Decision Making in Life Cycle Management - An Analytical Approach

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2 Abstract

How do you make sure that availability performance of your systems is good enough, and that the cost for achieving it is not too high? Throughout the life cycle of an advanced technical system, like an aircraft, train or power plant, countless decisions are made, on high and detailed levels, which have major impact on both overall performance and total ownership cost. Some are even decisive for the ability to reach the objectives.

Surprisingly often, such decisions are based on gut feeling only, or on very limited analyses. One reason may be that it is perceived to be too difficult and/or time consuming to get proper decision support. Lack of qualified data and uncertainties in early phases are seen to make it impossible to conduct meaningful research. In most situations however, decision support is not focused on providing exact answers, but rather on choosing the right direction going forward. Therefore, even analyses based on rough estimates, approximations and analogies can make the difference between failure and success.

This paper outlines the fundamentals of successful Life Cycle Management, a method to monitor your systems towards fulfilling the operational needs at the lowest possible Total Ownership Cost. The paper discusses critical decision points in different phases of the systems life cycle and suggests an approach to use modelling and simulation software to answer key questions and provide the required decision support.

3 Introduction

Procurement and ownership of advanced technical systems such as aircraft, trains and energy production plants is associated with huge investment costs, high complexity and substantial costs for operations and maintenance over the whole life cycle of the system.

Early decisions regarding concepts, requirements and choice of supplier will impact the Total Ownership Cost (TOC) more than anything else. Unfortunately these decisions need to be made without exact knowledge about all influencing parameters. To make these kind of decisions under major uncertainties calls for an efficient and systematic decision making process, using modelling and simulation tools to analyse the consequences of the decisions.

Another obvious conclusion is that there is a need to continuously monitor and control the systems over their life cycle in order to gain as much benefit from each system as possible. At the same time the costs associated with developing, owning and using the systems also needs to be monitored and if possible minimized.

We call this continuous process Life Cycle Management (LCM) as we look upon it as a management process or a tool to monitor the system towards fulfilling the operational needs at the lowest possible TOC, thus creating more affordable systems for the users.

4 LCM in theory and practice

As stated above, Life Cycle Management (LCM) is a method to manage the system towards fulfilling the operational needs at the lowest Life Cycle Cost (LCC). Various LCM approaches has been used by several organizations for many years. Our experience is however that most organizations don't benefit from the full potential of applying proper LCM. Some of the most common pitfalls are:

- LCC is used for accounting/budgetary purposes only, not to support decisions
- Operations and maintenance qualities are not addressed early enough
- Decisions are made without proper consequence analyses, for example modelling and simulation
- Poorly defined requirements that are either not relevant or creates contradictory incentives

To understand how to apply proper LCM and to avoid the pitfalls it is important to understand the fundamental mechanisms that need to be addressed.

To begin with, the driver for system acquisition and development should be the user´s need. The air force has to be able to produce a certain amount of flying missions, the train operator wants to be able to run a train fleet according to a time table and the energy producer wants his power plants to be up and running all the time. In addition, common for all users is the need to be efficient, i.e. be able to fulfil the needs to the lowest possible cost.

The user´s need can be translated into operational performance of the system which is defined as a combination of the technical capabilities and the **availability**, which is the extent to which the system is actually able to deliver its performance when asked for. The difficult task that we focus on in this paper is to make sure that the availability performance is good enough and the cost for achieving the required availability level is as low as possible.

How can we do that? One obvious way is to make sure that the system doesn't break too often and that the preventive maintenance needed to keep it running is not required too often. We call this **reliability**. Reliability is a factor defined by the system design that has to be taken into account from the beginning when designing a system. When acquiring a new system that has already been designed, you need to make sure that you understand whether the reliability has been an important design parameter or not. Poor reliability is a significant cost driver from a TOC point of view.

The next way to ensure that the availability performance is good enough is to minimize the downtime when a failure occurs or a planned maintenance task is performed. Downtime has to do with two things, and one of them also has to do with the system design. It is called **maintainability** and determines how easy and fast it is to perform maintenance tasks. The world is full of examples of systems where the design engineers clearly have not understood the impact of a certain design for the maintenance technicians, which has lead to systems that are very complicated and time consuming to maintain.

The other part of downtime depends on how we organize the logistic support of the system, and how much logistic support resources that we will need – the **supportability**. We can to some extent compensate poor reliability and maintainability with more logistic support resources to achieve the same level of availability performance. However, there will be a cost impact, not only to invest in all the extra resources, but also to perform all the repairs and planned maintenance tasks over the systems life cycle. Thus, it is possible to make a trade-off between system design and design of the logistic support system. The picture below illustrates the mechanisms and trade-offs needed to optimize operational performance.

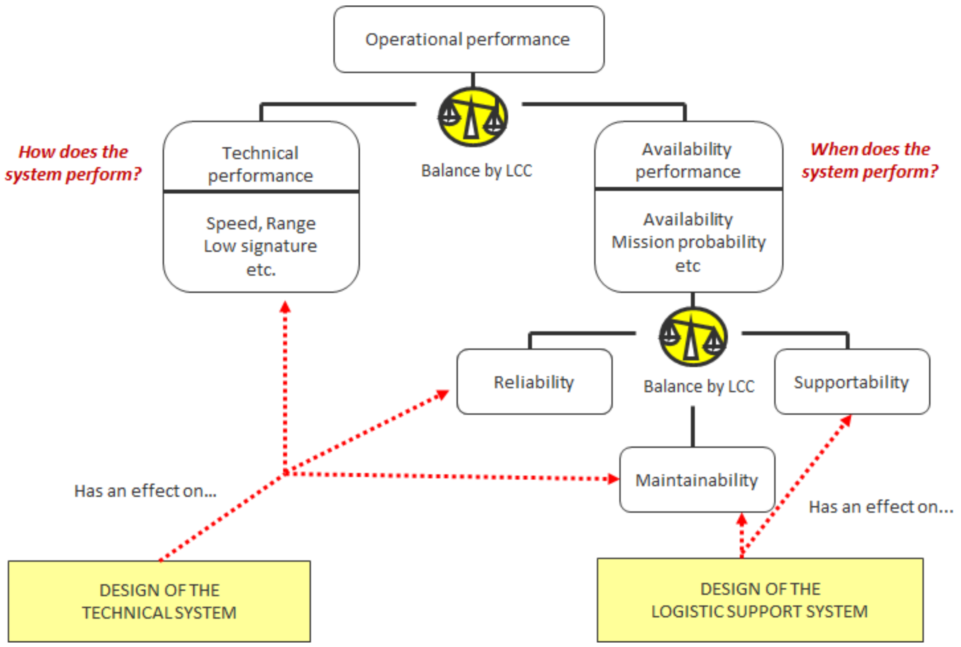

Figure 1. Operational performance and how to influence it.

To summarize this introduction to LCM in theory and practice:

- Availability performance has big impact on the user's ability to perform the tasks and operate the system as planned, i.e. on the operational performance
- Availability performance is best influenced in early system design by focusing on reliability and maintainability aspects of the design.
- Poor reliability and maintainability can be compensated with more logistic support resources and more maintenance, but often at a high price
- The availability performance has crucial impact on Life Cycle Cost (LCC) and the Total Ownership Cost (TOC).

5 Life Cycle Perspective and Decision Making

There are recognized international standards for system life cycle processes, like ISO 15288, however many of these processes will not give you any guidance on how to make decisions. In this paper we have chosen to focus on that perspective; the fundamental decision making process for balancing operational performance and total ownership cost.

5.1 Impact of decisions

From a customer and owner perspective any system typically goes through a number of phases starting with concept definition, specification and acquisition, continuing with system design and development, production, entry to service, operations and maintenance and finally disposal. All through the life cycle a program or product manager needs to make a lot of decisions regarding the technical system, its operations and maintenance and the logistic support. The important point here is that consequences of decisions made will not come in daylight until many years after a decision is made. That is the background to the classic LCC curve below.

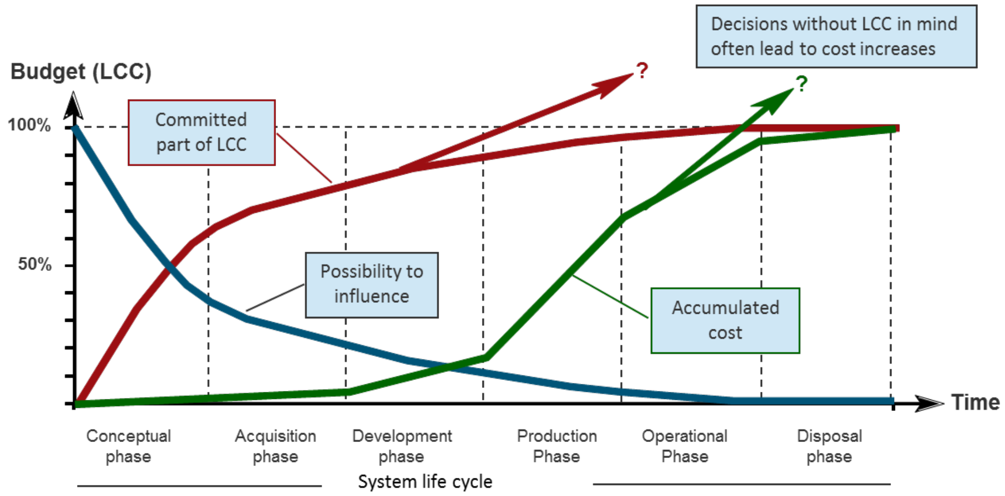

Figure 2. Characteristics of the LCC-curve.

The green curve shows the actual expenditures (both CapEx and OpEx) for a system throughout its life cycle. The red curve however, describes when your decisions make you commit to the costs, which usually occur long before the actual expenditures. Thus your possibility to influence the total ownership cost will decrease during the system´s life cycle according to the blue curve.

It is also important to point out that if decisions are made in later phases without analysing the potential consequences on operational performance and life cycle cost, there is a great risk that you commit to future cost increases.

5.2 Data quality

One issue when working with models is how to get relevant input data. Lack of data is one of the most common objections against using modelling and simulation. In most situations however, the required decision support is not exact answers, but rather understanding enough to be able to choose the best direction going forward. Even analyses based on rough estimates, approximations and analogies can make the difference between failure and success:

- The requirements for data accuracy and level of detail depend on the type of decision to be made.
- There are proven ways to mitigate "lack-of-data"-issues.
- There is always knowledge available in your organization that can help you to calibrate input data and validate results.
- Sensitivity analyses and what-if analyses will help you to evaluate the implications of data uncertainty and hence focus on the most significant variables.

The correct approach is to make use of the best available data and expand and refine the model as more knowledge and experience is gained from within your organization and from your suppliers. The picture below lists a few generic approaches that can be used in different stages.

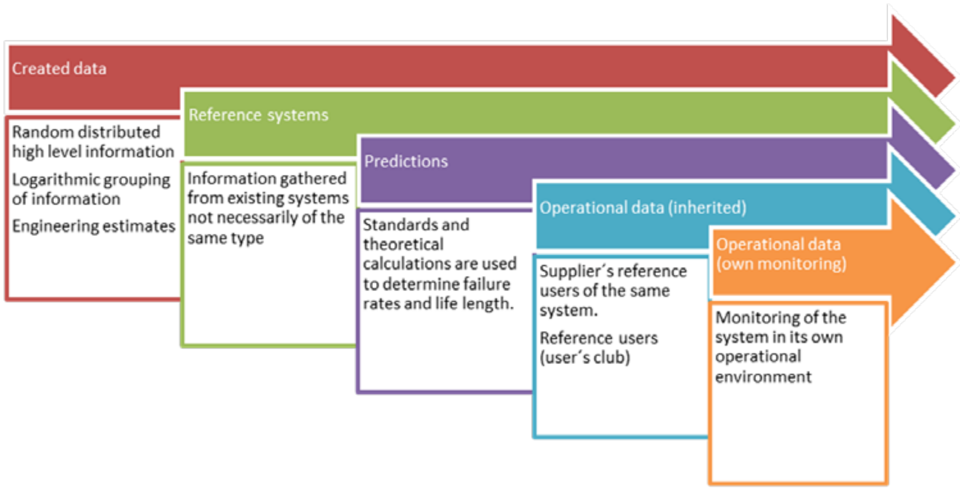

Figure 3. Methods to create data of better and better quality.

As a general recommendation, start with a high level model using rough data. The analysis will then support you in identifying what data is most important for the decision at hand. You can then put your effort to gain better data quality in the most important areas. As data quality will improve during a program you can gain from using this to further detail and improve your models.

6 Systecon´s analytical approach to LCM

When should you replace a fleet of systems? What requirements should be put on a new system? Which system should you purchase? What investments in logistic support, spares and other resources should be chosen? What improvements are most cost-effective to make to enhance my operations?

These are some examples of major questions for a system manager. They all require an understanding of what the consequences of the choices at hand will be on operational performance and total cost of ownership. The questions are complicated to answer since there are so many influencing parameters. The picture below illustrates the decision problem and the three main influencing domains.

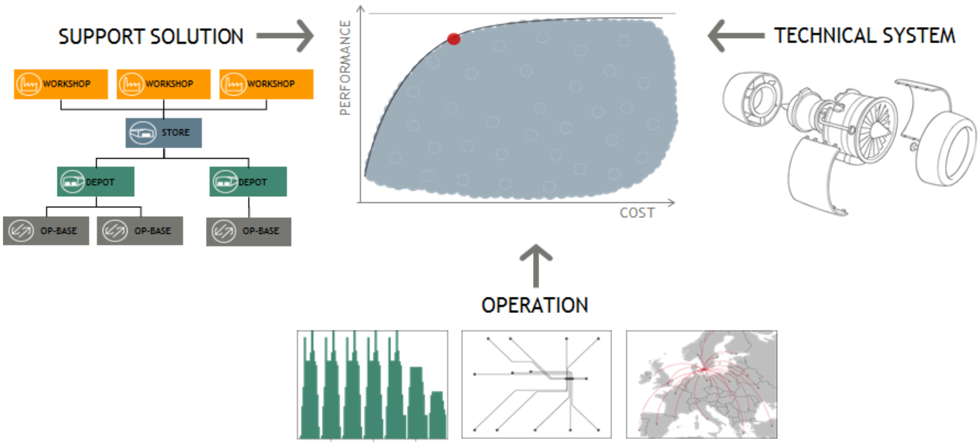

Figure 4. The dimensions that influence the relationship between cost and availability of your system.

Each domain is complex to describe, and changes in one domain, for instance a new operational profile, will often create a need for adjustments in the other domains in order to balance the operational performance and TOC.

To be able to assess consequences of alternative solutions in a systematic and consistent way throughout the system's life cycle there is a need to use an analytical approach supported by efficient decision support models.

Systecon use a combination of tools to assess different aspects of a decision. Typically, the optimization tool OPUS10 is used to identify the best logistic support solution from a cost effectiveness perspective and to optimize the spares assortment. The simulation tool

SIMLOX is used to validate sustainability and ability to handle different scenarios and to dimension fleet size, personnel, repair equipment and other resources. The cost calculation tool CATLOC is used for LCC comparisons, identification of cost drivers, budgeting and cost analysis. These tools work together as a suite to provide decision support for each type of decision and helps finding the optimal trade-off between cost and availability.

7 LCM Analytical work process

A general approach when working with LCM analyses:

- Define your system and scope, the decision at hand and the alternative solutions
- Define prerequisites and limitations for operations and maintenance
- Define influencing parameters and create your model
- Acquire input data. Begin with a rough data model.
- Validate the model and the data quality and improve data that has significant impact on the decision at hand
- Perform analyses and evaluate the results
- Perform sensitivity analysis, identify drivers of cost and effectiveness, iterate to find the best solution

7.1 Examples of decision points during the life cycle

In the early phases you make the major decisions which will commit most of the future life cycle costs. This means that it is in the early phases that we need to put in most of the effort. Nevertheless, to achieve the availability performance and the life cycle cost that the early decisions have made possible, you need to carry on making decisions in a systematic way throughout the rest of the systems life cycle. Otherwise, there is a great risk that you will suffer from uncontrollable increasing costs or poor availability performance.

Managing decisions over the life cycle with overall requirements and goals on macro level in focus, modelling detailed data on micro level is a true life cycle management challenge. The following chapters will take you through the systems life cycle to give a better understanding of some of the major activities that you will face in each phase.

7.1.1 Conceptual Phase

Examples of early LCM tasks in the Conceptual Phase:

- Define high level operational needs and requirements
- Evaluate alternative strategies and system concepts and their LCC consequences
- Evaluate alternative support concepts
- Define an LCM strategy
- Establish a budget for initial acquisition of logistic support resources and a LCC budget estimate

7.1.2 Acquisition Phase

Examples of LCM tasks in the Acquisition Phase:

- Translate operational needs into balanced specification requirements on availability performance, maintenance, logistic support and LCC
- Define evaluation models and data needs
- Specify support strategy and prerequisites for the acquisition
- Evaluate tenders and negotiate contract terms

7.1.3 Development and Production Phases

An Integrated Logistic Support Program, ILSP, should be included in the contract to secure that the system design is analysed, influenced and documented in a proper way. The various analyses and reports that are produced within the ILSP can be used as a theoretical verification of the requirements. A customer can also use this information to perform analysis and decide on the logistic support solution and what resources to acquire.

Examples of LCM tasks in these phases:

- Perform trade-off analyses between different design alternatives
- Follow up contractor deliveries and evaluate consequences on LCC
- Verify requirements
- Design logistic support system
- Optimize the logistic support resources

7.1.4 Operational Phase

Examples of LCM tasks in the Operational Phase:

- Establish a process for continuous improvements, analyse feedback, find bottlenecks and weaknesses in the support organization and make improvements
- Assess your spares assortment and make adjustments, i.e. reallocation and replenishment of spares
- Adapt to changes in the operations
- Develop support contracts
- Evaluate system modifications
- Update your models - Re-calculate LCC
- Analyse the optimal time for system replacement

7.1.5 Disposal Phase

Examples of LCM tasks in the Disposal Phase:

- Analyse and adjust the logistic support solution during ramp down and system replacement
- When stop buying spare parts and instead cannibalize on other system?
- When stop doing preventive maintenance?

8 Summary

Successful Life Cycle Management requires an ability to make well-informed decisions even in situations with high uncertainty and lack of experience data. In this context, it is important to have an ability to identify, understand and influence the key parameters that impacts operational performance and life cycle cost. This can be accomplished through the analytical approach provided in this paper, which is based on modelling and simulation of the operations and the logistics support scenarios. The approach makes it possible to balance different qualities against each other from a cost effectiveness standpoint, compare different solutions, understand the consequences of decisions and navigate towards the best possible solution with a life cycle perspective.