Life Cycle Cost Assessment of Maritime Command and Control Systems

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Abstract

Life cycle cost (LCC) analysis and modeling constitutes the process of evaluating alternative C2 systems in terms of life cycle cost figures of merit. Such an evaluation activity commences as part of the early decision-making process in conceptual design and extends throughout the subsequent design and development effort leading to an operational system. The LCC model will be used as a tool in the decision-making process.

The cost analysis covers the tangible parts of the C2 system, called the C2 system structure, that is personnel, equipment and facilities. The LCC calculations give the analyst an important boundary concerning the assessment process, as there are fewer boundaries to solutions on the technical side of the C2 system. This economical boundary is real in every case of the restructuring and will therefore give guidance to what one could include in the C2 system of technical solutions and how the organisation will be effected by these changes.

The paper discusses the economical aspect of the development of a future maritime command and control system and will give an overview of the analytical approach chosen.

1. Introduction

The Norwegian Defence Research Establishment (FFI) is involved in a project addressing the development of maritime command and control (C2) systems. The work is based on cost effectiveness calculations of alternative C2 systems. This paper covers the life cycle cost (LCC) calculations which is one of the two main components in the ranking of alternative C2 systems and often the one limiting the possible choice of technology. The assessment of C2 system's effectiveness, which is the other component, will not be covered in this paper. For those who are interesting in the method for determining the cost effectiveness of C2 systems see [Malerud, Feet & Thorsen, 1998]. Another paper addressing the C2 system effectiveness is [Malerud, Feet,

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Enemo & Bråthen, 2000] which outlines a method for establishing appropriate and quantifiable measures of merit (MOMs) for assessing the performance and effectiveness of maritime C2 systems in different scenarios.

It is important to recognise that there are budget constraints in defining C2 systems. There is a huge availability of highly efficient C2 system components, and the main challenge is often to design a system with the right mix of components within a given budget constraint. Since C2 systems are recognised as a critical force multiplier, focusing on cost as well as efficiency and effectiveness can enable the decision makers (responsible for procurements) to make choices between C2 systems and other force components, e. g. naval vessels and weapon systems.

The LCC analysis needs to be based on a definition of a program plan and profile illustrating major life cycle activities and the projected operational horizon for the system. Establishing these definitions has been an important part of the whole LCC process. These are to a great extent based on the current maritime C2 system.

The first stage of the C2 analysis describes the maritime C2 system as it is today. This system description forms a template for the description of alternative C2 systems. To ensure that the C2 concepts defined are related to the operational concept and Navy's mission, a top–down approach is applied.

There are several reasons to describe the "as is" system in detail. The most important reasons are to use today's maritime C2 system as a reference to compare alternative systems against. The description of the current maritime C2 system comprising description of personnel, equipment, methods and facilities organised to accomplish C2 of maritime operations.

2. **Model building**

The most important question when planning to build a new LCC model is the purpose of the model. The answer to that question will have great effect on what a successful model would look like in each particular case. For instance; If the model is going to be a managerial tool to be used on a daily basis over the whole period, it will certainly have to be very detailed and user-friendly. On the other hand, if the LCC model will be used to estimate (in the budgeting process) the costs of maritime C2 systems, the LCC model is much simpler. This question has been the most important determinant in fitting the right LCC model to the maritime C2 systems.

In our case, a model was established to get an overall estimate over a twenty years analysis period (1999-2018) as an economical constraint for the development of alternative C2 systems. In addition, the model needed to be flexible in how the data were described, because the data format was not yet determined. In addition to that, the model should be capable of doing the cost analysis (that means give us some LCC merits to use in benchmarking the "as is" system against alternative C2 systems) which would be required in the assessment process. This is an important requirement for the LCC model, as the main goal is to design a cost-effective maritime C2 system. This top-down approach ensures that the model is suited for the particular assessment.

2.1 *Cost classification*

The cost classification process determines how cost is represented in the LCC model. We have chosen to build three separate cost databases for personnel, equipment and facilities, respectively. Prior to the cost calculation, an extensive survey and organisation of the cost data for all the three databases was carried out.

In order to understand the methodology used to establish the LCC model it is necessary to have a basic knowledge of the structure of the database. The LCC model was implemented in a spreadsheet environment, and was mainly composed of two hierarchies:

- The personnel hierarchy; the structure used in describing where the personnel is located in the C2 system and how detailed personnel are specified in a given military unit.
- The equipment hierarchy; the structure used in the LCC model to describe the equipment which are part of the C2 system and how the costs are aggregation to subunits and military units.

The model hierarchy is based on the early design process where the main goal of the analysis is outlined. The structure of the equipment hierarchy is shown in figure 2.1.

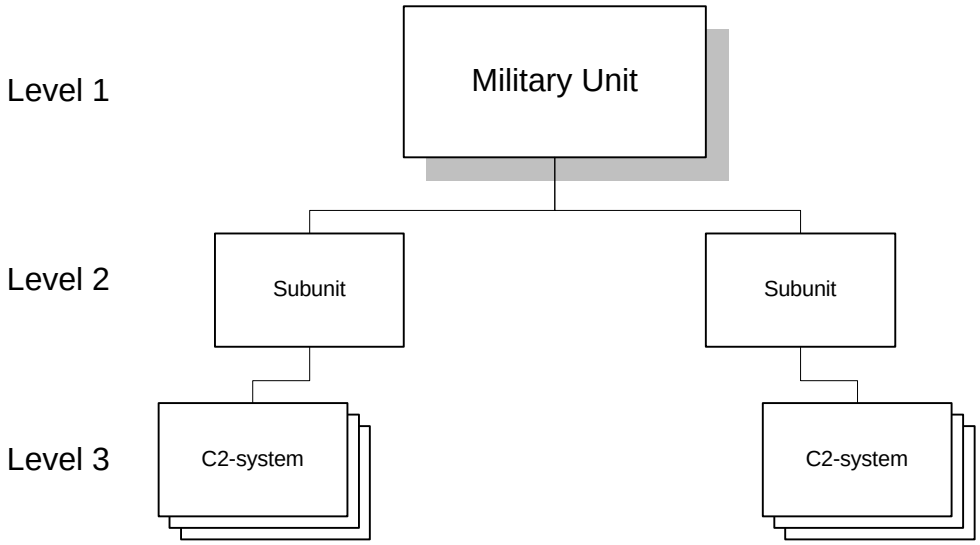

Figure 2.1 A visualisation of the equipment hierarchy.

The top level is the military unit, which for instance could be a frigate, a headquarter, a shore based radio station, etc. At these top levels the cost related to construction of facilities is given explicitly and not distributed down the hierarchy, as is the case for personnel and equipment.

The mid level of the hierarchy is subunits, which are included because of requirements to give detailed descriptions of the costs of one military unit. An example of the mid level could be the subunit in a Naval operation centre. Typical subunits are all the different cells in the naval

operation centre. The reason why we included this level in the hierarchy was the ability to present data in different subunits inside the C2 organisation.

The third and the lowest level in our hierarchy is the C2 system components. The cost estimates are explicitly specified at this level for the whole analysis period. The cost estimates consists of the following parts:

a) Annual investment costs for the C2 system components

b) Annual cost of upgrading the hardware and software for the C2 system components

c) Annual maintenance costs, which only include material-related costs. The maintenance costs do not include the personnel expenditures.

It is possible to describe the cost of the C2 system much more detailed than is chosen here, but from our point of view it will not contribute to our main goal. The main task is to use the LCC analysis as an assessment tool to evaluate and rank alternative maritime C2 structures and not as a managerial tool on a day to day basis.

The personnel hierarchy is organised in the same manner as the equipment hierarchy, but has only two levels. The two levels are military units and different personnel categories. Personnel data consist mainly of wages to the personnel (included overtime wages and overhead rate to the maritime personnel) and costs related to services given to military personnel.

2.2 *Cost calculations*

The cost calculation model is implemented in MS-Excel. In this model we may choose to calculate costs at different levels in the hierarchy. The costs are calculated over the period 1999 – 2018.

The model does also include the financial source of each particular investment cost, maintenance cost and updating cost. The model has to track the financial source because the cost data are given by several institutions. Calculations can then be sorted by financial sources in order to show the institution that is responsible for the different C2 system components.

2.3 *Results of the LCC analysis*

The output from the model may be a graphical representation of the total costs in different time periods or a matrix of costs, classified by personnel, equipment and facilities for different time periods. The results are presented as LCC figures of merits and will have several important implications in assessing the future C2 system.

3. **Data collection and system boundaries**

There are challenges related to defining the C2 system structure and to establishing the system boundary. This is for instance the case for C2 related equipment and personnel in ashore headquarters and afloat operation rooms, coastal radar stations, radio stations, coastal artillery forts, naval vessels, etc.

An important issue is how the system boundary is drawn in relation to personnel and joint equipment. Personnel involved in the C2 process often have additional roles besides command and control, and it is therefore necessary to determine how the C2 system boundary is defined in relation to personnel. We have chosen to include all the personnel who are engaged in C2 activities, but other classifications are possible as well. However, if the main goal is to study the personnel which is variable with respect to C2 processes then personnel that only has C2 roles should be included. The system boundaries are actually controlled by the nature of the study. To establish the appropriate system boundary is a major activity in the LCC analysis.

It is also important to reflect on how the costs of joint C2 components, which often is a part of maritime C2 systems, are included in the cost estimates. The maritime part of these systems are outlined by a definition process involving discussions with key personnel from the headquarters, naval defence staff and departments responsible for the development of each C2 system components.

The LCC analysis of the maritime C2 structure addresses the problem with data collection, which is a major part of any LCC analysis. Our experience is that the data is not available from one central source, but can be found in several institutions. This situation gives the analyst challenges on how to organise the collection process and how to represent the costs in the model. The best approach is probably to make the cost data as simple as possible and to involve the departments responsible for the development of each C2 system component in defining the cost development through the period 1999-2018.

4. **Assessment examples and results**

The LCC analysis shows how different parts of a C2 system, e.g. communication systems, sensor systems, information systems, command support systems, etc, are ranked from an economical point of view. Additionally, the LCC analysis results in cost estimates of personnel, equipment and facilities are given. The results of LCC analysis of the current maritime C2 system indicate, not surprisingly, that personnel are the most costly part of the C2 system. This leads to considerations about how to release more funds in order to fulfil the main goal of the military as a whole, which is to reduce the operating cost substantially. The use of the LCC figures and merits will help us to evaluate where the operating costs can be reduced substantially through restructuring the C2 system structure.

The results presented below are not meant to give the reader detailed conclusions of the LCC analysis from using our LCC model. The main objective is to show how results can be presented. The example given is a calculation of the equipment cost related to certain C2 system

components. By following the cost classification procedure as presented in chapter 2.1, the cost can be divided into three groups and shown as in figure 4.1.

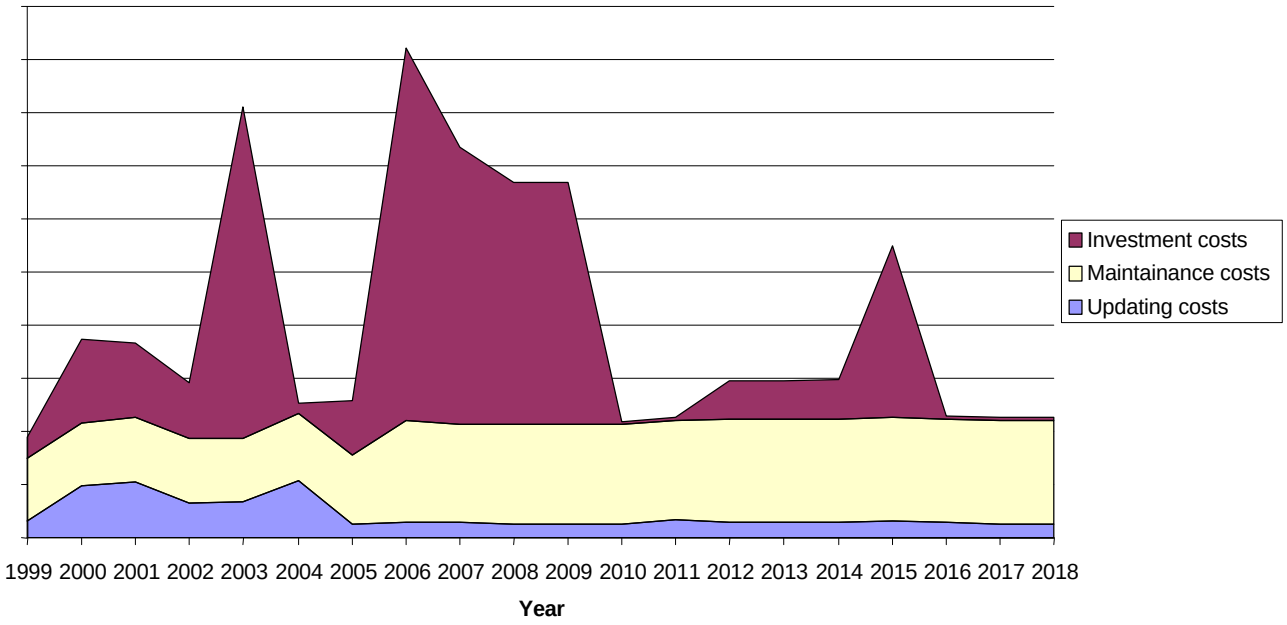

Figure 4.1 An example of costs presentation in the LCC model.

The figure shows how the costs of C2 equipment develop through the period 1999-2018 concerning investment costs, maintainance costs and updating costs. As we can see from figure 4.1, the C2 investments fluctuate much. The reason is that the procurement of new navy vessels in the period of analysis is planned and a share of the costs of the combat systems (the system which include C2 system components) is included in our definition of the maritime C2 system. The updating and maintainance costs are relatively stable over the period of analysis.

A LCC analysis of maritime C2 systems differs in many respects from traditional LCC analysis. The LCC analysis shows that the cost estimates, especially the costs related to updating, does not fluctuate much from year to year. In a traditional LCC analysis costs consist of one large initial investment, then a midlife update in the middle of the period and then salvage costs at the end of the period. This is not true for C2 systems. A C2 system is a system of systems, and the analysis shows that costs are distributed with an almost equal amount of money throughout any period, after the initial investment.

The LCC model could for instance be used to calculate how much money we can save by closing down the shore based radio stations in the mid period of our analysis or where in the C2 organisation we actually spend money today? The answers will often generate more questions, which can often be specified more in detail in a further LCC assessment. The LCC calculation can also be used to compare military units and C2 systems components with each other and assess the different mixes.

5. **Conclusions**

As shown in the paper, a LCC analysis is an important part of the process of evaluating alternative C2 systems. Such an evaluation activity commences as part of the early decision-making process in conceptual design and extends throughout the subsequent design and development effort leading to an operational system. The LCC model is used as a tool in the decision-making process.

6. **References**

[Malerud, Feet & Thorsen, 1998]. *A Method of Analyzing Command and Control System*. Proceedings of the Command and Control Research & Technology Symposium, Monterey, California, 1998.

[Malerud, Feet, Enemo & Bråthen, 2000]. *Assessing the Effectiveness of Maritime C2 systems – Measures of Merit*. To be published in this proceedings, Monterey, California, 2000.