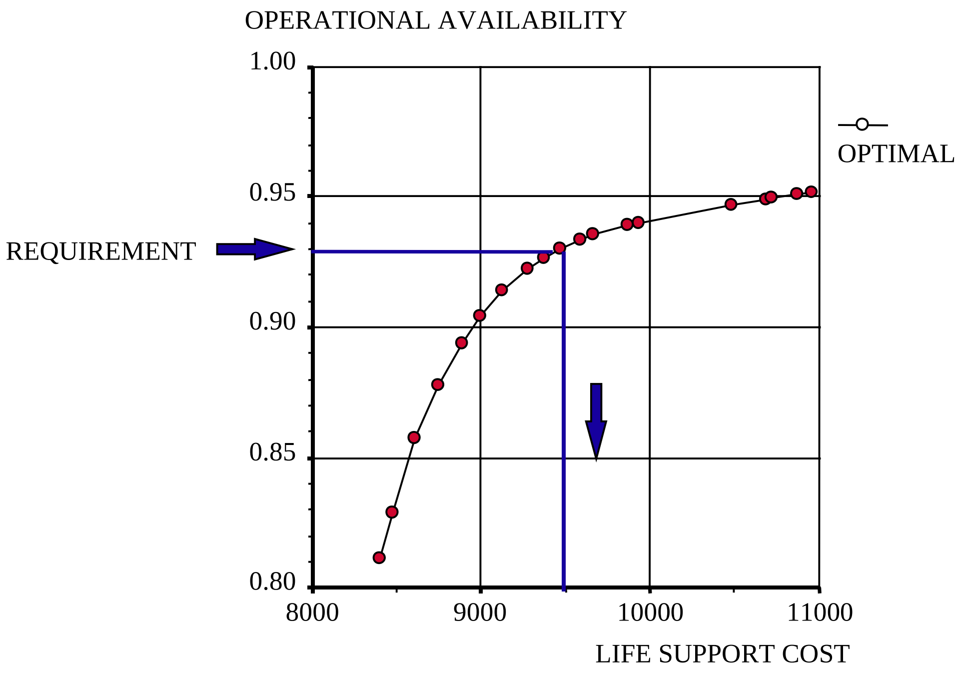

Figure 2: *Cost/effectiveness curve*

Adopting the systems approach we can hence work on adapting the technical system for support (system analysis, ILS), adapt the logistics support (LSA) and compare the costs with the costs of using more or less spares to glue the two parts together. Studying cost as well as effectiveness we make sure that all alternatives are evaluated against the same criteria and meeting the same requirements.

Sophisticated system-oriented models (OPUS10) do allow for various complicating factors that arise when tying technical system and support system together into one global system. Such factors might be multi-indenture systems (complex material structures, Figure 3 below), station asymmetry (sites on the organizational level are not identical), item-individual turn-around times and transportation times, incomplete repair / repair fractions (repair at different workshop depending on failure mode), stock restrictions, etc.

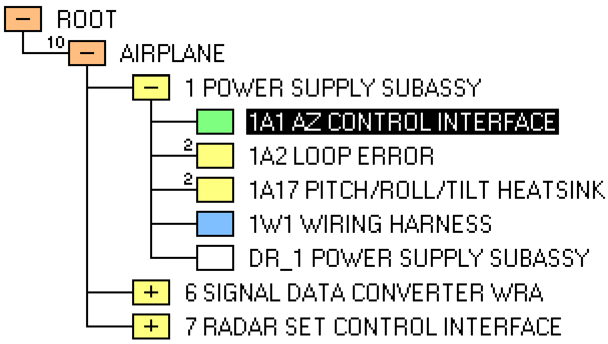

Figure 3: *A multi-indenture system breakdown (from OPSA)*

5. Comparison between SISS and systems-oriented models

To further illustrate the fundamental step taken when moving from single-item, single-site (SISS) modeling to the systems approach, let us look at the quality of the spares solutions produced by the two methods. Figure 4 shows a comparison for a typical case.

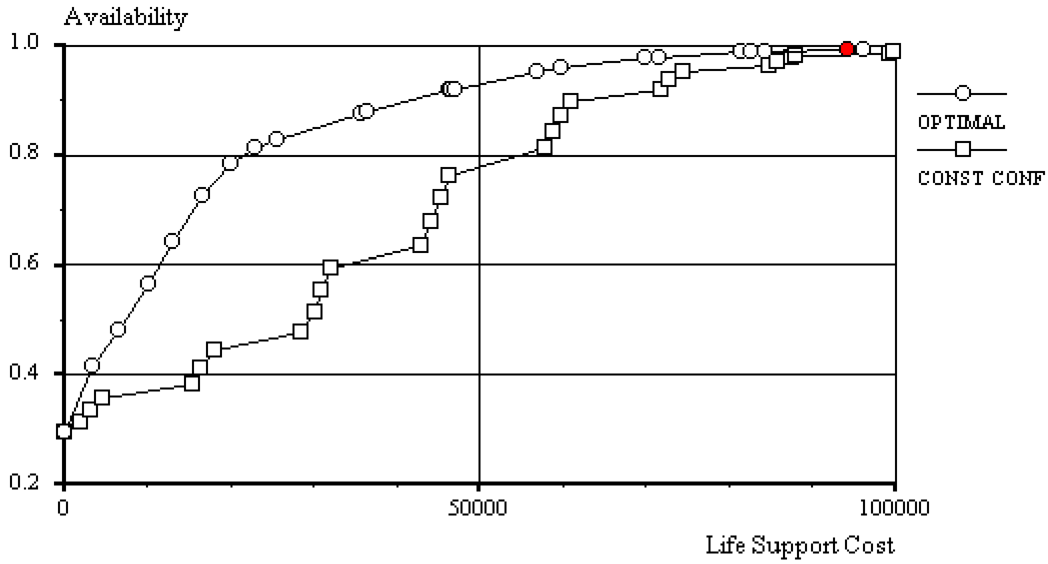

Figure 4: *Comparison SISS and OPUS10 (systems-oriented approach)*

The curves may appear to converge for higher investments. By enlarging the diagram around this region, we can see that this is an illusion (a matter of resolution). Obviously, adopting the systems approach we can save money and/or gain effectiveness.

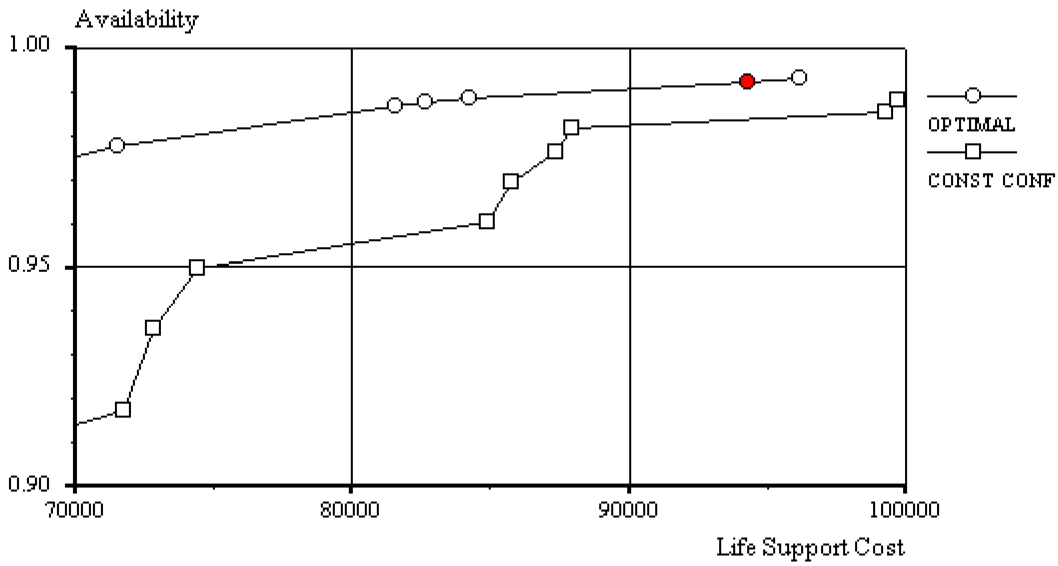

Figure 4b: *Enlarged portion of diagram in Figure 4*

Another example is the following. When the Royal Air Force (RAF) changed method from an item-by-item (SISS) to a systems-oriented one, they conducted a comprehensive comparison between the two approaches. An extract of the results is given below [Cla88]

Serial No	System No	SIM Investment (£)	OPUS Investment (£)	Saving	Saving % of Sim
1	15	1.262.736	859.523	403.213	31.9
2	16	3.065.550	2.766.124	299.426	9.8
3	17	427.000	403.000	24.000	6.7
4	19	1.914.832	1.638.734	276.098	14.4
5	20/21	1.160.674	691.608	469.066	40.4
6	24	78.326	66.732	11.594	14.8
7	25	234.975	210.008	24.967	10.6
8	26	370.300	192.178	178.1221	48.1
9	29	216.803	41.773	175.030	80.7
10	41	907.804	441.372	466.432	51.4
11	42	243.890	241.590	2.300	0.9
12	45	1.732	1.732	0	0.0
13	55	642.790	370.321	272.469	42.4
14	56	38.504	36.112	2.392	6.2
15	57	186.937	80.050	106.887	57.2
16	71	811.620	721.035	90.585	11.2
Total		11.663.473	8.761.892	2.801.581	24.2

Table 1: *Estimated savings, OPUS vs. SIM*

All in all the comparison indicated a potential for saving 12.6 M£ across 4 different projects.

6. State-dependent supply or support

Implied when discussing the systems approach and models for it is normally an assumption of *state-independent* supply. State independence means that the choice of supplying store is not influenced by the state of the support system. In many (not to say most) situations this is a reasonable assumption to make. However, with the development of more sophisticated and powerful information systems, state information is made accessible and can be used to improve (make more flexible) the spares supply.

Examples of supply flexibility are:

– Lateral support / supply
– Direct deliveries (expeditious shipments in emergency situations)
– Order (backorder) prioritization

Lateral supply is an example of abandoning the regular supplier and request spares from another (often neighboring) site. The sites are often located on the same echelon; hence the term “lateral“ supply or support.

Direct deliveries imply that in certain (emergency) situations, a faster (but more expensive) means of transportation is used. Finally, prioritization means that requests are treated and distinguished according to the urgency of the request. The general idea is that it is more important to satisfy waiting customers than to simply restore the stock level. When the standard first-come-first-serve (FCFS) strategy is used, no prioritization takes place.

The effects of employing flexible supply can be extremely beneficial. The stock invested in can be more efficiently utilized, hence decreasing the spares investment required to reach a given performance target. We shall illustrate this by examples below. We also refer to a comprehensive study conducted by Alfredsson and Verrijdt [AV99].

In OPUS10 version 4 fundamental steps towards building a model for supply flexibility have been taken. In this version is included a strategy where sites can form a lateral support group supplying one another with spares in stock-out situations. The strategy is assumed to be time greedy, which means that lateral shipments take place if they save time. Also included in the strategy is order / backorder prioritization. Note, however, that emergency shipments (that is, direct deliveries) are not implemented. The main limitation is that symmetrical (or near symmetrical) support organizations are required.

7. Comparison Opus10 flexible vs. Opus10 classic

It is interesting to compare the spares requirements when allowing / disallowing the supply flexibility permitted in OPUS10 version 4. We refer to the case of not applying flexible supply as OPUS10 classic and the other one as OPUS10 flexible.

For example, we have used the new feature when determining an add-on procurement of spares for a helicopter project. Using the flexible supply strategy we needed to buy spares for 2.0 MSEK reaching a given effectiveness target. Not allowing for flexible support, the additional investment was 14.0 MSEK. Thus, a saving of 86%! could be made.

Another example is taken from an electronics project, with a fairly straightforward support organization (see Figure 5). The system is a complex electronic equipment. Due to confidentiality no detailed data can be given.

The results from the study are shown graphically in Figure 6. The diagram plots operational availability against spares investment for four different situations.

NO LATERAL: No supply flexibility is implemented, that is, the classic OPUS10 strategy is assumed. Points on the curve represents spares allocations optimized against this strategy.

ANALYSIS: The allocations generated in NO LATERAL are evaluated when the flexible strategy is applied. Note that the availability but not the spares investments are affected.

REALL 19: One of the solution points in ANALYSIS/NO LATERAL (point 19) is reallocated using the reallocation mode in OPUS10 version 4. This means that the spares assortment is fixed but that location is flexible. OPUS10 optimizes the location against the flexible strategy.

LATERAL: Supply flexibility is implemented according to the OPUS10 flexible strategy (lateral supply and backorder prioritization). Points on the curve represents spares allocations optimized against this strategy.

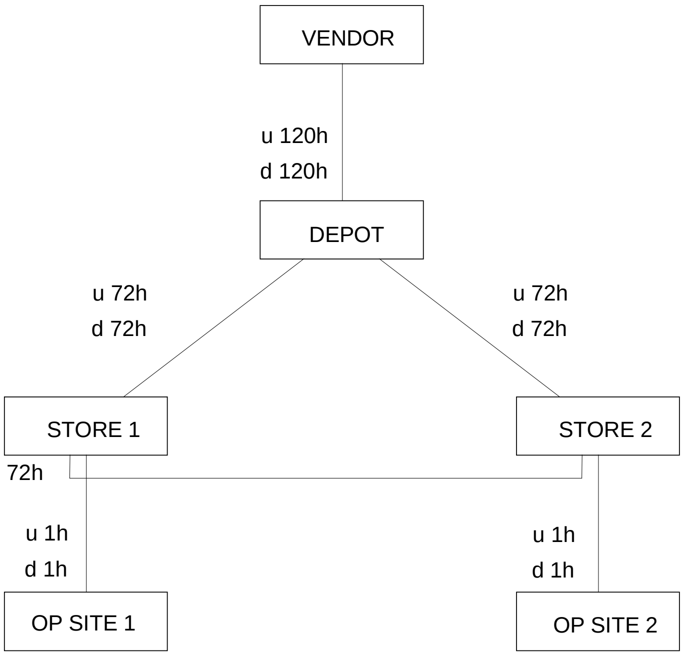

Figure 5: *Support organization for electronics project*

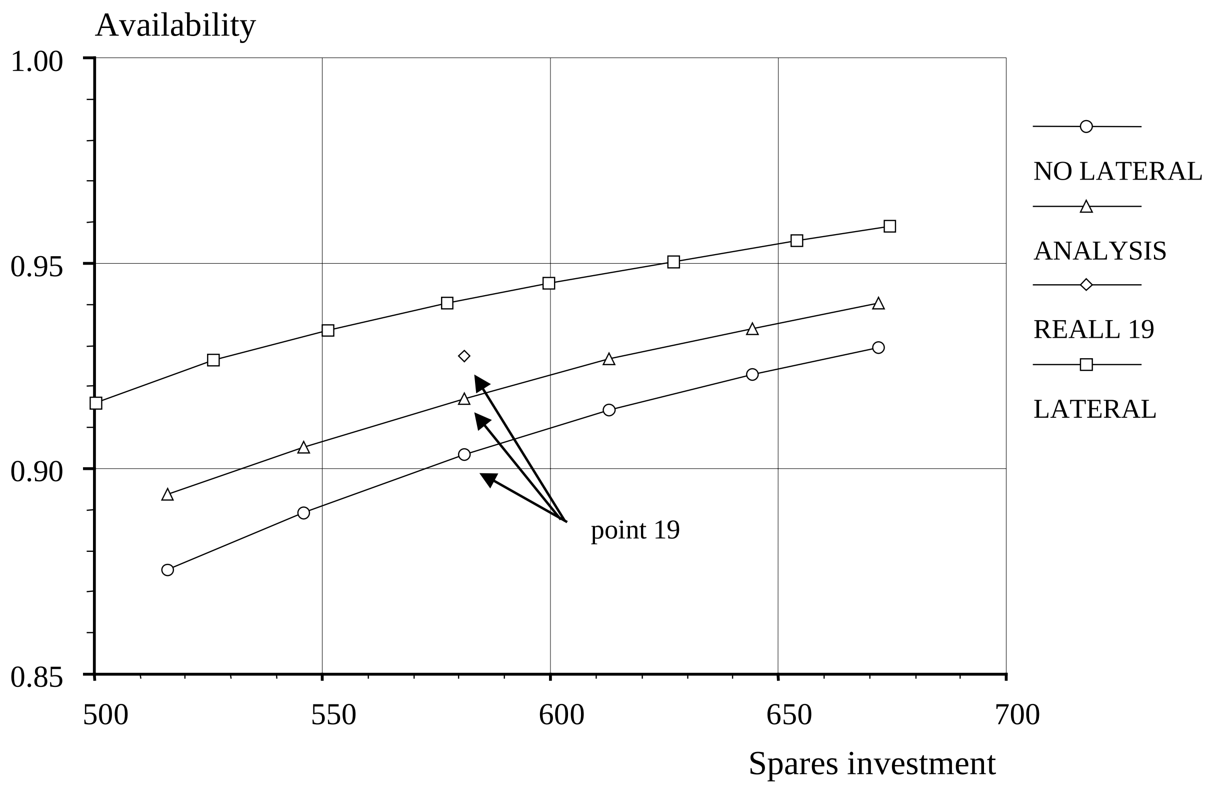

Figure 6: *Results for electronics project*

Let us assume that we want to reach an availability target of 92.6%. Then the results are as follows:

Case	Availability	Investment	Savings*
NO LATERAL	0.9296	672	
ANALYSIS	0.9269	613	8.8%
REALL 19	0.9273	581	13.5%
LATERAL	0.9263	526	21.7%

* Savings are given as percentages of 672.

On the cost side we note the following. Knowledge of the correct effectiveness when determining spares allocations according to OPUS10 classic could save 8.8%. (We reach the availability requirement at an 8.8% lower investment). If, moreover, we could reallocate the stock to work optimally in the new flexible strategy we could save a total of 13.5% in spares investment. However, we *do not* reach the optimal one generated when optimizing against the flexible strategy, and the gap is significant! The spares mixes generated under the classic strategy are not optimal when applying the more flexible strategy.

We of course come to a similar conclusion when looking at operational availability. With NO LATERAL we reach an operational availability of 0.9034 for a cost of 581. By applying flexible support *without* changing the assortment and allocation, the operational availability reaches 0.9170, improving the availability 0.0136. If a reallocation (without changing the assortment) is done, the operational availability reaches 0.9273, a further improvement of 0.0103. Optimizing against the flexible strategy we could reach 0.9403, at a slightly lower cost!

In summary,

– the cost saving and/or gain in effectiveness obtainable when implementing flexibility can be substantial
– spares allocations generated assuming the classic strategy may be far from optimal when applying the flexible strategy

8. Concluding remarks

Taking the step from single-item, single-site methods and adopting a systems approach has been a fundamental step within the field of logistics support. We believe and hope that this paradigm has been fully embraced by the whole logistics community. Nonetheless, we believe that it is now time to move even further and start investigating and implementing supply flexibility. As our examples do show, the potential for cost savings and improved system effectiveness supports and motivates this endeavor.

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