Requirements on a Spares Provisioning Analysis Tool

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Table of content

		Page
1.	**SUMMARY**	**3**
2.	**BACKGROUND**	**3**
3.	**THE PROBLEM**	**3**
4.	**THE USE OF SPARES OPTIMISATION PROGRAMS**	**4**
5.	**SAMPLE OF REQUIREMENTS ON A SPARES OPTIMISING PROGRAM**	**7**
5.1	Shall be able to handle a “Flexible Multi-echelon Support Organisation”	7
5.2	Flexible Multi Indenture	11
5.3	Be able to optimise	11
5.4	Ability to handle different problem types	13
5.5	Different measures of effectiveness	13
5.6	Different operational profiles	14
5.7	Be application independent	14
5.8	Large cases/Calculation times	14
5.9	Open interfaces	15
5.10	Be able to run on a standard PC	15
5.11	Be user friendly	15
5.12	Be commercially available	15
5.13	Solid support and regular upgrades	15
5.14	Other requirements	16
6.	**CONCLUSION**	**16**
List of references		**16**

1. SUMMARY

The Spares Provisioning Analysis Tools have a much wider role to play then the name indicates. They work with an input of both System Data and Logistic Support Organisation and with an output consisting both of cost and effectiveness. Hence they can measure impact of changes both in the System as well as in the Logistic Support Organisation.

Some of the requirements for a Spares Provisioning Analysis Tool are:

It shall
- be a flexible multi echelon tool
- be a flexible multi indenture level tool
- be able to optimise
- handle different problem types
- have several effectiveness measures
- be fast and able to handle large cases
- be possible to run on standard PC's
- have an open interface
- be application independent
- be commercially available
- have solid support and regular upgrades.
- have good training and documentation

Just to mention some requirements. There are more.

2. BACKGROUND

The author has for more than 25 years been responsible for the development, application and marketing of such a tool - OPUS10.

Over the years a multitude of requirements have shown up mainly in the internal consultancy work but also in the requirements both from potential customers as well as from existing customers. For more info on the OPUS10 development, see attachment 1 and ref [Wåå 97].

3. THE PROBLEM

The aim of the spares provisioning is to acquire and allocate the correct mix and amount of spares to fulfil the availability requirements. In the military arena the requirement to endure a certain period of time also has to be observed. All this should be done at lowest cost.

It is clear from pure intuition that for each cost level it is possible to find a combination of spares that is more efficient than all other combinations. If the results for each cost level are connected with each other an optimum curve is achieved. On this curve each point represents an optimal assortment. The curve below shows the result from the optimisation function in the OPUS10 computer program.

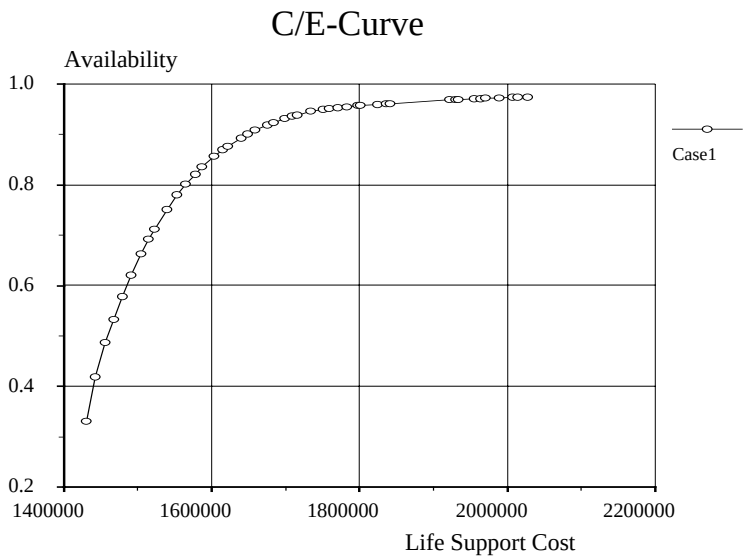


Figure 3.1. Availability as a function of the investment in spares. Optimum curve

For a more mathematical problem description see ref [Alf 98] or [She 92].

4. THE USE OF SPARES OPTIMISATION PROGRAMS

The use is more widespread than the name implies. Such a program is more or less necessary for the following methods.

- o System Analysis (frequently performed as LCC (Life Cycle Cost))
- o LSA (Logistic Support Analysis)
- o Spares questions

A rough explanation of previous terms could be as follows:
System Analysis: ”Keep the Logistic Support organisation constant and vary the System”.
Logistic Support Analysis: ”Keep the System constant and vary the Logistic Support Organisation”.
Spares questions: Keep both the System and the Logistic Support Organisation constant and vary the spares amount, assortment and allocation.

A Spares Optimising program provides the necessary bridge, not only between

- Technical system ***and*** the Logistic Support Organisation
  but also between
- Requirements fulfilment ***and*** Cost

This can be illustrated by the following figure.

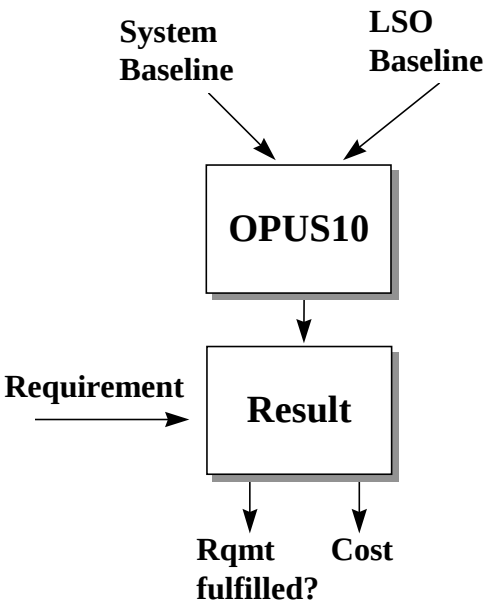


Figure 4.1

This can be illustrated further by an example of one of the OPUS10 outputs - the C/E-curve.

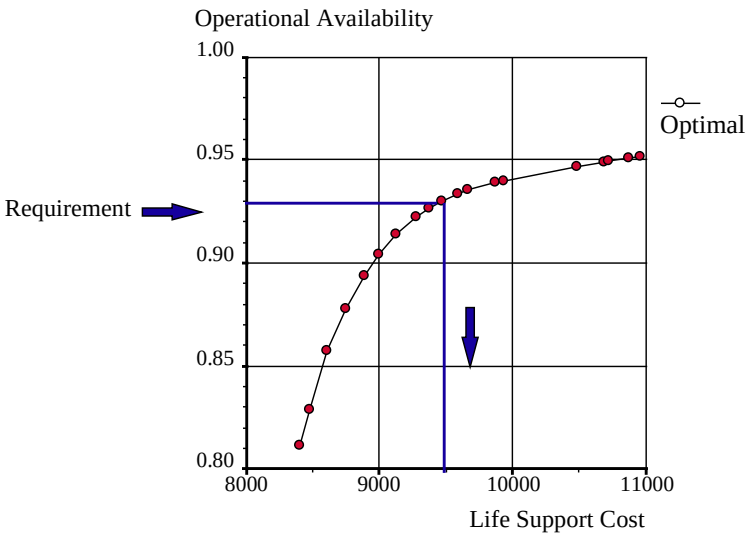


Figure 4.2

The spares optimisation is necessary for successful LCC application since it generates the cost-effectiveness curve. This cost-effectiveness curve is necessary both to ensure that the alternatives under comparison are compared at the same effectiveness level and the ensure that the established effectiveness requirements are fulfilled.

The use of the C/E-curve in contracting is illustrated below.

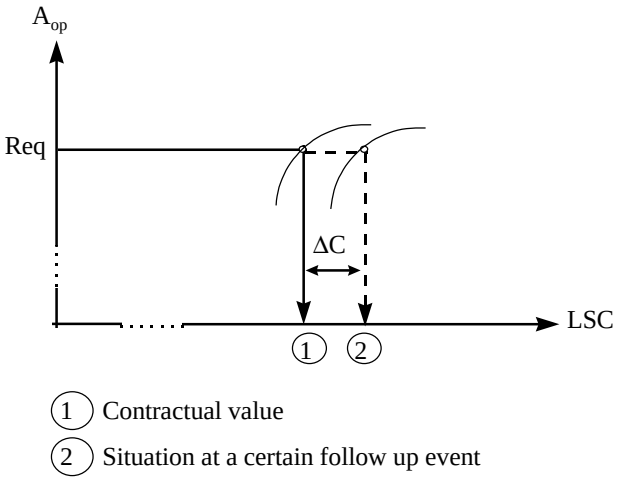
The contractor undertakes to deliver a system that fulfils a large number of requirements including:
- Reliability/Availability
- Life Support Cost limit

As a basis in the contract there are:
- A Life Support Cost model
- Customer input data
- Contractor input data including a ***contractual baseline*** (i.e. a system description in the form of a system break down with data at LRU/SRU level)

The system is subject to development. Hence the contractor can not undertake to deliver a system that in all details is identical to the contractual baseline. His undertaking is to deliver something that

a) Fulfils the requirements
b) Has a LSC below the agreed limit
c) In time and at agreed price
etc

Those deviations between the contractual baseline and the current baseline have to be taken care of by OPUS10 and the LSC model. This is illustrated below - the requirement and cost are tied together with the OPUS curve.



This is further illustrated by the following example.

A_{op} = 0.95 MTBF = 100 hrs MTTR = 1 hr gives
MTW = 4.263
Assume it is necessary to add an LRU
New data MTBF = 98.7 MTTR = 1 hr gives
MTW = 4.195

Result:

a) Acquisition price: Fix price. No change (The contractor has to absorb the cost)
b) Investment in spares: Higher (lower MTW and a moved OPUS10 curve)
c) Larger failure flow (more site repairs and more LRU repairs)

The contractor has to compensate the customer.

The table below shows some cases where OPUS10 is used not only in the evaluation, but contractually as well. (See also [Wåå 98:1].

Summary LCC cases

	OPUS10 used	**Degree of difficulty**	**Spares impact**	**OPUS10 contractual**	**See ref**
Low Coverage Radar	Yes	Large	Large	Yes	PåW 82
Oslo ATCC	Yes	Medium	Medium	Yes	Wåå92
JAS Aircraft	Yes	Large-Medium	Medium	Yes	Båå95
Rapid Trains	Yes	Medium	Low	No	AkB94

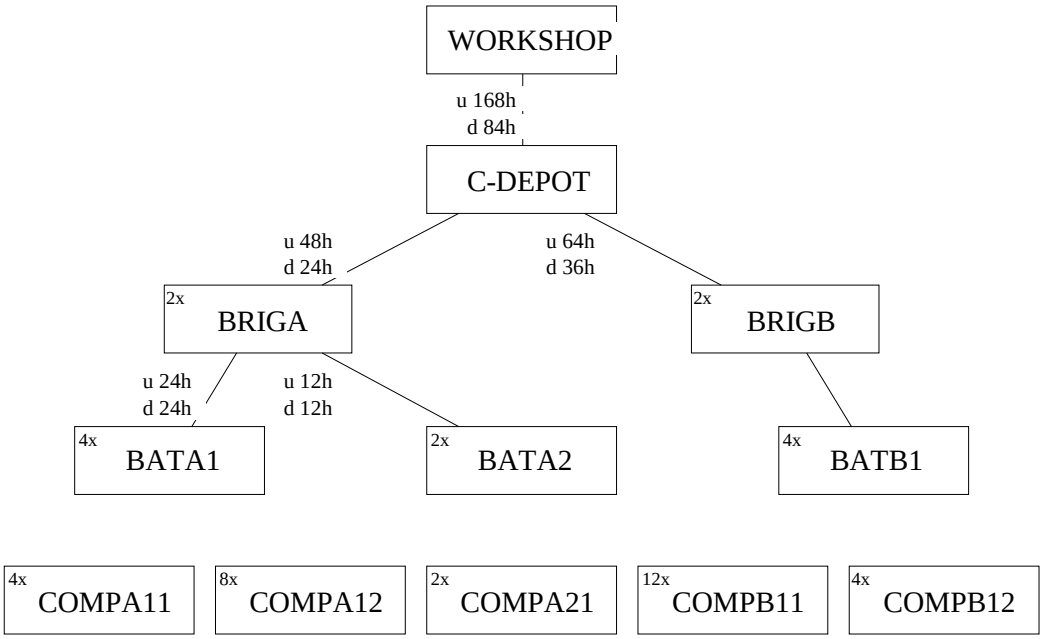
Table 4.1. Some LCC cases

5. SAMPLE OF REQUIREMENTS ON A SPARES OPTIMISING PROGRAM

The lay-out of this chapter is such that for each requirement there is a clarification of ***what*** it means and comments on ***why*** it is important.

5.1 Shall be able to handle a "Flexible Multi-echelon Support Organisation"

Multi-echelon means that the spares are stored on more than 1 echelon. The support organisation can look as below.



A number of complicating factors pop up like ***unsymmetrical (***stores on the same level are not identical), ***item-individual*** turn-around times and transportation times, ***forbidden*** stocks, minimum/maximum stocks, direct routes etc.

Some comments can be made:

- Unsymmetrical: The stores are not identical e.g. the stock at BATA1 is different from BATA2
- Item-individual: As an example, the different items can have different repair times at workshop
- Forbidden stock, certain items are not allowed at certain stores e.g. due to risk or security
- Minimum/maximum: For some reason a min or max figure is considered more interesting than the optimum value (could be a minimum of 1 instead of 0)
- Direct route: (Emergency shipment) In case of special high priority a shipment could be made that shortcuts all intermediate stores and goes directly
- Non-hierarchic: Geographical reason can sometimes make it profitable to always shortcut some intermediate echelons e.g. BATA2 could as an alternative be supported directly from the C-depot
- Lateral support: (or more general - network support). The support is made from any store that has the requested item
- Base Repair Fraction: Certain repair fractions might be performed closer to the system (e.g. at COMPA or BATA level)

The program shall be able to solve the organisations that are relevant - the organisations shall not adopt to what the analysis tool is limited to handle.
This can be illustrated from a Logistic Support Analysis study.

The study concerns with the Process Control and Data Acquisition (PCDA) system for 4 different platforms.

The platforms are
- o Gullfaks A (GFA)
- o Gullfaks B (GFB)
- o Gullfaks C (GFC)
- o Sleipner A (SLPA)

The PCDA system is slightly different between the platforms.

The present support organisation is given below (”The autonomous case - no co-operation between bases or platforms”).

Autonomous Stores

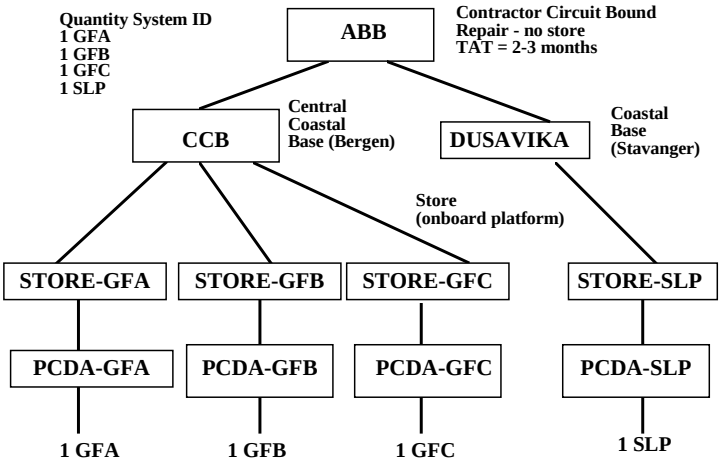


Figure 5.2

A number of different structures and scenarios are investigated as shown below.

Joint on-shore bases

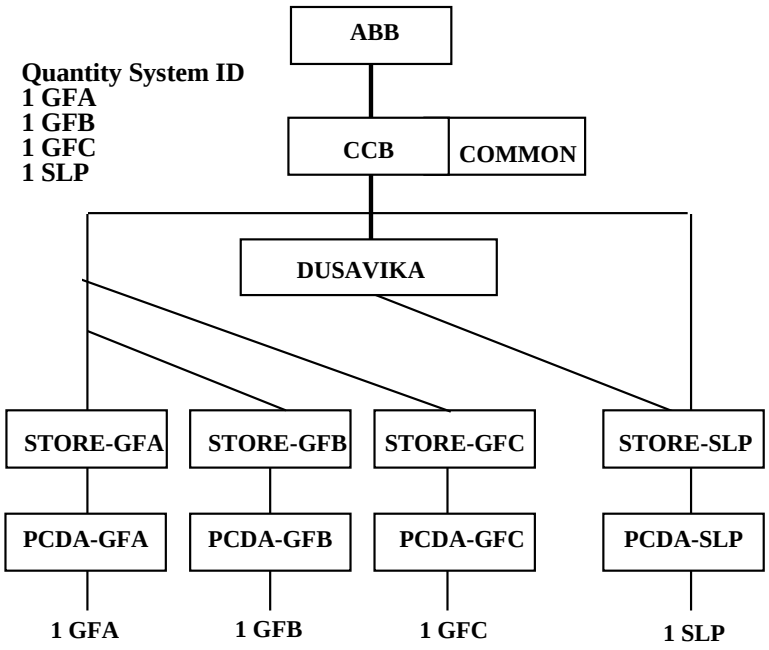


Figure 5.3

The common items (i.e. the items that are used both on the GF platforms and on the SLP platform) are stored only on the Central Costal Base. Consequently SLP is supported both from CCB and Dusavika.

Contractor agreement. (Support contract)

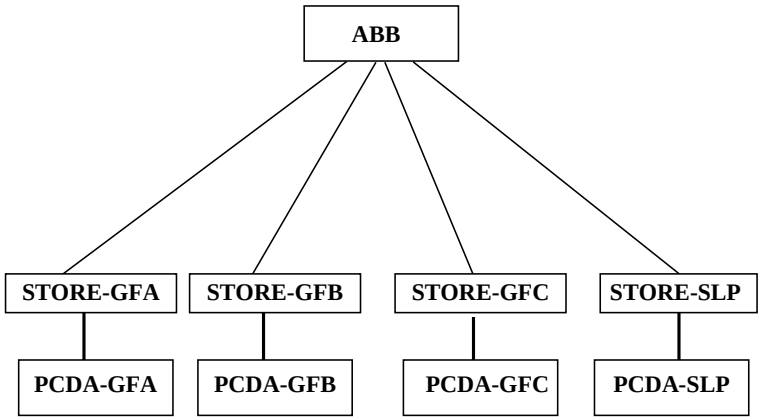


Figure 5.4

See also [Wåå 98] for more details.

5.2 Flexible Multi Indenture

Multi-indenture level means that spares of different levels of indenture (or break-down) are studied at the same time like shown below.

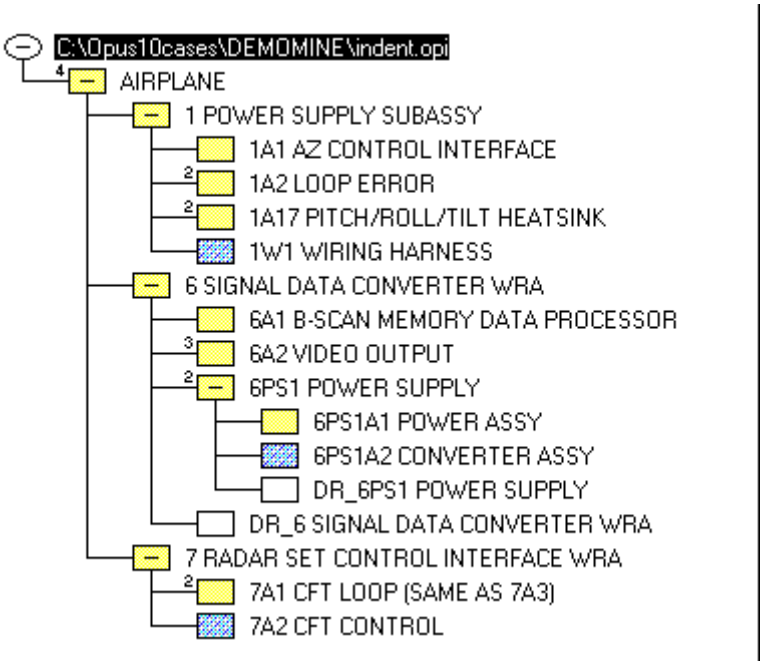


Figure 5.5. A multi-indenture system break-down (from OPSA)

Again, complications show up like ***commonality*** both in systems and on lower indenture items, ***repairables*** vs. ***non-repairables***, ***partly repairables*** and the program has to be flexible enough to handle it.

Examples:
- The problem may contain slightly different systems (e.g. some LRU:s are different)
- Some SRU:s may be part of more than one type of LRU
- It is necessary to be able to handle both repairables, partly repairables and discardables in the same run

etc

Again the program has to look at the actual problem. The different way to configurate and support the system is an important part both of LCC and LSA. Also an alternative that ***can not*** be studied has a psychological tendency to block the progress.

5.3 Be able to <u>optimise</u>

An optimising spares program gives a cost/effectiveness curve which is optimal in the sense that points below the curve gives either higher cost or lower effectiveness compared to the points on the curve.

It is possible to either save money or gain effectiveness by optimising.
The amounts that can be saved (at the same effectiveness) by optimising are surprisingly large as can be seen by the following examples.

Example 1:
RAF did a comparison between its traditional model SIM and OPUS10 and came up with the following results - results that also led to RAF became one of OPUS10 major customers.
The table shows a series of subsystems where the comparison is performed at the same effectiveness level and showing the saving in OPUS10 favour.

Serial No	System No	SIM Investment (£)	OPUS10 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 5.1

All in all the comparison gave a ***saving potential on 4 projects of 12.6 M£.***

Example 2:
An OPUS10-study of an ***Offshore Process Control System*** gave the following results.

Existing stock	MNOK 15.286
Necessary stock	MNOK 5.699
Ought to be acquired (***not*** in stock)	MNOK 0.541
In stock and needed	MNOK 5.158
In stock and ***not*** needed	MNOK 10.130

Table 5.2

Other improvements

a) IBM reports a saving of 250 MUSD in stores investment and 20 MUSD annually and at the same time an improvement of 10% of the parts availability in the first line stores.

b) A case study using OPUS10 involving another major computer manufacturer reports for one of the regional stores:

Case 1: Saving 79.1%
Risk of shortage lowered 40%

Case 2: Saving 82.5%
Risk of shortage lowered 19%

Of course it is surprisingly that not ***all*** spares recommendations are optimised but the truth is the most spares acquisitions are ***not*** optimised - although measured in number of acquisitions, not volume. The major ones of course tend to be optimised.

5.4 Ability to handle different problem types

Problem types

When analysing spares one is frequently faced with fundamentally different types of problems.

- Initial acquisition and distribution
- Calculation of cost and effectiveness for a given assortment of spares with a given allocation between the stores. This mode is called *analysis*
- Optimisation of the distribution of a given assortment, called *reallocation*
- Optimisation of add on acquisition to a given distribution, called *replenishment*
- Optimisation of add on to a reallocated distribution, in OPUS10 called *reallocation followed by replenishment*

Existing spares assortment and allocations frequently are not optimal. One reason may be that they were not optimised from start - another may be that the utilisation of the system has changed. A third may be that the organisation has changed. Whatever the reason this deviation ought to be corrected. (See also ref [Isd 99].

5.5 Different measures of effectiveness

The primary measure in most multi-echelon multi-indenture spares optimising is NBO, Number of Backorders i.e. the number of not fulfilled spares demands. From this measure a number of various effectiveness measures can be calculated:

Stock oriented measures

- NBO: Number of Backorders
- MWT: Mean Waiting Time
- ROS: Risk of Shortage

System Oriented Measures
- MDT: Mean Down Time
- A_o: Operational System Availability
- NOR: Expected number of Systems Not Operationally Ready

Furthermore there should be possibilities to achieve those measures broken down both to individual item as well as individual store. See also ref [WåI 92].

The use of spares optimising programs is related to some form of fulfilment of system requirements. Those requirements are written in a form that fits the project, not necessarily the tool. Hence a number of different measures are needed. Furthermore, in some cases the requirements are expressed in such form and such environment that a computer calculation is necessary. As an example see [Caf 97) for examples with the OpSSim simulation program.

5.6 Different operational profiles

Two major operational profiles can be separated:
- Steady state conditions
- Mission oriented conditions

The steady state conditions reflect either continuous operation or repetitive type of reasonably similar missions. The mission oriented conditions refers to a single (reasonably long) mission.

Again it is important to be able to reflect reality as closely as possible. Of course there exist a multitude of scenarios between those two extremes. In such cases it may be good to have a simulation program that can be linked to the spares optimisation. Such an example is OpSSim..

5.7 Be application independent

Some programs are tailored to certain types of equipment and/or certain organisations. This should be avoided.

It goes without saying that it is of great value to the program users to be able to use ***one*** program instead of a large number. As an example should be noted that many contractors deliver equipment to widely different applications and support organisations.

5.8 Large cases/Calculation times

A typical system might have 500 different items and the organisation might contain several different stores. See as an example the figure 5.1 that contains 11 stores. This means that we have to solve an optimisation problem with 500x11=5500 independent variables. Add to this that the process has to be repeated for each point in a C/E-curve (could be 30-50 points typically) and we have a very large problem.

We have encountered cases with over 100000 independent variables. In spite of the fact that the computer power has exploded during the last decades it is a very large problem. If the calculation algorithm is not very fast the pure time consumption could make a calculation prohibitive.

5.9 Open interfaces

Most users have their materiel data (break-down-list, cost/price information, failure rates/demands rates etc) in one or several databases. Frequently those bases are tailored. The effort to standardise has improved the situation to some degree but still there tend to be a lot of adaptation to simplify the data transfer.

The most important thing is to have an open interface i.e. that information concerning details of the program interface can be achieved.

5.10 Be able to run on a standard PC

The type of calculations needed require a considerable amount of computer power. As an example can be mentioned that during the 70-ies OPUS had to be run on one of CDC major machines.

Practically all data handling now is handled on PC's. In those cases when this is not the case the program of course has to run on the existing set of hardware.

5.11 Be user friendly

User friendliness has to be handled with a certain care since it does not mean the same to the beginner as to the experienced user.

When selecting a program or assessing its "user friendliness" do not look only after how friendly it is at the first glance. Look at how smooth it is to operate for the experienced user.

5.12 Be commercially available

In order to get a program of this kind the user can:

- Develop this own (either in-house or under contract
- Get it (free of charge or at a low cost) from someone that has developed it, e.g. government agency
- Buy it as a COTS

It is not possible in general to state the best way. In terms of the spares optimising programs it has shown however that the surviving programs are developed and in particular - supported - on a commercial basis.

The commercial basis is a very good driving force for rational decisions and continuous improvements - provided that the business idea is sound.

5.13 Solid support and regular upgrades

A program that is not supported will within surprisingly short time be outdated both in available hardware platforms and in users familiarity with the man-machine interface.

Both hardware and operating systems are replaced regularity with an increasing pace. Unless your program supplier has a good support and regular upgrades your program will soon be useless. This could be very serious since the projects using the program tend to be of long duration.

5.14 Other requirements

In the previous paragraphs some important aspects have been brought up. There are of course others that might be considered. As an example can be mentioned an ambitious evaluation performed by the Royal Australian Air Force (RAAF). In their evaluation they used 36 evaluation criteria each one of them assessed with a certain Weight factor. Then for each of the criteria an assessment of compliance ranging in 5 steps from “Exceeds Requirement” (4) to “Non-Compliance” (0).

6. CONCLUSION

The decision on the selection of a spares optimising program is important because you may have to live with it for a long time since the projects where it used can cover a long period of time. In addition to the requirements above one might at a consequence add:

- Select a program with large installation base
- Select a program that constantly is improved and updated

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The OPUS10 development

THE START

In the late 60'ies the Swedish Navy were in the process of changing from large ships to smaller ships . Also the electronics changed from electronic tubes to solid state and circuit boards. As a consequence the Maintenance and Logistic Support changed. Previously a technician equipped with electronic tubes and other discrete components, a soldering-iron, some other tools and a manual could repair the equipment. Now a large number of different circuit boards become necessary.
The cost for spares became a considerable fraction of the overall cost and it became interesting to answer spares questions like

- Have we the right mix?
- Have we the amount?
- Right allocation?

An onboard spares recommendation for Arte 722 and Torpe 696 was handed over from the contractor. The Naval Material Department placed an order to Systecon AB to review the recommendation.

RESULT

Systecon developed a computer program that minimised the investment in LRU (Line Replaceable Units) needed to fulfil the requirement of highest allowed Risk for shortage.

It was shown that it was possible to achieve the same effectiveness with an assortment costing 1.0 MSEK as the contractor recommended assortment costing 1.7 MSEK.

The contractor had already started the production in accordance with his own proposal. However he decide to deliver the spares in accordance with his proposal but only charge 1.0 MSEK for it.
Thus, a consultancy contract on SEK 25000 saved SEK 700000 for the Navy.

From this start the development of a spares optimising program - OPUS10 - continued.

TODAY

The program has grown through the years and a multitude of modifications and improvements have been introduced. The pres
ent version OPUS10.3 is:

- Leased to over 90 users and over 400 licenses
- Used in 15 countries
- Used by 8 Air Forces and 5 Armies
- Used by a large number of Defence industries including some of the largest like
  - BAe
  - Daimler-Benz Aerospace
  - Lockheed-Martin
  - Northrop-Grumman
  - Raytheon
- Used by all major Swedish Defence industries

For further reading on the program development see [Wåå 97].