MULTISENSITIVE LCC ANALYSIS WITH ESTIMATES

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ABSTRACT

Life Cycle Cost analysis is aimed to monitor and minimize total cost. The LCC analysis is used by managers, decision makers, ILS engineers for system acquisition, proposal writing, management, development, production and through-life support.

Cost-effectiveness is an evaluation involving both performance and cost. The best performing system may not be the most cost effective one. Therefore, when analyzing the acquisition of any complex system under uncertainty, thorough sensitivity analysis is required to generate robust results. The methodology presented in this paper demonstrates how to evaluate cost-effectiveness for a system that involves both measurable and assessed characteristics for better decision making.

BASIC PROBLEM

Life Cycle Cost (LCC) analysis is the structured collection, analysis and presentation of complete cost data, aimed to monitor and minimize total Life Cycle Cost. LCC analysis is a key tool for system acquisition, management, development, and through-life support activities. Total LCC is defined by creating a Cost Breakdown Structure (CBS) and allocating cost variables to each CBS component. Then bottom-up cost estimating should be performed, supported by detailed examination of the costs and parameters affecting LCC.

The principal methods of LCC analysis are as follows:

- Cost-to-Cost (CTC) Estimation
- Cost Estimate Relationship (CER)
- Cost by Similarity

The basic problem is how to determine an interaction between Acquisition Cost, Life Support Cost, and Gross Sales as a function of logistics and performance parameters (e.g., Output, Personnel, Training Time, Documentation).

An innovative solution for this problem developed by the author provides both methodology and tools for optimization and trade-offs between the above characteristics, thus supporting cost-effective management.

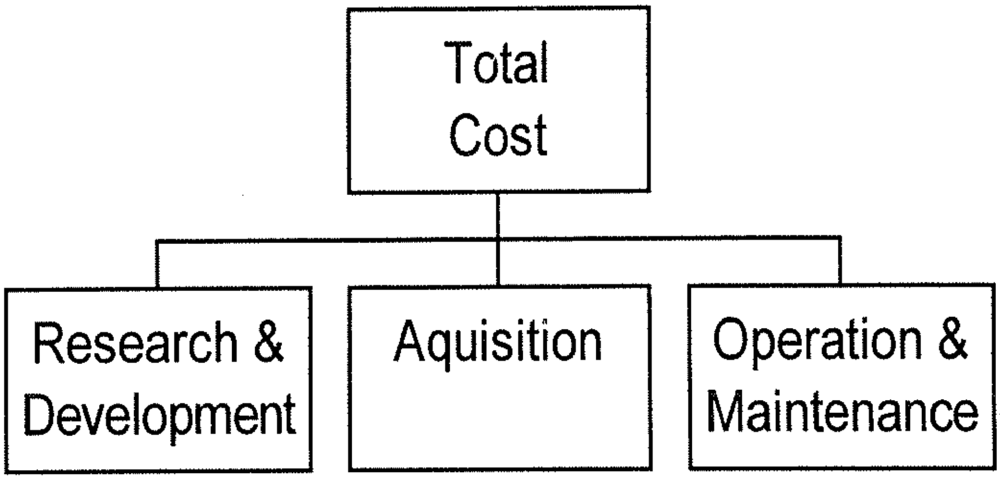
COST BREAKDOWN STRUCTURE

A Cost Breakdown Structure (CBS) of most projects consists of the following cost elements:

◊ Research and Development
◊ Production Infrastructure
◊ Acquisition
◊ Integrated Logistics Support
◊ Operation & Maintenance

Elements of the Cost Breakdown Structure are only those cost items involved in a particular project/ program.

CBS Example



In the example study, the manufacturer evaluates a cost model based on these two factors. Compute the Total Cost as a total of cost associated with Acquisition and Production & Maintenance. That is

$$Total\ LCC = \sum C_i\left(\alpha_1^{(i)}, \alpha_2^{(i)}, \ldots, \alpha_k^{(i)}\right)$$

where c_i is the cost associated with cost element i, and $a_j^{(i)}$ are cost parameters.

MOTIVATION FOR SENSITIVITY ANALYSIS

The Sensitivity Analysis is intended for computing changes in the model's output according to changes in any global variable. This technique identifies major cost drivers, supports trade-off analysis and indicates the effect of altering critical parameters and assumptions.

Each estimate of a Cost parameter is made by experts or professionals working in a certain problem area. Hence, a cost estimate cannot be precise (from Measurement Theory point of view).

This is true for all 3 types of cost estimates listed above.

Therefore, any point estimate of LCC will serve as some indication of a relationship between alternatives, but it can sometimes be poor basis for decision making.

The best way to increase the confidence of the results obtained is to perform Sensitivity Analysis on the Total LCC versus main primary parameters.

Sensitivity Analysis (SA) is a well known method for evaluating the dependence between an input parameter (argument) and output result (function).

In Cost Assessment, Sensitivity Analysis is of vital importance since it allows for the following:

1) Prove (or refute) the confidence of results obtained.
2) Determine the robustness of LCC point estimates for several alternatives.
3) Detect basic parameters which have the greatest impact on the Total LCC in order to evaluate them as thoroughly as possible.

4) Define those basic parameters which provide the largest marginal improvement with the aim of increasing Total Cost-effectiveness.

COMMON INFLUENCE FACTORS AND MAIN TYPES OF SENSITIVITY ANALYSIS

In many cases, several primary Cost elements depend on one "common" parameter. A common influence (or global) factor is a measurable characteristic which can vary over a definite range.

Common influence factors may have opposing tendencies on the evaluation process. Some examples of Common Influence Factors are presented in a Table below.

Common Influence Factor	Impact on Performance with increases in factor	Impact on Cost with increases in factor
Customer Maintenance Training, man-hours	Improves manpower management, thus improving internal logistics and external logistics.	Increases acquisition cost, increases life support cost
Logistics Support Analysis	Improves storage and delivery logistics, thus improving internal logistics.	Increases acquisition cost, decreases life support cost

There can be a point where cost effectiveness is maximized. The Sensitivity Analysis, helps determine this point.

There exist many techniques and approaches to applying Sensitivity Analysis. We introduce a classification based on the relationship between input parameter(s) (arguments) and output results (function). This classification clarifies the application area of Sensitivity Analysis and its main advantages.

Suggested classification for Sensitivity Analysis types:

1) One input parameter - one primary Quality Characteristic.
2) One input parameter - many primary Cost Parameters.
3) Many input parameters - many primary Cost Parameters.

The first two groups comprise One-parameter Sensitivity Analysis, while the last group is the Multi-parameter Sensitivity (Multi-sensitive) Analysis.

ONE-PARAMETER SENSITIVITY ANALYSIS

This relatively simple type of Sensitivity Analysis includes the cases when a Sensitivity Analysis argument is contained in only one primary Cost Characteristic of a certain object defined by the Cost Breakdown Structure.

Minor deviations of a primary Cost Parameter value may affect the difference between Total LCC point estimates for several alternatives.

It is strongly recommended to perform Sensitivity Analysis on most primary Cost Parameters. This will ensure completion of the following tasks:

1) Checking the robustness of the final decision obtained by comparison of Total LCC point estimates for all alternatives under analysis.
2) Finding primary Characteristic which has the greatest impact on the Total LCC.

The well known Pareto technique can be used with this purpose:

- Calculate two sets of Performance values for all primary Cost Parameters decreased and then increased by 25–50%.
- Place the obtained Performance ratios in descending order for both sets.

- Calculate 20% of difference between the maximal (or minimal) Performance and 1.0.
- Select those primary Cost Parameters which cause more than 20% of the maximal difference obtained.

The resulting primary Cost Parameters must be evaluated as thoroughly as possible.

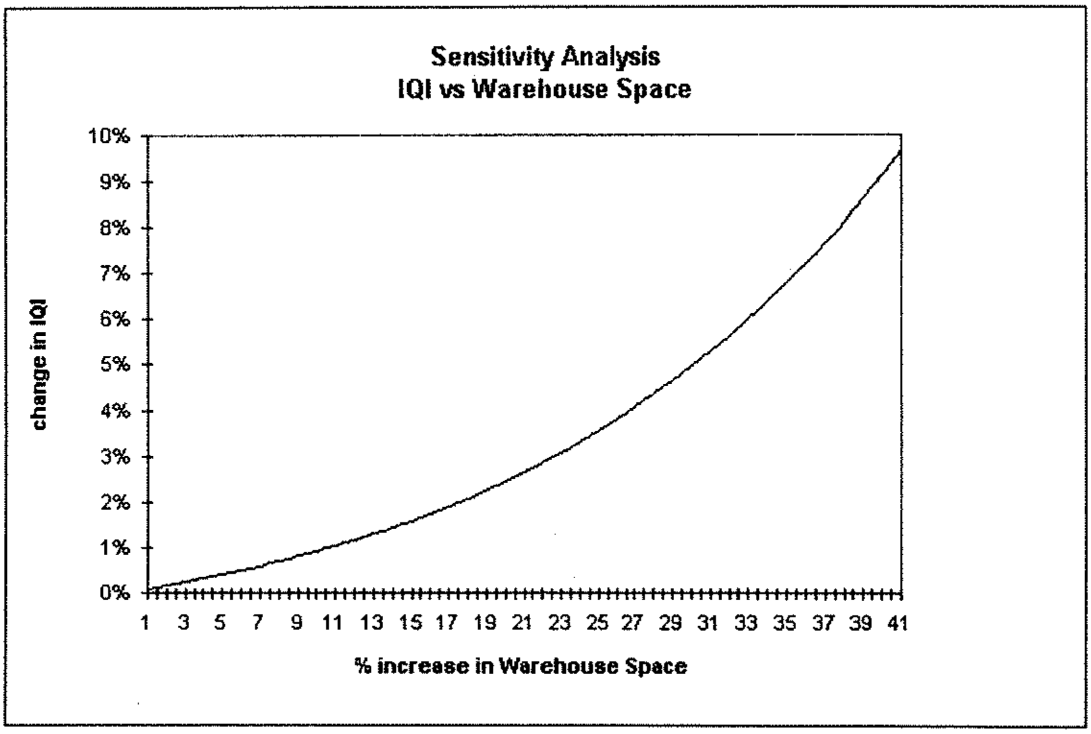
If cost analysis is performed with the help of specialized (or even universal) software tools, all the above calculations can be performed very easily. In any case, the following two groups of primary Cost Parameters must undergo Sensitivity Analysis:

1) Ambiguous Cost Parameters
2) Cost Parameters with a Cost estimation function having an extreme point (such as a parabola).

Example of Sensitivity Analysis

In our example, storage space has a positive correlation with Logistics Cost. Increases in storage space will increase the Cost of Logistics, and in turn increase the overall Performance Index.

This is an example of one-parameter sensitivity analysis. All other factors and parameters are unchanged.



MULTI PARAMETER SENSITIVITY ANALYSIS: ISO-COST CURVES

In many real-world projects, multi-parameter Sensitivity Analysis is required. Any application in Cost Assessment and Decision Making areas include, as a rule, a few important Cost Parameters. In such cases a problem is to find the best combination of all these characteristics which provides the highest Performance Index divided by Total LCC for one or several alternatives. It's almost obvious that such calculation for all possible combinations of several Cost Parameters is practically unfeasible. There exist a few methods for solving multi-parametric problems. Basing on wide practical experience, we suggest an approach that we call "Multisensitive LCC curves".

This method is rather convenient and relatively simple for implementation together with providing powerful analytical possibilities.

The main idea behind this method is to generate a set of Regression Cost curves for several fixed values of the Performance Index.

The principle steps to be performed are as follows:

- Select a set of discrete Performance Index values; for instance, 0.6; 0.7; 0.8; 0.9; 0.95.
- Write down an analytical expression of relationship between Performance Index and two (or more) Cost Characteristic which should be optimized.
- Transfer this expression to the form where one of the primary Cost Characteristic is a linear function of the other primary Characteristic and constant Performance Index value.
- Take the inverse functions for the two (or more) function and substitute them into the above linear dependence. Inverse transferring may be done analytically if possible, or alternatively - in graphical form.

Finally, we receive an Multisensitive LCC curve — a dependence of one primary Characteristic value on another one for a certain Performance Index value (see an illustration below). A set of such Multisensitive LCC curves allows to define the rational combination of two or more Cost Parameters providing the highest possible value of Performance Index.

COST EFFECTIVENESS SENSITIVITY ANALYSIS

Since the relationship between costs and priority setting isn't always obvious, one should perform a *cost driven* sensitivity analysis.

There are two types of cost driven sensitivity analyses:

- Cost effectiveness - examines the ratio of Performance/CBS over changes in the global variable.
- Performance versus Cost - examines the possible Performance values for various CBS index values.

Cost Effectiveness Example

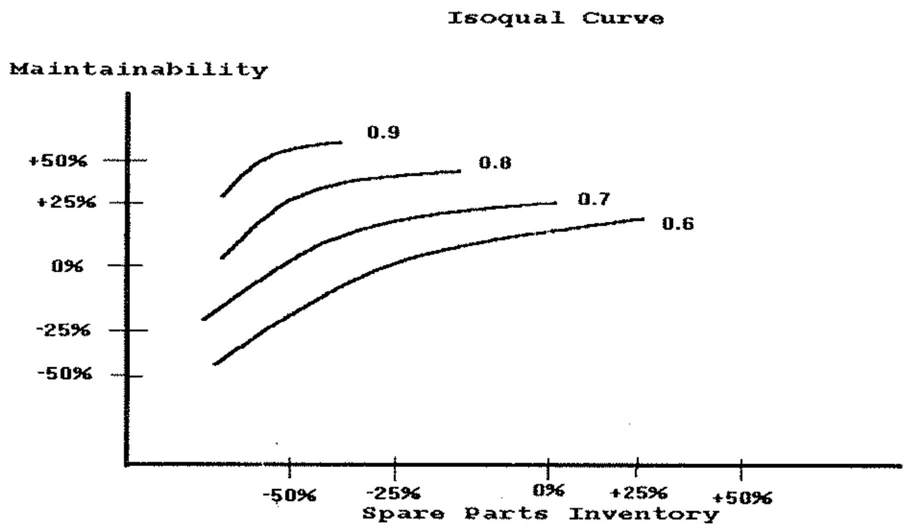
When considering costs, we may find that improving the overall performance by 50% requires an outlay of $1 million, while an increase of 25% costs only $5,000. In this case, it's more *cost effective* to aim for a small increase in the performance.

For variations in the global variable, we compute the Performance indices and Total LCC. The highest ratio represents the most cost effective action.

Training	Performance	Total LCC	Ratio
50%	0.40	0.50	0.80
75%	0.40	0.70	0.57
100%	0.50	1.00	0.50
125%	0.60	0.70	0.86
150%	0.60	0.50	1.20

In this example, the most cost effective decision is to increase training to 150% of its current level. Note that lowering training to 50% of its current level, or raising it to 150% of its current level, results in the same cost index—due to economies of scale. However, the Performance at the 150% level is significantly higher. This indicates that the right strategy is to raise the level of training, because for the same amount of money, there is a 50% increase in the Performance.

An example of Multisensitive analysis for the Maintainability and Spare Parts cost is depicted in Figure below.



SOFTWARE TOOLS FOR LCC SENSITIVITY ANALYSIS

There exist several software tools for LCC analysis in both commercial and military sectors. Some widely used tools are CASA, PRICE, EDCAS. But each of them includes one pre-defined, rigid cost model. A package supporting flexible user-definable cost models based on the analogy, parametric and other engineering techniques is D-LCC (Decision by Life Cycle Cost). D-LCC provides varying levels of sophistication, and a range of advanced options to support sensitivity and financial analyses. D-LCC provides bottom-up cost estimating, supports detailed examination of the costs and parameters affecting LCC, and performs Net Present Cost analysis.

D-LCC's most important features are as follows:

- D-LCC allows the user to apply pre-defined LCC models as well as to **create new Cost structures** and models. An existing CBS can be easily tailored to meet all needs of any particular project.
- **Product Tree Cost Calculation** option allows for incorporating the Product Tree parameters in LCC model and calculating any required cost elements (like spare parts cost for each Level of Repair) across all Product Tree items.
- **Net Present Cost (NPC)** In financial and budgetary analysis, a necessary requirement is to identify the present value of future cash flows called Net Present Cost. The NPC analysis also provides comparison of options with different inflation and discount rates, and is enhanced through sensitivity analysis of these rates.
- **Cost Profile** Analysis D-LCC supports detailed examination of dynamics of future cash flows over multiple time periods.

CONCLUSIONS and RECOMMENDATIONS

The developed methodology for estimation of cost-effectiveness, improved direction tracking and decision making for managers usually working under conditions of mixed quantitative and ambiguous data. The method is self-checking, in that sensitivity analysis provides for verifying the directions recommended and the results obtained. Reliability, safety, logistics and quality are classical areas for applying the developed approach.

Decision makers in manufacturing industries should apply the Multi-parameter Sensitivity Analysis when appropriate, in order to ensure that optimal and rational decisions are made.

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