Front End Analysis
A Key to Cost-Effective Logistics

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ABSTRACT

High cost for maintenance and logistics support often comes together with poor operational system performance. In such an unfortunate situation people often find themselves locked in by constraints from poor handshaking between the system itself and its logistics support system. Factors contributing to this failure can be identified as deficiencies in a Systems Engineering interaction structure that will be presented in the paper.
The paper further presents these factors and outlines some of the possible solutions. It is shown how an early access to a System Configuration Baseline with approximate data will keep the iterative process going. Also the paper will show how to generate such a Baseline at a very early stage as well as computer tools for such generation and the applications in the process. Further some comparisons with actual real life projects will be made.

1. INTEGRATING LOGISTICS SUPPORT ANALYSIS WITH THE SYSTEMS ENGINEERING PROCESS

1.1 Introduction

The situation described above seems to occur as a result of forced compromises, involving what can be afforded and what can be tolerated. In retrospective it is often easy to identify, say four or five of, the most important factors causing the problem. However, often enough, it is too late to find economically feasible solutions.

To prevent this from happening, Logistics Support Analysis (on the System Level) must become an integrated part of the Systems Engineering process. In spite of good intentions, or even firm requirements for such integration, it often doesn't happen. Factors contributing to this failure are deficiencies in the Systems Engineering interaction structure shown in figure 1.1. In the following, we will examine these factors and outline some of the possible solutions.

1.2 An Iterative Process Description

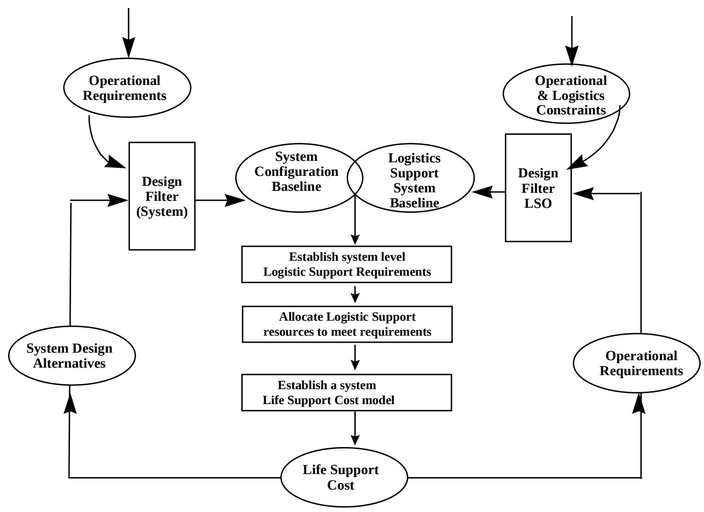

Figure 1.1

See also Ref. [Ebe 87] and [Wåå 87].
The figure illustrates the iterative nature both of the Systems Analysis and the Logistics Support Analysis.

1.3 Comments on the process blocks

Operational requirements: Given from outside of the project. Will contain both technical performance parameters like range, speed etc. as well as RAMS oriented measures.

Operational & Logistics Constraints: In the development of a new system there are a lot of resources that exist and that will influence upon the project (like manpower, facilities etc.).

Design Filter (System): Represents the know-how about systems (a "pool" of technical expertise) that will help us to
a) Generate a System Configuration Baseline
b) Judge the feasibility of questions and suggestions for alternatives

Design Filter (Logistic Support Organisation - LSO): Represents the know-how about LSO's (a "pool" of the expertise of our Logistic Support System) that will help us to:
a) Generate a number of feasible LSO's
b) Judge the feasibility of questions and suggestions for alternatives

System Configuration Baseline (or System Baseline): A **faked** description (on the LRU level) of the system with unit costs and demand rates. (What is needed of system information to run a multi-echelon, multi-indenture program for Logistic Support and Spares Optimisation. OPUS10 is such a program and this denomination will be used onwards.) This description may or may not be supplemented by the information needed for other LCC input (like repair times etc.). The use of a program to support the generation of a system baseline is commented upon later.

Logistic Support System Baseline (or LSO Baseline): A description of the LSO with stations, links and times (turn-around-times and various transportation times). (What is needed in terms of LSO description to run OPUS10.)

Establish System Level Logistic Support Requirements: The transformation of the Operational Requirements combined with the Operational & Logistics Constraints into requirements that can be used for dimensioning of resources (like Operational Availability, MDT, Risk of Shortage etc.).

Allocate Logistic Support resources to meet requirements: Run OPUS10 for each LSO alternative and assess a spares investment that will fulfil the System Level Logistic Support Requirements (and thereby the relevant Operational Requirements). Allocate other resources as well (e.g. if a station is assumed to repair LRU's there has to be)

- Manpower (with training and documentation)
- Test equipment and other instruments and tools
- Facilities
- etc.

Establish a system Life Support Cost Model: Generate a Top-Down-Bottom-Up model, i.e. a set of equations that will reflect the aspects of the Life Support Cost (LSC) that we like to study.

Life Support Cost: Calculate the figure for LSC. Although the figure as such actually is of less interest, the relation between various cost elements and alternatives are of immense interest and they will more or less automatically generate questions and requests for alternatives. In the author's experience the achievement of LSC results is the key factor and it will irresistibly fuel the improvement process.

System Design Alternatives: Improvements in the System Design (e.g. the split of a critical LRU, improved demand rates of certain LRU etc.). Will update the System Baseline.

LSO Alternatives: Improvements in the Logistic Support (e.g. add or delete stations and/or echelons, changes in TAT's and transportation times etc.). Will update the LSO Baseline.

2. NECESSITY OF A BASELINE

It should be obvious from figure 1.1 that the entire System Engineering approach to logistics will fall apart if established baselines for system configuration and logistics support organisation are not available. Hence there will be no credible logistics support requirements and feedback of alternatives will have less meaning. It is important to realise that establishing baselines early enough in a project, to allow for an interaction according to figure 1.1, in most cases will imply a drastic change in engineering management policy. The traditional engineering process with a top-down gradual system definition, eventually revealing the system design, simply doesn't work here. "*Can't give you any data. The design is not frozen yet.*" will in a microsecond switch to "*Can't change anything. The design is frozen.*" This situation must be avoided . Systems operations modelling, requirement analysis, logistics support- and cost analyses require detailed data to be meaningful. These efforts have to start up-front in a project to have an impact, which of course is the reason for it in the first place.

Baseline management is not only a matter of engineering policy. It also involves the practical management of systems and logistics engineering data and the decision process of updating such data.

It is difficult to get data early in the project. Bearing in mind that it is only early in the project that the possibilities for effective influence are open we have to accept that challenge and adapt our methods and mentality to this. It is a challenge but remember:

- No system design start totally from scratch - a lot actually is known
- It is better to do something with uncertain data than to wait - when the good data are available it is far too late

3. USE OF A DATA GENERATOR

3.1 <u>OPUS10 and OPSA Data Generation</u>

One of the most important tasks when performing early analysis is to get 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 figures.

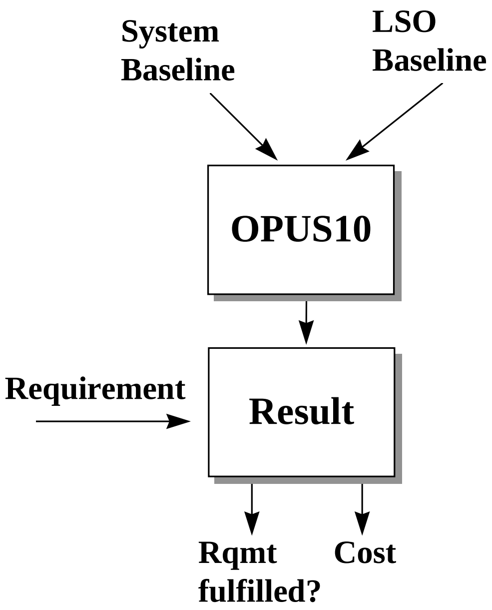

Figure 3.1

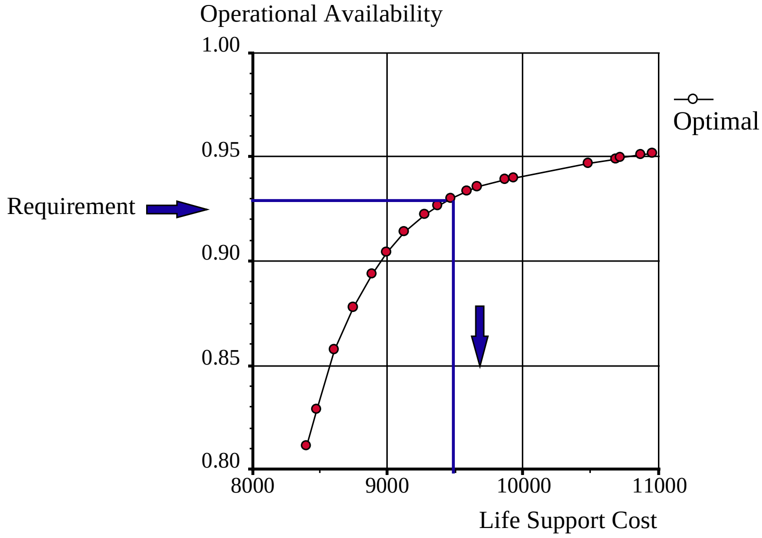

Figure 3.2
(C/E-curve output from OPUS10)

3.2 Computer tools

We can here identify in particular the following functions
- Materiel Data Handling/Data Generation
- Logistic Support Requirements
- Logistic Support and Spares Optimisation
- LSC (or LCC calculation

Materiel Data Handling/Data Generation
Handled by the ***OPSA*** program
This is function generates - or later in the systems engineering process - takes care of the data at the LRU (sometimes SRU) break down level (like failure rates, unit cost, no of each, replacement times, workshop repair times etc. Furthermore OPSA summarised and ranks data as well as deliver to OPUS10. See also OPSA in attachment 1.

Logistic Support Requirements
In some cases requirements are formulated in such a way that a computer program is needed to analyse the possible requirements fulfilment.
Sample of programs: KRAVP, ARECA, MrP, ASTOR, SIDRIX, OpSSim.

The SIDRIX program is a comprehensive simulation program that simulates the operation of the Rapid Trains in the presence of faults and other disturbances together with limited repair resources. See also ref [PåK 92]
OpSSim is presented in ref [Caf 97] and in Attachment 1,

Logistic Support and Spares Optimisation
OPUS10 is a member of a class of programs denominated multi-echelon, multi-indenture level spares optimisation programs. An excellent description of this class of programs is given in [She 92].

Multi-echelon means that the spares are stored on more than 1 echelon. 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.
Multi-indenture levels means that spares of different levels of indenture (or break-down) are studied at the same time. Again, complications show up like **commonality** both in systems and on lower indenture items, **repairables** vs. **non-repairables**, **partly repairables** etc.

See also [Wåå98].

LCC programs
Although the LCC calculation is straight forward and simple (in particular in comparison with the Spares Optimisation) the sheer amount of alternative calculations make a computer program necessary. It will also permit a number of useful functions like sensitivity analysis, automatic plotting etc.
Examples: PALSC, SYCAP, LCCDEMO, etc.
These programs tend to be based on more or less tailored spread-sheets.

3.3 The OPSA Data Generation and the Iterative Process

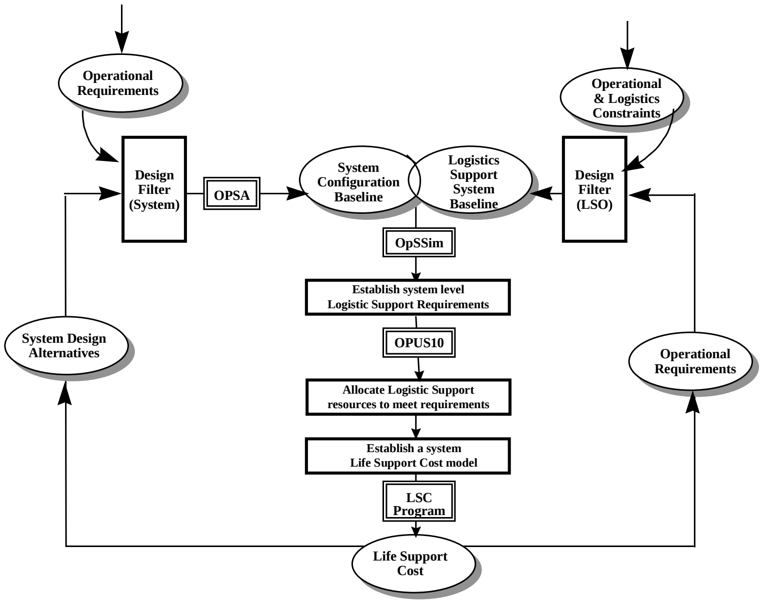

Figure 3.5

The steps in a study are as follows:

a) Based on the requirements of the system, estimate (= intelligent guess) the following
   - o Overall demand rate per system
   - o Sum of LRU cost (1 of each - see note)
   - o Number of different LRU's

Note: *The sum of LRU-cost is in a reasonable relation to the unit cost for the system. This relation has to be assessed by experience from various branches.*

b) Three parameters of technical nature have to be included
   - o Cost spread
   - o Demand spread
   - o Correlation between cost and demand

The meaning of those parameters are understood from the following figure.

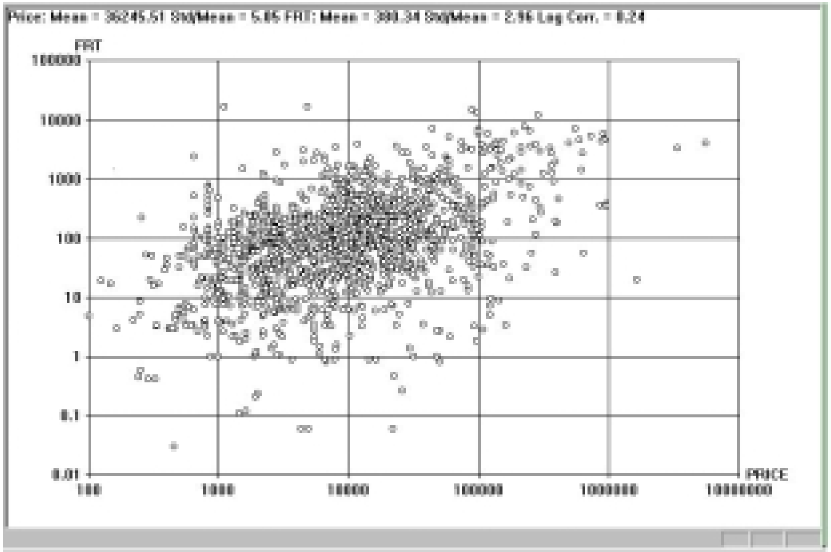

Figure 3.6
(a plot of LRU Demand Rate vs LRU Unit Cost for a major system)

c) Generate a couple of system baselines by using **OPSA** and the information produced under a) and b). (Use a couple of generations to be able to select a typical rather than extreme result.)

d) Generate one or several Logistic Support Organisations (2 versus 3 echelons, contractor involvement, transportation alternatives etc.). (Suggestions for Logistic Support baseline.)

e) If necessary run a suitable program e.g. **OpSSim**. Feed the results onwards.

f) Run **OPUS10** (on a couple of generated LRU sets and different LSO's). May also be done to simplify the selection of the "typical" system baseline.

g) Select suitable runs and ambition level from each one - you now have a spares investment as well as future spares cost estimate and also an effectiveness measure.

h) Generate a cost model (make it simple - use "top-down-bottom-up"-type of model).

i) Estimate other necessary inputs (e.g. investment in test equipment, training and documentation as well as future cost inputs like repair times, need of preventive maintenance etc.).

j) Run the **LSC program** and look specially on the ranked sensitivity runs.

k) Look at possible improvements.
It should be remembered that it may be difficult at this very early stage to be clear enough to discuss system configuration improvements. The important thing (at this stage) however is to look at suitable LSO alternatives.

You now have an opinion on
- Are the operational requirements in the right ballparks for the state of the art?
- Critical cost elements (where will the money go?)
- A reasonably good concept for the Logistic Support Organisation

With this in your hand you can proceed further on in the project.

Now we can continue and let us have a look at the improvement activities during a tender evaluation. However, before doing that let us take a look at the accuracy. How correct will the result be? It goes without saying that the results are not accurate. As will be shown in the para 4, however the results are accurate enough for the early analysis purpose. Also the alternative - do nothing - definitely is not better. Some steps however could be taken:
- o Adjust the technical parameters (spreads and correlation) by analysing your present products. (Use the general internal knowledge.)
- o The items in the upper right hand corner (high demand and high unit cost) are the critical ones. They should be scrutinised and perhaps replaced with (adjusted) experience values. (Again - use the specific internal knowledge.)

Quite a lot is known about your system even if it is very early - an aircraft needs engine(s) and engines have a very high cost and a comparatively low failure rate. Find a corresponding LRU and replace it with what you assume about the engines and rerun OPSA for the remaining part of the system.

3.3 Introducing the OPRAL

As systems grow more complex the question about the LRU repair and the related question of test equipment becomes more important. A key capability when solving those questions is to be able to analyse those questions in the same context which means that the spares investment must be optimised in the same run as the location of test equipment is optimised. This is done by a technique developed by Dr P Alfredsson, Ref. [Alf 97], and implemented in the OPRAL program (OPRAL = Optimum Resource Allocations). OPRAL uses OPUS10 as the engine to calculate cost and effectiveness for each set of combinations of spares and test equipment.

4. AN EXAMPLE

The following is an example of the early studies of a Low Coverage Radar.
(Taken from Ref. [PåW 82]

Before submitting the RFP a number of studies were performed with the following scope:
- o Validation of the Reliability Performance Requirements in the RFP
- o Validation of the LSC model
- o Establishment of a reference for the LSC evaluation
- o Training of the LSC team

Note: *LSC = Life Support Cost*
The cost elements included are shown in figures 4.1-4.3.

When doing so a dummy radar was invented using historic data as well as technique similar to the one used in OPSA.

The results achieved during the study phase were later compared with the outcome for the best tenderer in the first evaluation. The agreement is surprisingly good proving that not only did the team do their homework and used solid methods but also that they had been lucky. The following diagrams show the comparison.

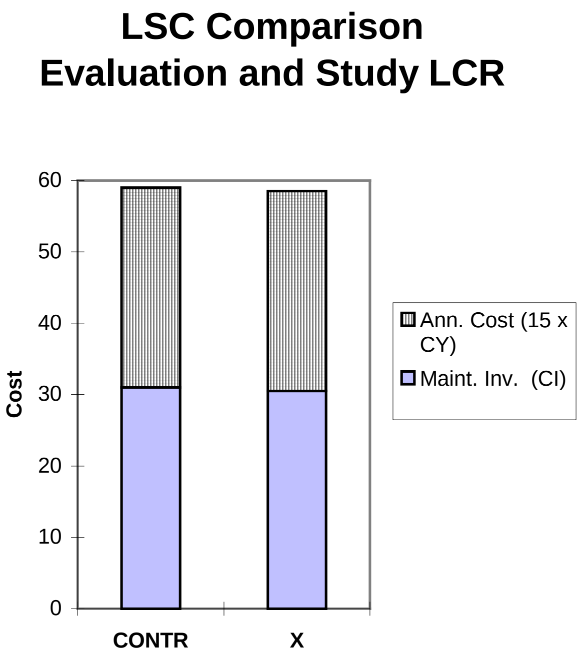

Figure 4.1

Excellent agreement both for investment and the annual cost over 15 years.

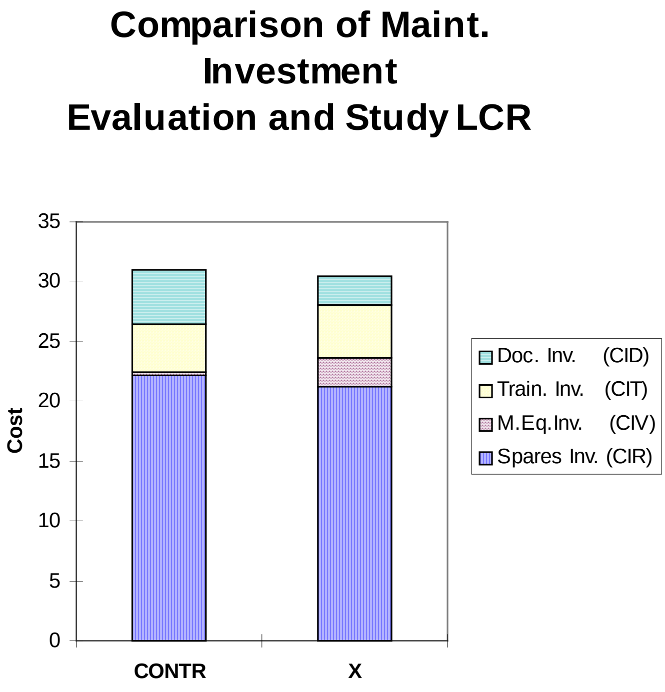

Figure 4.2

Excellent total agreement but here the team overestimated the need for maintenance equipment and the team underestimated the cost for documentation. The terms “underestimated” and “overestimated” are used in relation to what was clarified in discussions. There was a need for less test equipment than estimated by the team and the offered cost for documentation was higher than what the team had roughly estimated. The dominating cost element-investment in spares was calculated by OPUS (at that time OPUS7) and it was surprisingly correct indicating that the method of allocating cost and demand rates to the estimated number of LRU’s was reasonably good.

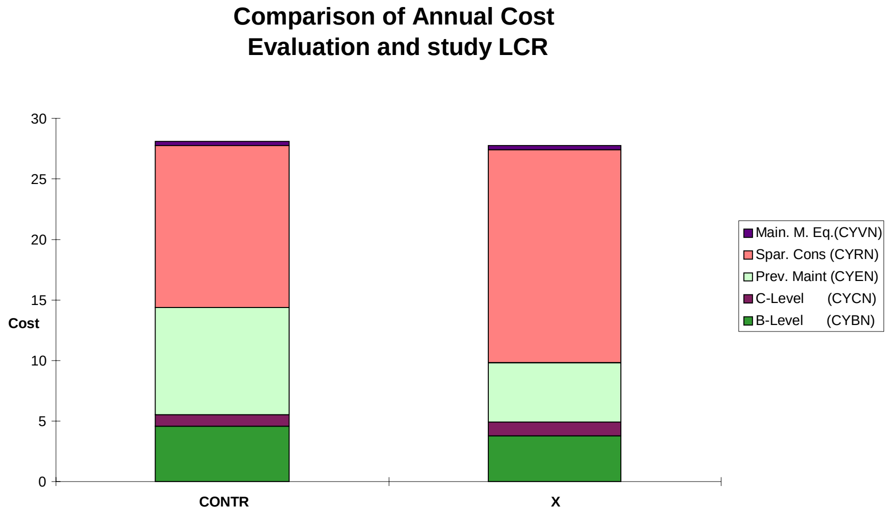

Figure 4.3

Excellent total agreement but the tenderer overestimated the need for preventive maintenance and the team underestimated the warranted TX-tube life (and as a result overestimated the TX-tube cost over the life).

The process now can move along into

- Tender evaluation (for examples on methods and improvements see ref [PåW 82]
- Contracting (for examples on improvements see Ref [AkB 94] (Rapid Trains) and [Båå 95] (JAS39 Gripen)
- Contracting and verification. See Ref [Wåå 82] and [Wåå 94]

5. CONCLUSION

The method presented in this paper has been applied in a number of acquisitions with good results. It will certainly help to overcome the general problem for logisticians to get in early and get results.

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