

LIFE CYCLE VALUE IN PRODUCT DEVELOPMENT: A CASE STUDY IN THE TRANSPORTATION INDUSTRY

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Abstract

Several factors prevent enterprises from having a holistic perspective during product development. Important aspects include increased product complexity and significant uncertainty with regard to technology. For products with a long life cycle this is extremely important since development and life cycle costs are high. The combination of complexity of system design and the limits of individual human comprehension typically make it difficult to envision a best value solution.

In an attempt to encircle a more holistic perspective of value, the concept of Life Cycle Value has evolved within the Lean Aerospace Initiative, LAI. The implication of this is development of products incorporating life cycle and long-term focus including cost and performance and reliability factors. A similar perspective has evolved within the Lean Aircraft Research Program, LARP, in Sweden.

This paper contributes a new study of how life cycle aspects are taken into consideration in a large corporation in the transportation industry. The purpose of the research was to examine relative contributions to product development and determine factors that significantly promote the ability to consider the life cycle perspective. The results will be discussed with respect to tools, methods, requirements, metrics, leadership and other organizational factors, innovation, and enterprise relationships.

Keywords: Life cycle, value, product development, transportation industry

1. Introduction

1.1 Background

Emphasis on accounting for the whole life cycle when developing a system has grown since the mid-1960s. Publications by Blanchard et al regarding life cycle issues, especially on the topic of Life Cycle Cost, LCC, are now sources for a variety of interests. LCC involves all costs associated with a system, including R&D, production and design (including operation and maintenance for production capability), system operation and maintenance, as well as system retirement and phase-out costs [1].

Recent research with similar thoughts in mind has focused on how to take into account affordability [2] and supportability issues in product development. Consideration of life cycle issues, such as supportability, early in product development has proven to be economically beneficial for industries that produce products with varying degrees of complexity. Xerox was one of the companies that evaluated support requirements early in the design stage. The

company found that considering support issues rather than by implementing Design for Manufacturing (DFM) methods to increase productivity [3] saved more money.

In an attempt to encircle a more holistic perspective of life cycle issues the concept of life cycle value has evolved within the Lean Aerospace Initiative, LAI. The creation of life cycle value implies a balance between cost, performance and other attributes in a product’s life cycle perspective. The concept of life cycle value and its implications have been studied in three different cases: F/A 18 E/F, JAS 39 Gripen and F-16 C/D [4]. Based on these case studies a life cycle value creation framework was introduced that comprised three phases; value identification, value proposition and value delivery. Based upon qualitative results from the three cases, six attributes could be identified as significant contributors to a more holistic life cycle perspective. A capability maturity matrix was introduced based on the three case studies. As an extension of this work a fourth case study, B-777 was done and the previous work was also refined [5].

Several factors prevent companies from having a holistic perspective during product development. Important aspects include increased complexity of the products, development cycle time, significant technological uncertainty, and communication and human issues. During the development process several often-conflicting factors have to be considered, as is clearly illustrated in figure 1.

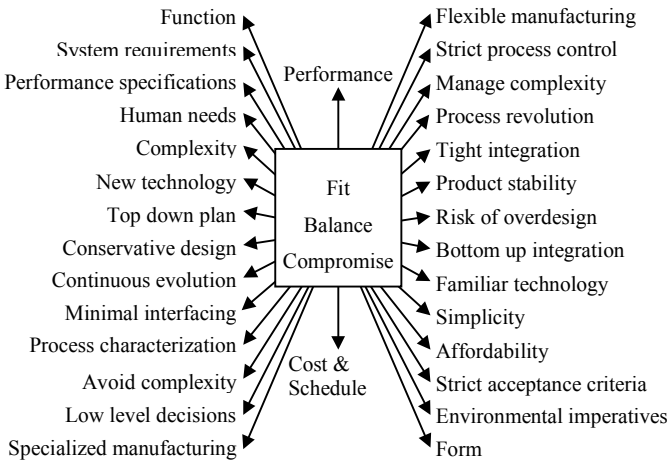


Figure 1. Tensions in Systems Architecting [7].

In addition to this, for complex systems with a long life cycle, different technologies age and become obsolete at varying rates [6]. The combination of complexity in system design and the limits of individual human comprehension typically prevent a best value solution to be envisioned.

1.2 Aim of the study

The aim of this case study was to see how life cycle issues were taken into account during the product development process for products with a long life cycle. One important aspect of the study was to investigate how industry is balancing cost-oriented demands, such as LCC, with other demands related to the long life cycle of the particular product, i.e. upgradability, technology insertion and development time. Another aim of this study is to compare the results from the tactical aircraft study to another industry.

2. Setting

2.1. Life Cycle Value Framework

A value creation framework is a holistic perspective that can be utilized in product realization. More specifically, a framework for life cycle value provides a holistic view of system value, including life cycle considerations. A system in this context is the answer to the users' needs in terms of operational capability. This includes user procedures, maintenance procedures and support systems as well as scrapping. One conceptual framework for life cycle value has been developed within LAI that has been further developed in the tactical aircraft study [4] and refined [5]. The framework, further refined in this paper, consists of three partially sequential and iterative processes based mainly on a systems engineering [8] and a life cycle perspective: value identification, value proposition and value delivery.

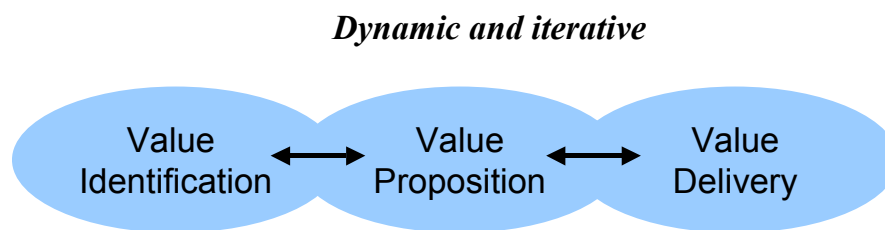


Figure 2. Life Cycle Value Creation Framework [5]

The value identification process involves recognizing all a system's stakeholders and articulating their needs and expectations in the form of system goals. Each stakeholder contributes unique information regarding corporate strategies, market analysis, consumer or operator needs, and the timing of system development and availability based on their perspective. Balance must then be established for the voice each stakeholder is given regarding the system development.

A key aspect of value creation is the transition from goals and ideas to a system architecture and concept. Establishing a value proposition for a system involves balancing the stakeholders' expectations and system goals based on the common objective of creating life cycle value. The combination of complexity of system design and the limits of individual human comprehension typically prevents a best value solution from being envisioned. [7] notes there are just too many variables. Involving multiple stakeholders to cooperate in conceiving and developing a value proposition for a system is a practical way to manage the issues of system design. It is critical to create alignment between the stakeholders regarding the value proposition developed. The value proposition and stakeholder support must then be clearly communicated throughout the enterprise. Iterations between value identification and value proposition facilitates maintaining a holistic a life cycle oriented perspective in a phase of product realization where this is critical.

Product development is focused on value delivery, as is producing, operating and sustaining the system. A good value proposition in the form of a system specification considers several system concepts, and is the basis for the life cycle value for a product. Although most of a system's properties and costs, including LCC, are the basis for the product's life cycle value, it is only to be seen as a starting point for delivering life cycle value. Strategies, practices, tools, and methodologies to consider life cycle value utilized throughout product development are prerequisites for value delivery since there are many ways to develop and improve a system's life cycle value within a given value proposition.

2.2 The Case Studied

In the present investigation, Bombardier Transportation (here after referred to as Bombardier), the train producing part of the company Bombardier, was selected. The reason was that both trains and aircrafts have long life cycles, are expensive to develop and are produced in fairly small series. One important difference that could affect the development process, including the life cycle considerations during product development is that the company has another market situation than military aircrafts. Bombardier was undergoing a transformational change brought about by a deregulation of the train transportation market in Sweden. The deregulation resulted in a totally new market situation for the train producer. As a consequence few large customers have been replaced by a number of smaller operating customers. Some of these cooperatively own Transitio. Transitio owns and leases trains to different operators and acts like a train pool to the operators. A new business scenario is that trains change users several times during a life cycle.

The project studied here was called Regina. The aim of the Regina-project was to develop a regional train. Regina was intended to be a flexible product designed to fit many different customers. It was intended to be the basis for a whole new family of products. A fundamental change in how a product was specified, designed and developed compared to previous product development projects took place at the producer. Previously, the producer had developed and produced their products to customer specifications. In the Regina-case the producer created the specification internally based on demands from direct and indirect stakeholders. Some of these are Transitio, the railway carriage owner, railway carrier operators responsible for the local traffic, maintenance organizations, train personnel, Public Railway Inspection Authority and the National Rail Administration.

Another new aspect of the Regina-project is that maintenance is offered to the customers. The intent to offer maintenance to customers should be a strong driving force to prioritize an LCC perspective in the product development project. The Regina-project was chosen was that it is a fairly new product. It is therefore possible to compare the intention of the development project with the actual result. This study focuses on the development project.

3. Research Approach

3.1 Interview strategy and data collection

This research is focused on how life cycle issues are taken into account in product development. Since it was desirable to compare the results from this study with previous interview studies done in the tactical aircraft industry, interviews were conducted to gather information. The interviewees were selected according to a heterogeneous sampling strategy [9]. The implication of this is that there is a deliberate strategy to select individuals with varying interests. Interviewees were therefore selected to represent different functional departments and roles in the project within the producer's organization. System integration and development, mechanical development and integration, production, and the purchasing, LCC and product planning departments were represented in this study. The nine interviewees also included the head of the development department at the time and the technical project manager for the project in question.

An interview format consisting of a quantitative and a qualitative part was distributed to the interviewees before the interview was conducted. The format was a slightly altered version of the interview format that was used in the tactical aircraft research project. The aim

of the changes was to remove questions that were not applicable to the transportation industry. Interviews were then held as individual face-to-face interviews with each of the interviewees. All interviews were recorded and the conclusions from the interviews were sent to the respective interviewees for feedback. The final paper was also sent to Bombardier for feedback.

3.2 Analysis of collected data

The qualitative part of the interviews is the main source for the analysis. Quantitative data is merely used as support for the qualitative analysis in this case study only when the answers were pointing in the same direction. The qualitative data was clustered into different categories [10]. These were analyzed and compared to the results from the case study of the tactical aircraft industry. Feedback on the conclusions from the interviews was sent from most of the respondents thus strengthening the reliability of these results.

4. Findings

In an attempt to get them to discuss life cycle issues from a broader perspective than just LCC, the interviewees were asked what they thought about the life cycle value perspective that has been developed within the LAI. The findings from this case study were clustered into following attributes:

- Holistic perspective
- Organizational factors
- Methods
- Requirements and metrics
- Enterprise relationships
- Knowledge management

The different interviews at Bombardier indicated that all parts of the organization were aware of the importance of considering LCC and other related issues. However, most of the interviewees also thought that there was room for improvement both in terms of methodology, education and external relationships. The level of importance and the level of performance for the different attributes, as indicated by this case study, are illustrated below.

<i>Critical Importance</i>	<ul style="list-style-type: none"> •Knowledge Management •Metrics •Organizational factors Balance Project/Functional Organization 	<ul style="list-style-type: none"> •Requirements •Methods •Tools <ul style="list-style-type: none"> •Cost estimation •Databases
<i>Significant Importance</i>	Benchmarking	<ul style="list-style-type: none"> •Tools <ul style="list-style-type: none"> • Modeling • Simulation •Logistic tools
	<i>Improvement Needed</i>	<i>Well Executed</i>

Figure 3. Observed Level of Importance and Performance of Main Attributes were extracted from the qualitative part of the interviews and supported by the responses of the quantitative part of interviews.

4.1 Holistic perspective

This investigation indicated that in this broader perspective the life support cost, LSC, for a product has to be weighed against the end users business scenarios i.e. revenue. In the future, the dynamics between cost and revenue can thus be included in a life cycle perspective in product development. This way of reasoning generates a whole new way of thinking where the view is extended from cost focus to a cost and customer revenue focus, see figure 4.

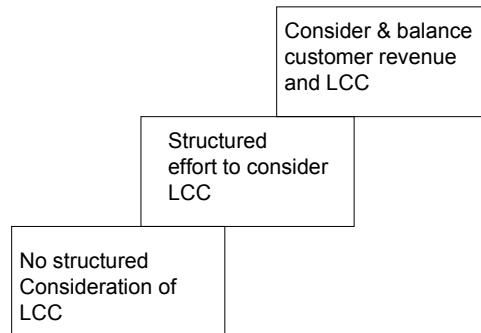


Figure 4. The figure is an illustration of the development of life cycle considerations during product development, i.e. it represents different levels of maturity.

The results indicated that it was important to consider life cycle issues, especially on the managerial and executive levels. However, most of the interviewees indicated that there are improvements to be made, as illustrated by table 1 below.

Table 1. Resource prioritizations done during the product development project based on the mean value of the prioritizations from the respondents. (The respondents were asked to prioritize how they would spend 100% of their development resources)

Design aspects	Resource prioritizations
Technical performance - fulfilling specified performance attributes and efficient use	33%
Total cost including LCC, production development and operating costs	19%
System attributes necessary for maintainability and supportability	13%
Schedule during development and availability during operational phase	28%
Uppgradability	8%

One obstacle is that LCC is another demand on the product “on top” of all the other demands. The methodology needs to be improved to make it easier for designers, engineers and other groups to consider issues related to LCC.

4.2 Organizational factors

One important factor was that the RAM/LCC (Reliability, Availability, Maintainability) department was located close to the engineering departments and represented in each

development project. Engineering departments' access to operational experience and data improved significantly through the collocation with RAM/LCC. The project members responsible for RAM/LCC contributed to the opportunity to gain a holistic perspective of the product life cycle in the development project, i.e. to find issues that need to be prioritized from a LCC perspective. There was however a fear that this collocation would affect contacts with aftermarket activities in the long run.

One lesson learned was that improved collaboration between the RAM/LCC department and the purchasing department would further contribute to the ability to consider LCC and other life cycle related issues. Communication between heavyweight project managers and the functional organization also needs to be improved to fully exploit the expertise in the functional organization.

4.3 Tools and methods

There is an ongoing effort in developing methods that can be used in the product development project especially towards the system design department. One important effort is the creation of a database containing operational and predicated results. Access to operational data would give designers indications as to where the greatest problems are in the products used. Modular management [11] has also been investigated in a life cycle perspective meaning that a strategy is sought where one driving force for modularization is technology development speed. The view of the potential of modularization varies, however, between different interviewees. A decision support model to facilitate decision-making was also sought, where LCC could be weighed against other product attributes during the product realization process.

4.4 Requirements and metrics

Contract requirements have significantly promoted the consideration of LCC and related issues during product development both within the core enterprise and at its suppliers.

Standard methodology has been used to break down customers' LCC demands on a product level to a system and sub-system level. Metrics related to LCC are continuously developed. It is however still quite difficult to break down requirements from a top level to a sub system and component level. Changes in the defined metrics are therefore considered to be difficult to handle.

4.5 Enterprise relationships

The relationship between the system integrator and the suppliers is considered to be very important. The interviewees indicated that the competency related to LCC at the different suppliers varied significantly. Metrics therefore had to be validated. In some cases the responsibility of the LCC-related commitments are shared between the systems integrator and the supplier. These commitments are usually settled in the contract with the supplier.

Lessons learned in supplier collaborations are that it is important to verify the metrics from the supplier and that delivery time for LCC related metrics has to be specified in the contract. Further, the purchasing department would need to have better knowledge about life cycle related issues to be able to negotiate more efficiently around these matters.

4.6 Knowledge management

Knowledge management was brought up as a field for improvement that could significantly influence the life cycle related properties of the product. In most cases the interviewees meant

that the knowledge transfer from previous projects to current projects could be more structured and generally better. Initially, the intention was to utilize experience from a previous project in the current project. This proved to be unfeasible, however, since the Regina-project was eventually run parallel to the actual project. A lesson learned here was that a larger gap in time would have benefited the transfer of knowledge between the projects.

5. Analysis and Discussion

When comparing this case study to the study of the tactical aircraft industry the six main attributes extracted from the results of the tactical aircraft study constitute a good point of reference. The main contribution from this case study is that there is intent to include the end users revenue into the value proposition discussion. This leads us to the reasoning that life cycle value for the customer (from a producer perspective) can be described as the difference between customer revenues during the product's life cycle and the LSC and acquisition cost including the costs for acquiring extra functionality or technology. From the producer perspective it can be defined as the difference between the customer revenue over the product's life cycle and LCC as well as costs for extra functionality and technology insertion.

5.1 Holistic perspective

In summary, the holistic perspective encompassed two main dimensions: consideration of the entire system and the entire life cycle. In the tactical aircraft study, 49% of the respondents felt that the concept of life cycle was deployed in most areas of the enterprise but the level of understanding was inconsistent. This percentage corresponded to 67% at Bombardier.

Including the end users business scenarios and revenue into value proposition and early product development stages is one way of addressing lifecycle value. Balancing this and a life cycle cost in a structured way will be the next large step forward. Still, there are problems to be solved before that step. Finding simple tools to balance requirements and educating designers would lead to significant improvements in their ability to take the product lifecycle into account. Another promoting effort is already in the product planning stage; the producer was planning for several different end users during the product's life cycle as well as an improved ability to plan maintenance. The option to include information systems and service can be seen as another way of including a life cycle perspective.

5.2 Organizational factors

Organizational factors, in short, comprised the need to collaborate across functions within the organization. In both investigations it was found that increased cross-functional collaboration could occur at the expense of specialization.

5.3 Tools and Methods

Tools and methods to support product development were considered to be of some importance and quite well deployed in both studies. However, the emphasis on which tools that were considered to be important was quite different. In the tactical aircraft case, the simulation tools, common databases, were considered to be important. At Bombardier, databases with operational data were also considered to be important. A decision support tool was also sought. One way of dealing with the problem to balance the different requirements is to have clear interface between customer demands and system to be followed up enables the balancing of different aspects during product development.

5.4 Requirements and Metrics

Requirements and metrics are ways of clearly establishing and articulating customer needs and desires. In a complex system incorporating, allocating and measuring technical requirements is an integral part of value delivery for the system. In both case studies, the contractual demands based on the requirements specification for the producer/supplier had clearly affected the consideration of life cycle issues. However, at Bombardier, methodology to breakdown LCC-demands were much more strongly emphasized and under development.

5.5 Enterprise Relationships

Enterprise relationships mostly encompass the relations to suppliers and collaboration with them. These are of key importance to maintain the continuity of the program goals through the life cycle of a system. In both cases, one problem was the varying competency in LCC among suppliers.

5.6 Leadership and Management

Leadership and management practices are important facilitators to achieve the best life cycle value. At Bombardier, the top managers were considered to understand the importance and value of life cycle considerations in product development. However, there was a need to communicate this view throughout the organization. In the fighter aircraft case studies, the need for clear roles and practices for decision makers were considered to be important.

6. Conclusions

The implication of life cycle value for a commercial business segment such as the train transportation industry can be described from the perspective of the customer or the producer.

From a producer perspective, life cycle value for the customer can be described as the difference between customer revenues during the product's life cycle and the LSC.

Life cycle value from the producer perspective can be defined as the difference between the customer revenue over the product's life cycle and LCC as well as costs for extra functionality and technology insertion. Customer revenue here would encompass both incomes from sales of the system and from extra functionality and technology insertion during a product's life cycle. The option to deliver full maintenance with the product is another approach towards a holistic commitment, which would also further affect the necessity and the priority of life cycle considerations, especially LCC, in product development.

It is important that the producer takes the customers perspective into account early. During the value identification phase, the producer should include customer ability for revenue during the product's life cycle as one variable. It should be balanced with other performance characteristics and LCC. This should then be included in the value proposition that is the basis for value delivery.

A decision support model for facilitating decision making during the value delivery phase process should be based on the value proposition. A clear interface between customer demands and system demands enables such demands to be followed up and prioritized. During the design of the system architecture it is important to enable follow-up of the effects of design changes. All of these steps have to be iterated during the maturation of the design process. Communication of such information throughout the project is essential.

Design methodology that takes the maintenance perspective into account and includes technology development speed for different components of the design could lead to improvements enabling upgradability of the product through its life cycle. Further communication of the importance of life cycle issues with the implementation of supporting methods and processes on a simple enough level could lead to effects for products with a long life cycle that are comparable with the quality movement in the industry.

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