Chapter 3 – LIFE CYCLE COSTING IN THE PAPS PHASES

3.1 GENERAL

Most nations use their own standards and nomenclature for describing the life cycle of a project. In multi-national projects and documents for use in various national and multi-national contexts, a common standard is needed. The Phased Armaments Programming System (PAPS) provides such a common standard, approved and accepted by NATO nations. For this reason, the PAPS definitions of the life cycle phases have been adopted in this report. Accordingly, this chapter is structured along the lines of PAPS.

A short introduction to PAPS is given below, and the PAPS phases are described in Section 3.2. The following sections describe the method and application of life cycle costing techniques that are appropriate to each of the PAPS phases. Note that Section 3.6 is devoted to programmes where a system is bought rather than designed and built.

For consistency, each section covers:

- A summary definition of the phase as given in PAPS.
- The life cycle costing inputs and outputs expected from that particular phase.
- An illustration of the benefits that life cycle costing studies can bring in this phase.
- The types of life cycle cost analysis that can be conducted in this phase.
- The life cycle costing methods that can be employed in this phase.
- An example to illustrate the use of life cycle costing in this phase.
- The process to be followed for conducting life cycle costing in this phase.
- A method for assessing risk at this phase.
- References where further information can be obtained.

The PAPS life cycle phase definitions are used in this report because they constitute an internationally approved standard. National and other standards differ from these, however. In order to find the section(s) in this chapter relevant to a given phase in a project or programme using different terms and definitions, it is therefore necessary for the reader to first "translate" these to the equivalent PAPS phases.

For the nations contributing to this study, the relationship between national standards and PAPS are already provided in the information matrices shown in Annex A. Furthermore, an international standard for dividing the life cycle into stages exists, defined in the international standard for system life cycle processes, ISO 15288. A short description of this, including a description of the relationship between the PAPS life cycle phases and the ISO 15288 life cycle stages, is provided in Section 3.10 of this chapter. These may also serve as inspiration to readers using other standards.

3.1.1 Make or Buy

The PAPS covers the life cycle of a programme from identification of a need for a new capability through specifications, design, production, use and eventual retirement of the system. It is general enough to cover most national and other life cycle models for this type of programme. However, in many defence organisations, particularly in smaller nations, the typical life cycle of weapons systems and other materiel systems is substantially different, because systems are bought rather than designed and built. This has wide implications for the whole life cycle management process, including life cycle costing, especially in some of the earlier phases of a programme.

In essence, buying a system involves a choice between relatively few, clearly defined and well described and documented alternatives, informed through a process of market research. In contrast, designing and building a system from scratch means choosing a solution from a practically infinite number of possibilities through a process of design, development, and manufacture. These differences have important implications for life cycle costing with regard to the process and method to be followed, the data available and the desired results.

Hence, the difference of a "buy" programme from a "make" programme as described in PAPS is so great that it warrants a special treatment. This is given in Sub-section 3.2.9 which covers the decision between building or buying a system, and introduces an alternative "procurement" phase to replace the "design & development and production phases" in the case where the decision has been made to buy a system. Section 3.6 covers life cycle costing in this alternative "procurement phase".

3.1.2 PAPS Background

The handbook on PAPS was published in February 1989 as AAP-20 (Allied Administrative Publication) by Defence Support Division of NATO International Staff.

The stated overall objective of PAPS is "to provide a systematic and coherent, yet flexible, framework for promoting co-operative programmes on the basis of harmonised military requirements". It is further stated: "The philosophy behind the PAPS concept is straight forward".

There is a finite and fairly consistent number of points (milestones) in the life of a weapon system programme when the nature of the programme changes. At these milestones, decisions must be made regarding alternative courses of action. PAPS is intended to provide a structured approach to aid decision-making at these milestones for all management levels involved in co-operative Research & Development and production programmes within NATO.

PAPS is primarily intended for use in a multi-national weapon system procurement programme in a NATO framework, involving two or more nations working together to fill a common capability gap. However, the principles laid down in PAPS are applicable to national programmes as well, especially since it is repeatedly emphasised that PAPS should in any case be adapted to the conditions of the individual project.

Though the main focus is on the milestones, PAPS also describes the phases between the milestones, thus dividing the life cycle of a system into separate well defined phases. An overview of these phases and the milestones that separate them is provided in Figure 3-1, short descriptions of the phases are provided in Section 3.2, while descriptions of the milestone definitions are found in Annex E.

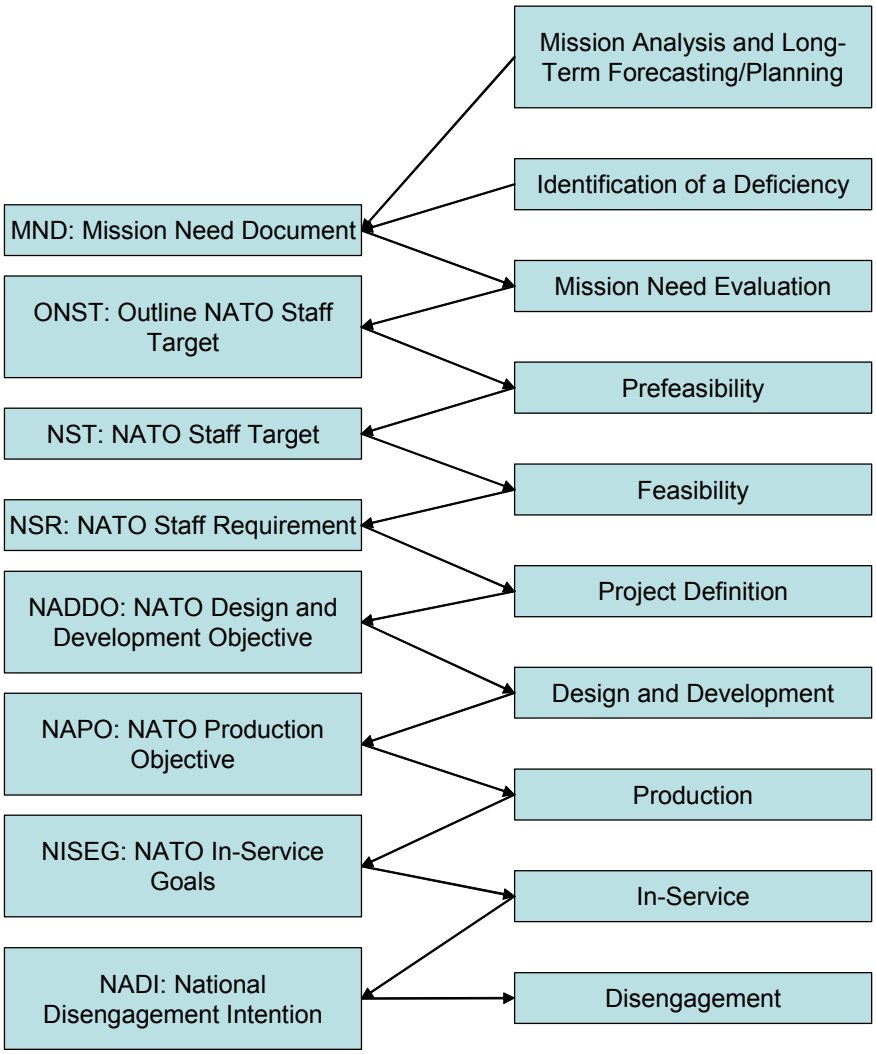

Figure 3-1: PAPS Life Cycle Milestones and Phases.

3.2 PAPS PHASES

The following descriptions of the life cycle phases have been drawn directly from AAP-20.

3.2.1 Mission Need Evaluation Phase

A statement based on a mission analysis, identifying in broad outline a quantitative or qualitative operational deficiency that cannot be solved satisfactorily with existing or planned forces and/or equipment.

3.2.2 Pre-Feasibility Phase

The work in this phase will determine whether or not the Outline NATO Staff Target merits a deeper feasibility study. It is conducted either by industry and/or government agencies, or by NIAG (NATO Industrial Advisory Group). Its aim is to examine the proposal, assess the trade-off points and make a broad assessment of the practicable alternatives and also the penalties involved in adopting certain courses of action. This study should establish the feasibility of suitable solutions consistent with the timetable of needs. The pre-feasibility study will result in the establishment of a NATO Staff Target.

3.2.3 Feasibility Phase

A feasibility study is carried out by industry or government agencies or a combination of both with the object of providing a technical appraisal of the feasibility of developing and producing an equipment with the performance required by the NATO Staff Target. The study identifies areas of technical risk, recommends characteristics of the system(s) and gives the optimum balance between performance, cost and development time. The study also indicates areas where considerable advances on the existing state of knowledge are likely to prove necessary for successful development. It also indicates the means by which the recommended solution will be achieved, suggests a programme for project definition, development and production, with a preliminary estimate of the costs for these stages. The feasibility study must result in the establishment of a NATO Staff Requirement.

3.2.4 Project Definition Phase

This is the process of thoroughly exploring all aspects of the proposed project and to examine the relationships between the required performance, development time and cost. The areas of technical uncertainty are examined and possible trade-offs are evolved in order to achieve a satisfactory balance between performance, development time and cost. These trade-offs may lead to amending the operational requirement. From then on, performance requirements and detailed requirements regarding the technical characteristics are established so as to meet the operational requirement under the best conditions.

These requirements will form the basis of the establishment of a development programme and of more detailed and realistic estimates of development time and cost. The overall results of the studies carried out during project definition will be used for the discussion on whether to proceed with the development or not.

3.2.5 Design and Development Phase

This phase of a programme calls for design engineering work aimed at full validation of the technical approach and ensures complete system integration to the point where production contract action can be taken.

The design and development phase embraces all activities from the preparation of the development contract to the approval of the equipment as ready for introduction into service. During the course of this phase, the configuration of the equipment is gradually improved. Factory trials are carried out to evaluate the results of the design and development activities as far as technology and economics are concerned.

The engineering work comprises prototype production and technical evaluation trials to determine the technical capability of the complete system. The subsequent user trial is designed to test the material under realistic conditions. The criteria are tactical mission, military requirements and easy maintenance and repair.

At the end of the phase, the design status for the manufacture of the equipment is determined on the basis of statements about technical readiness and field operability.

A unanimous agreement is required in the steering committee on all provisions, especially operational characteristics, financial commitments, agencies involved, follow-on measures, and industrial involvement.

3.2.6 Production Phase

The production phase has been defined as: the manufacture of a system, sub-system or equipment in a plant or factory using series (i.e. full-scale) manufacturing techniques.

The production phase embraces all measures taken to initiate and carry out series production of equipment in accordance with the operational requirements and the final development specification up to delivery to depots or unit stores. At the beginning of the phase a production contract will be concluded by the management office, established by the NPSC (NATO Project Steering Committee).

By this stage, a statement should be obtained from the Steering Committee on the logistics support and training arrangements for the equipment. Whenever possible and appropriate, common logistics support (including the option of the NAMSA (NATO Maintenance and Supply Agency) and/or training arrangements should be established.

During this phase several activities aiming at full logistics supportability have to be pursued by the management office, such as:

- Production Control.
- Quality Control.
- Acceptance Trial.
- Codification.
- Configuration Control.
- Modification Trials.

3.2.7 In-Service Phase

This is defined as the operational utilisation of equipment by nations. The in-service phase embraces the totality of activities aimed at maintaining or restoring full serviceability of the equipment. It includes procedures and trials concerning introduction of modifications.

3.2.8 Disengagement Phase

This phase encompasses the withdrawal of equipment from operational utilisation in accordance with the NADI (National Disengagement Intention).

3.2.9 Alternative Procurement Phase (Make or Buy Decision)

The NATO PAPS phases describe the process to be followed in developing and procuring a new system in order to fulfil a capability gap. However, at some point in the NATO life cycle the decision has to be made either to develop a new system or to procure an off-the-shelf new system. In practice, this would be one of the options to be considered. Figure 3-2 shows that in the case of a traditional development programme (make track) all the NATO life cycle phases can be followed. Alternatively, in the case of acquiring a new system (buy track) some phases from the NATO life cycle will be replaced by a procurement phase to allow for a direct acquisition. The figure provides a simplified overview of the PAPS NATO life cycle phases for a make or a buy decision. It is always possible to go to a procurement phase from any phase in the PAPS process. However, the most suitable moment to decide on a buy decision would be after the project definition phase.

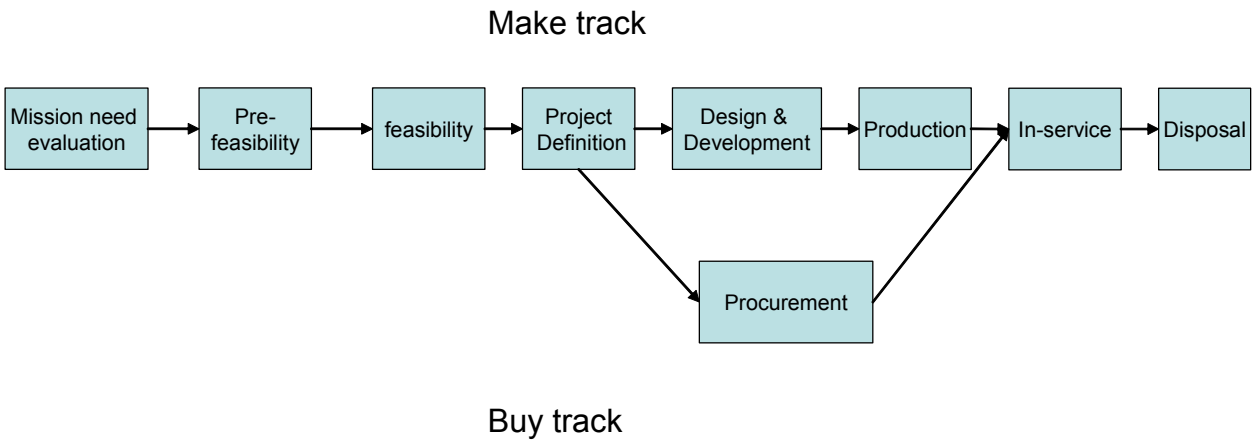

Figure 3-2: Make or Buy Track PAPS Life Cycle.

A procurement phase may replace the design & development and the production phase. A more detailed description of this phase can be found in Section 3.6.

3.3 MISSION NEED AND PRE-FEASIBILITY PHASE

3.3.1 Summary Definition of Phase

This phase is to determine the operational capabilities of military forces that are required to carry out assigned missions, roles and tasks. A comparative assessment is conducted to identify any deficiencies that may be related to the element of risk required. This process is then followed by a pre-feasibility study to examine the practicable alternatives and establish the feasibility of suitable solutions consistent with the time-table of needs.

The pre-feasibility phase is arguably the most important phase in a programme. It is where decisions are made when the amount of supporting information is at a minimum.

3.3.2 Inputs

Equipment programmes come into existence as a result of work to identify capability gaps[1]. These studies address the extent of the capability gap, the numbers of equipment or types of platforms required and the technologies that can help to fill the gap. A capability gap will trigger the requirement to conduct a balance of investment to consider a 'strategic fit' in a wider context. Several options will be included here including a 'Do Nothing' or 'Do Minimum' options on legacy systems as well as conducting a thorough evaluation on the benefits of procuring new and novel systems. At this phase in the life cycle it is unlikely that the costs can be identified in a great deal of detail, rather an understanding of the total programme costs and the uncertainty surrounding these estimates is required.

Since cost and performance data are likely to be immature care should be taken to avoid new conceptual proposals being given unwarranted advantage in comparison with those that have been more thoroughly explored. For this reason, the processes employed to support and undertake the balance of investment normally embrace the following:

[1] NATO Capability Based Planning: SAS-057, SAS-063 and AC/327 SG b WG 1.

- Qualitative approaches that exploit the judgement of military and technology subject matter experts who will draw on operational evidence and technology application opportunities.
- Quantitative approaches that will employ mathematical modelling of physical system behaviour (principal measurable attributes) within the context of representative operational or business situations.

To support the activities above, a systematic, rigorous and auditable process needs to be adopted. This process will be supported by the Outline NATO Staff Target document and an outline CONOPS (Concept of Operation) statement from the NATO project steering committee. Cost models that provide a holistic (e.g. whole) estimate of cost and time are essential for this phase. The cost models should also provide the estimates with defined confidence levels and have the ability to provide a 'what if' capability.

3.3.3 Outputs

The outputs from this phase should indicate which of the options are feasible and affordable (see also Section 2.9) and should be taken forward for further study. The life cycle cost estimates should support the refinement of the NATO Staff Target.

3.3.4 Life Cycle Cost Benefits

Life cycle costing at this phase is conducted at a very high level and is used to demonstrate the relationships between performance (e.g. fleet mix/sizes), procurement policy and life cycle costs. This will ensure that all the issues associated with the alternative solutions are considered and evaluated on a through life basis.

3.3.5 Types of Life Cycle Cost Studies

The types of costing studies being conducted at this phase are predominantly restricted to high-level balance of investment, cost benefit analysis and cost-effectiveness studies utilising the life cycle cost as one of the measures. Typical examples of these applications are given at Sub-section 3.3.9. All these studies are usually supported by Operational Analysis to establish needs and numbers and performance measurement criteria.

3.3.6 Methods Employed

The life cycle cost estimates derived during this phase usually employ Bayesian, Parametric, Analogous, Expert Opinion, or Rule of Thumb techniques. A description of these methods is given at Chapter 4. These methods are well established and can provide a holistic estimate to meet the requirements of the study. However, care should be exercised when considering an analogous approach. To avoid error, it is essential that all comparison using analogy is conducted on a 'like for like' basis. Therefore some normalisation of the source platform/system/equipment is likely to be required. As in this phase only limited quantitative information will be available, also decision support methods or simulation methods like system dynamics can be used.

3.3.7 Life Cycle Costing Process

Figure 3-3 provides a simple illustration of the life cycle costing process. It shows that at this PAPS phase the source data to support the life cycle costing is likely to be immature. Therefore a greater reliance on the types of data sources indicated should be expected. In addition, there will be a high level of assumptions in terms of the likely performance/design parameters of the systems being evaluated. Risk is likely to be measured in a more qualitative rather than quantitative manner.

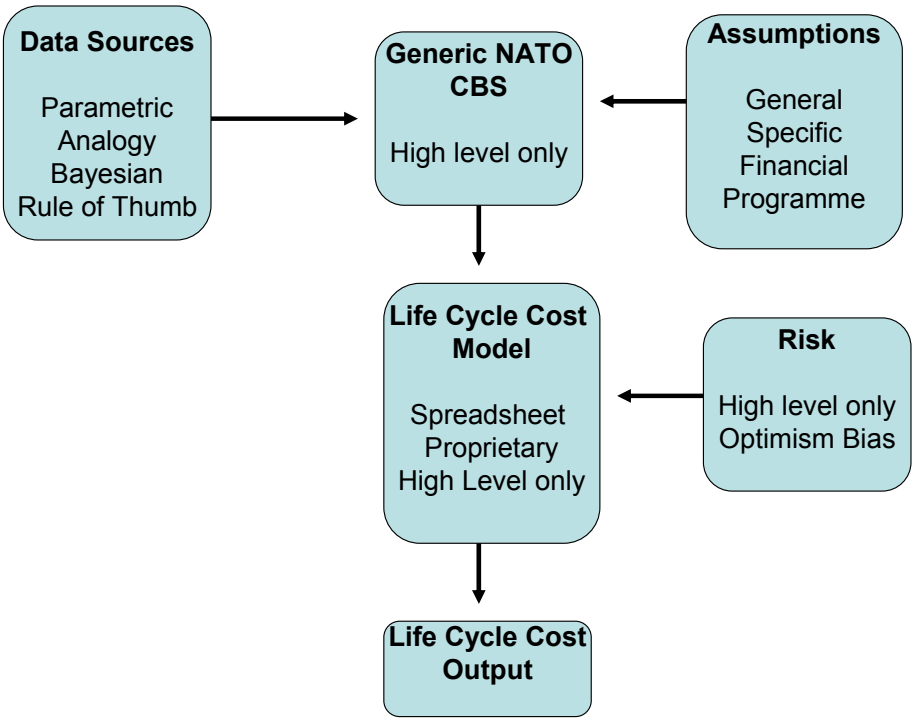

Figure 3-3: Simplified Pre-Feasibility Phase Life Cycle Costing Process.

It should be expected therefore that the life cycle cost output will be an understanding of the total programme costs and the level of uncertainty surrounding them. In summary, the key considerations to the life cycle costing process for this phase are:

- The principal data sources are likely to be parametric based and for speed and ease of use a commercially available cost estimating model is likely to be employed.
- There will be many ground rules and assumptions to be recorded and assessed.
- The risk will be measured at the very top level probably utilising some high level risk register or optimism bias technique (a detailed description on risk analysis is given at Chapter 7).
- The life cycle costs are likely to be reported at the principal cost element level of the generic NATO CBS only as shown in Figure 10-1, but probably analysed at a slightly lower level of granularity.

3.3.8 Risk Assessment

During this phase the identification of risk will be conducted at a very high level. It is likely to be a combination of single line statements and will probably contain a mixture of issues as well as risks. The cost analyst will need to distinguish the difference between them in order to ensure that only the relevant applicable risks are to be included in the cost estimate.

Where there is no risk register or risk record, an optimism bias technique can be employed. Here it could be used to redress over optimistic tendencies by making empirically based adjustments to the cost estimates (this technique is explained at Appendix A to Chapter 7).

At the very minimum, the life cycle cost estimate produced at this phase should include or indicate the level of financial risk exposure.

3.3.9 Examples

The following sub-sections demonstrate three alternative applications that are traditionally employed at this phase. These are: Balance of Investment, Cost Benefit Analysis and Cost-Effectiveness assessment.

All the cost estimates for the examples shown were conducted using a Bayesian estimating approach. This approach was adopted because:

- No suitable analogies were available without substantial data normalisation thus introducing a large uncertainty into the source data to be used for generating the CERs.
- No design data was available to establish nominal or realistic historical based CERs.

The utility of this approach may be illustrated further by considering the evolution of a programme. At its earliest stages, prior to any design or development work, estimates of design characteristics supplied by the estimator cannot be anything but imprecise. Through the Bayesian approach, the technique will then rely upon the (more certain) design norms, which it generates. As design and development proceed more certain information will become available to the estimator for input and estimates will be based progressively more upon such data. When design and development are complete design characteristics will be known exactly. Further details and an example on the technique are given at Chapter 4.

To complete the studies the life cycle cost estimates were linked to a decision support tool to provide a two dimensional view of the options being evaluated.

3.3.9.1 Balance of Investment

Balance of Investment studies traditionally employ portfolio analysis techniques and are used extensively in industry and commerce to analyse component business units of a particular portfolio of activities. The approach uses a technique, here called Factor Weighting Analysis (FWA), in order to allow the user to compare the key characteristics of each activity in comparison with other activities at the same level.

Portfolio Analysis has been very widely used in North America and Europe particularly in the private sector. Considerable research has been carried out to determine how it should be best employed and what benefits it confers to the user. Generally speaking, it is now an established part of strategic planning and management in the pharmaceutical and other high research industries. This technique is now being tested and used to evaluate and support investment strategies for defence portfolios.

Figure 3-4 shows an example of the results of a portfolio analysis. The diagram shows the estimated military value and risk of a group of weapon systems designed to counter enemy sea mines. These are all systems in the “detect, classify, and identify” sea mines category or portfolio. Bubbles are sized according to resources expended over a 16 year period. Resources in this case include the acquisition costs over a six-year period plus ten years of operating and support costs. Risk is an amalgam of assessed values of the challenge in developing, transitioning, and operating a system. Finally, the numbers associated with each bubble are return on investments or, roughly, expected military value divided by cost, or bubble size. Further details on the portfolio analysis technique can be found at Chapter 9.

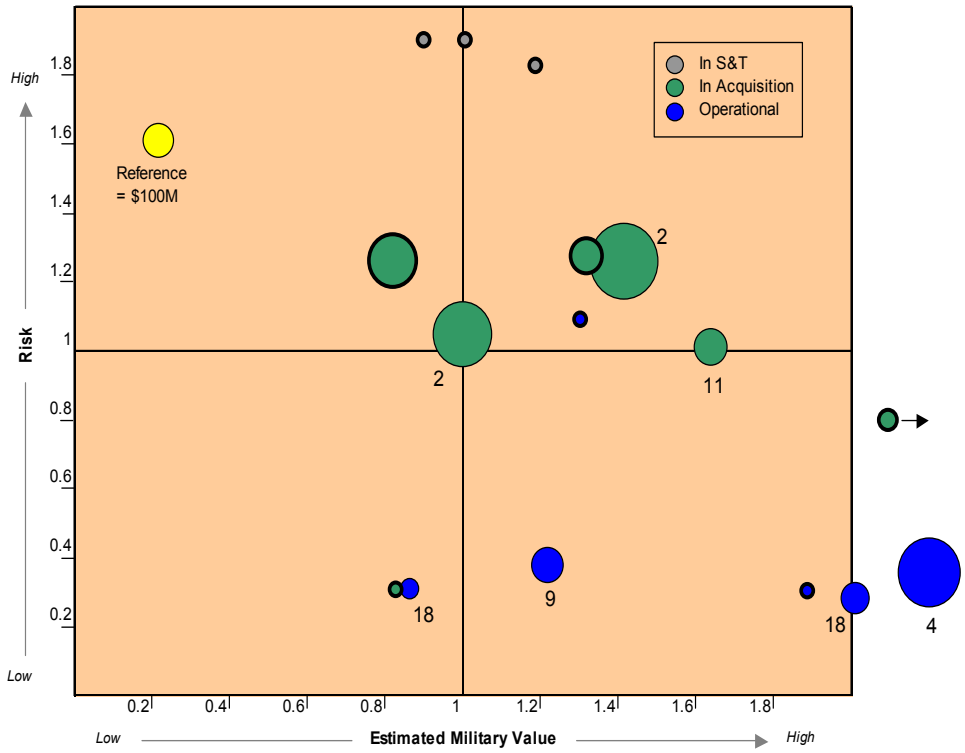

Figure 3-4: Military Balance of Investment Example.

3.3.9.2 Cost Benefit Analysis

Cost Benefit Analysis (CBA) is widely accepted as a vital support tool for economic analysis on defence programmes. It is primarily used:

- To assist decision makers.
- To provide transparency of issues.
- To quantify the effect of changes.
- To help in achieving national and multi-national consensus.
- To help to prioritise and compare projects.

A formal definition of an 'ideal' CBA might be:

> *"An objective study in which the costs and the benefits of a particular project's options are fully quantified in economic terms, taking full account of the times at which the costs are paid and at which the benefits accrue".*

Usually a CBA is conducted as a net present value analysis (see Sub-section 8.2.2.) by cumulating and discounting annual cash flows associated with a particular programme. On the basis of such an approach, summary statistics such as net present value, benefit/cost ratio, pay-off periods and internal rate of return can be determined.

In practice, things are not usually quite so straightforward. While costs and most types of benefits can generally be quantified after a little research, an economic breakdown of all the projected benefits can sometimes be more elusive.

The example shown at Figure 3-5 explores the benefits trade-off between live flying, synthetic training environments and aircraft in-service life in the provision of current and future heavy lift helicopter and light utility helicopter, rotary wing capabilities.

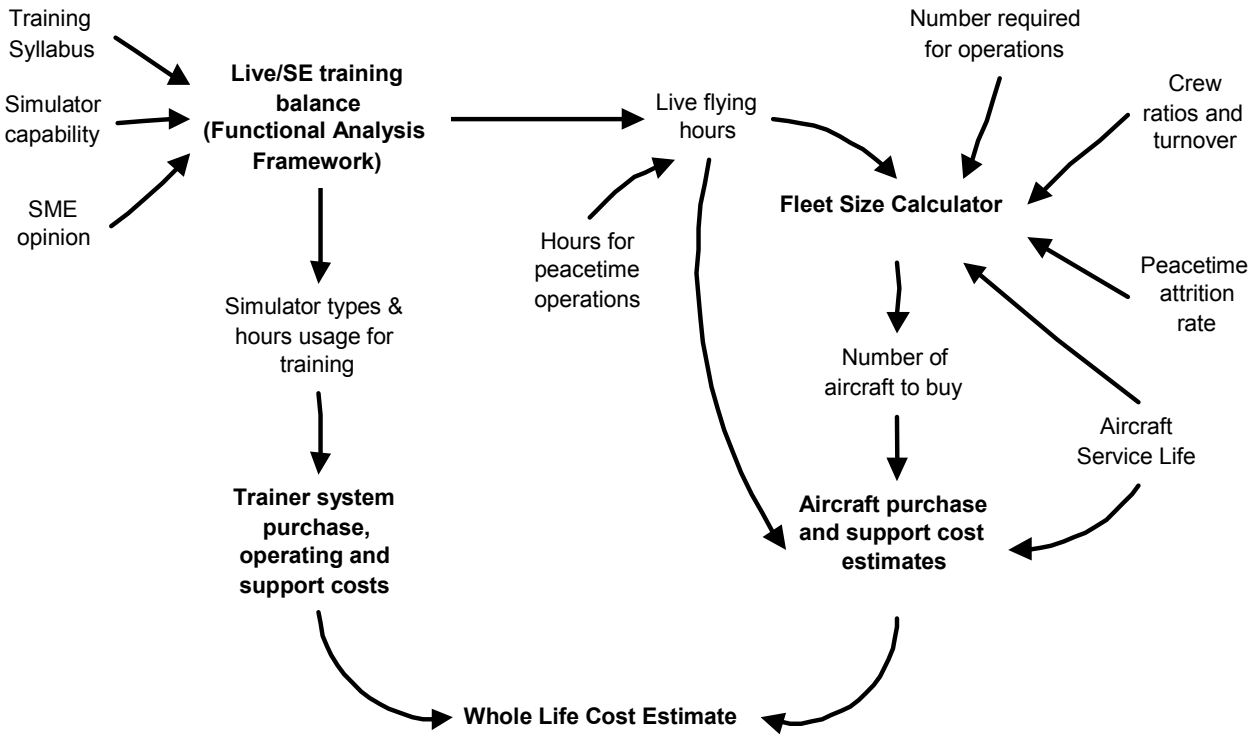

Figure 3-5: Benefits Analysis Example.

The figure presents a top level view of the influences affecting the whole life cost estimate. The items in bold text indicate calculation steps (and further influence diagrams) leading to the whole life cost output. Input data and intermediate data values are shown as regular text items.

In this instance the fleet size calculator, the functional analysis framework and the training system cost provide the study boundary and the mix of systems to be evaluated. The whole life cost estimates allowed the following analysis to be demonstrated:

- The most effective mix between the various aircraft and simulators.
- When to replace aircraft with simulators.
- The overall value of the return on investment.
- The timeframe of when the return can be expected.

3.3.9.3 Cost-Effectiveness Assessment

In the UK, this is typically referred to as a COEIA (Combined Operational Effectiveness and Investment Appraisal). Other nations may use different nomenclature, but in reality, it is the same type of analysis. The value of effectiveness is obtained by determining the principal attributes for MOPs (Measures of Performance) and MOEs (Measures of Effectiveness) and converting these to a single FOM (Figure of Merit). These provide the plots for the vertical axis. The life cycle costs (either constant or discounted) provide the measure for the horizontal axis.

Figure 3-6 illustrates a typical plot comparing performance and cost. The single value derived plots have been adjusted to allow for the uncertainty surrounding the weighting, scoring and cost. From these results the decision makers can choose which to take forward for further consideration.

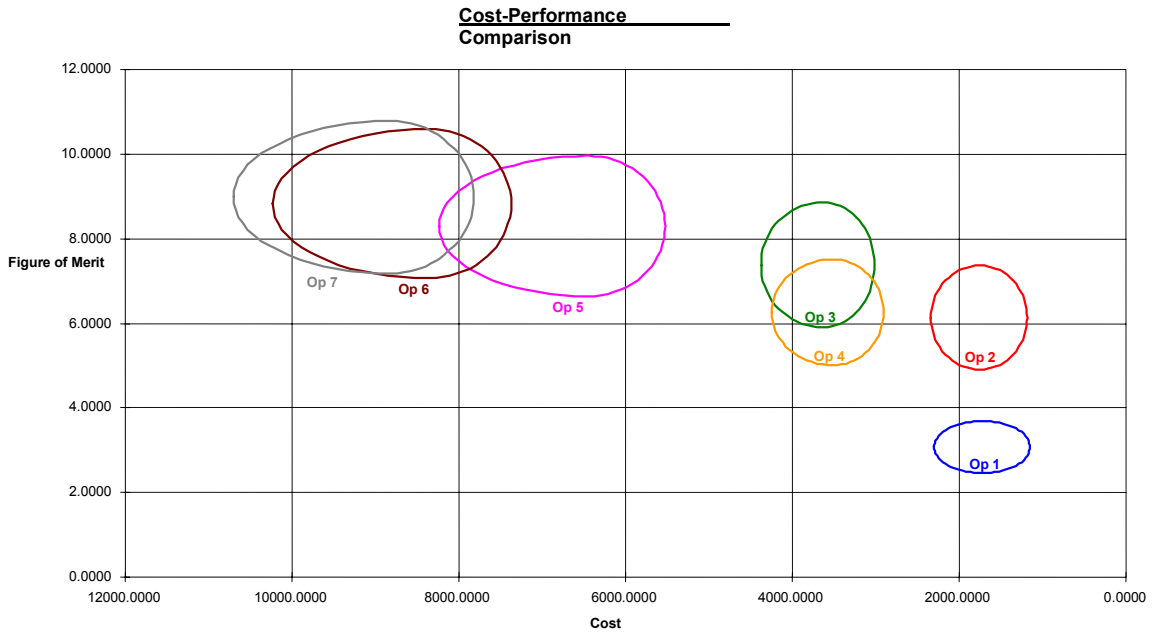

Figure 3-6: Cost-Performance Plot Example.

In this instance, Option 1 can be discounted as Option 2 provides better performance for the same cost. Option 4 can also be discounted as it provides the same level of performance as Option 2, but at larger cost. Options 5, 6 and 7 are significantly more expensive, but offer benefits in enhanced performance. Using this technique, the decision maker therefore has the means to be able to balance the level of acceptable performance with the cost available.

3.3.10 References

[1] UK MoD, General Instructions and Guidance on IAB and Delegated Approvals, Edition 8, March 2003, Annex F [unpublished MoD Documents].

[2] Decision Analysis for the Professional, Peter McNamee and John Celona (3rd Edition) – SmartOrg.

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[5] Pidd, M. (2004), 'Systems Modelling – Theory and Practice', The Management School, Lancaster University, John Wiley & Sons Ltd.

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[9] British Standard EN 60300-3-3:2004, Dependability Management Application Guide – Life Cycle Costing.

[10] HM Treasury Supplementary Green Book Guidance (Joint Service Publication 507).

[11] UK MoD, Operational Analysis – Foundation for the Business Case, November 2003, Director General (Scrutiny and Analysis) [unpublished MoD Documents].

[12] www.ams.mod.uk

3.4 FEASIBILITY AND PROJECT DEFINITION PHASE

3.4.1 Summary Definition of Phase

This is where a broad outline of the function and desired performance of new equipment or weapon system is assessed. These phases will identify 'candidate' system options and solutions and identifies areas of technical risk. All the studies conducted during these phases will give an optimum balance between performance, cost and time. This will result in the provision of a preliminary estimate for the life cycle cost of the overall programme.

3.4.2 Inputs

These phases will commence with an agreed and fully documented NST (NATO Staff Target). During these two phases, the project changes from a theoretical state to a much more concrete one. The objective of the phases is to produce the full definition of the future product from its specifications (e.g. a precise description of what it will be from what it is meant to do).

These are the most important phases from a cost forecasting point of view since many of the decisions will have a profound and lasting effect on the project and on its future costs. In fact, so many aspects of the eventual system and programme requirements will be frozen during these phases that most of the cost reduction possibilities are forfeited during these phases. It is therefore extremely important that a high quality life cycle cost estimate is constructed and updated during the whole duration of these phases and that it must be used to support the various decision making processes. Typically, the following decisions are taken during these phases:

- The type of technology and material required to build the system.
- The type of contract and industrial structure (including future production rates, support modes and all smart acquisition related issues).
- The possible use of intermediate system introduction and incremental development.
- A strategy of how the system will be used and supported (e.g. ILS studies, etc.).

3.4.3 Outputs

The outputs from the feasibility phase will be a detailed NSR (NATO Staff Requirement) and, from the project definition phase, a NADDO (NATO Design and Development Objective). To complete these documents the life cycle cost estimates will be supported by industry data. Some design data will be

available. The life cycle cost estimates will be available at all the major line item level in the cost breakdown structure.

3.4.4 Life Cycle Cost Benefits

Life cycle costing is conducted at a much more detailed level than the previous phases. More information should be available on the system design and logistic support. This will make the life cycle cost and logistic support analysis much more substantive and meaningful.

3.4.5 Types of Life Cycle Cost Studies

The type of life cycle cost studies to be conducted during this phase varies according to the degree of precision required by the decision to be taken. In general, the costs become more precise and dedicated to some aspects of the programme as it progress in time. Typical examples of studies include:

- The evaluation of technological choices requiring an analytical description of the product, and the scope of the cost estimate may need to consider various sub-assemblies or even components within the whole system.
- Major procurement issues (depending on the proposed acquisition strategy) may require a much broader approach and necessitate expanding the costing boundary to include elements (e.g. facilities and personnel costs) often only considered at later phases in the programme.

When comparing different solutions, it is essential to verify that the costing boundaries (scope) considered in the life cycle cost estimates are consistent and that the capabilities provided are comparable. Particular note should be taken when no alternative solution is apparent. This would result in a decision to:

- Not to acquire the capability (which may have a political cost) or,
- To keep using existing systems (with, usually, increased in-service costs due to the need to overcome obsolescence or recover natural wear and tear).

In conducting life cycle cost estimates on multi-national programmes, great care must be applied to the assumptions of deployment. Although each nation may have slightly different deployment and supportability, for cost modelling purposes, a consensus should be agreed so that there is consistency in the life cycle cost outputs. In this way, optimised solutions can be evaluated to address both national and multi-national concerns.

3.4.6 Methods Employed

During the previous phases the life cycle costs would have been derived using a form of parametric approach with many assumptions. The risk assessment would have been conducted at a high level and, as expected, the overall level of uncertainty would have been significant.

During the feasibility and project definition phase the level of design detail available will be increased thus allowing for refinement of any parametric based estimate. This will be supplemented by information (e.g. system breakdown, component reliability, system maintainability, etc.) from industry and further information on the planned logistic support. This will allow a more detailed life cycle costing to take place and probably also using some optimization methods. Although in this phase more detailed information will become available, the method of analogy will still be used quite often employing in-house cost models. Also at this phase a detailed and fully quantified risk register should be available for conducting a cost risk analysis.

3.4.7 Life Cycle Costing Process

Figure 3-7 provides a simple illustration of the life cycle costing process. It shows that at this PAPS phase the source data to support the life cycle costing is likely to be more mature in terms of system engineering design therefore the total reliance on parametric approaches will be reduced, but the refined parameters should still be used as a sanity cross check. More data should now be available from industry and a more detailed population of the cost breakdown structure can commence. It should be possible to populate all the major line items in the cost breakdown structure.

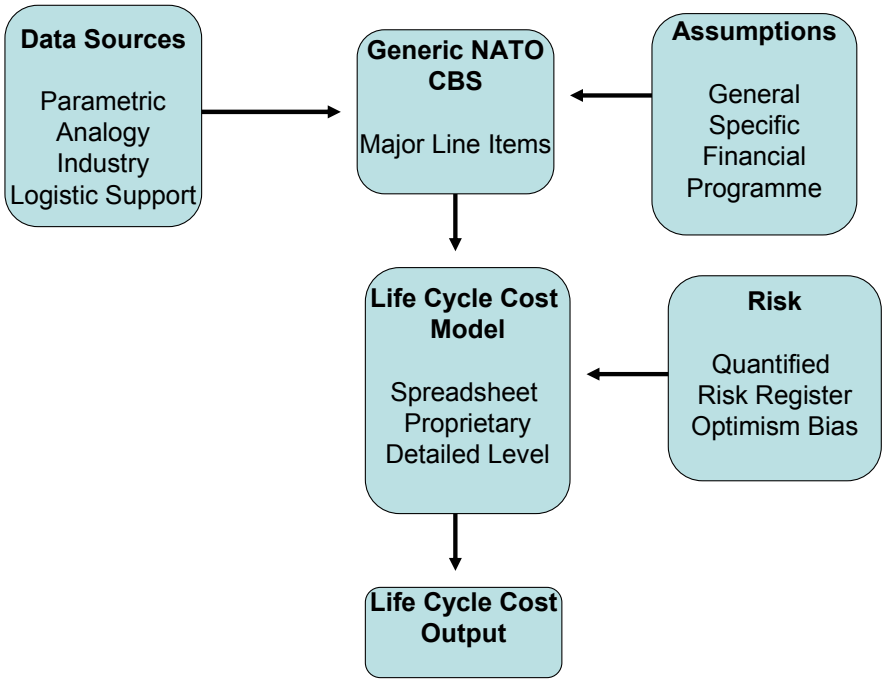


Figure 3-7: Simplified Feasibility and Project Definition Life Cycle Costing Process.

All the risks should now be captured and quantified within a risk register to provide the basis for conducting the cost risk analysis.

At the completion of this phase it should be expected that the life cycle cost output will be an understanding of the total programme costs (all major elements of the cost breakdown structure) and the level of uncertainty surrounding them. In summary, the key considerations to the life cycle costing process for this phase are:

- The principal data sources are likely to be parametric based and likely to be supplemented by information from industry.
- Some design data is likely to be available to refine the estimates and provide an initial baseline for the operating and support costs.
- The life cycle costing is likely to be conducted using in-house models and the results cross-checked and supplemented (if possible) using an alternative method. This provides two independently developed estimates to support the robustness of the life cycle cost estimate.
- There will be many ground rules and assumptions to be recorded and assessed.
- The risk will be measured at a reasonable level of detail probably utilising a quantified detailed risk register and cross-checked using an optimism bias technique.

- The life cycle costs are likely to be reported at the principal cost element level of the generic NATO CBS only as shown in Figure 10-1, but probably analysed at a slightly lower level of granularity.

3.4.8 Risk Assessment

In the feasibility and project definition phase a more detailed risk analysis will be conducted than in the earlier phase. The risk will be measured at as detailed a level as possible probably using a quantified risk register. If possible an optimism bias technique should be used. See for an overview of the optimism bias technique Appendix A to Chapter 7.

3.4.9 Example

As previously mentioned, this phase requires close, continuous collaboration between the research community, the user, and the developer as alternative technologies are assessed and as performance parameters are refined. As Figure 3-8 shows, life cycle cost estimates of alternative options are critical inputs in choosing the best future system or technology (Path 1 or Path 2, in this simple example) for meeting emerging war-fighter requirements.

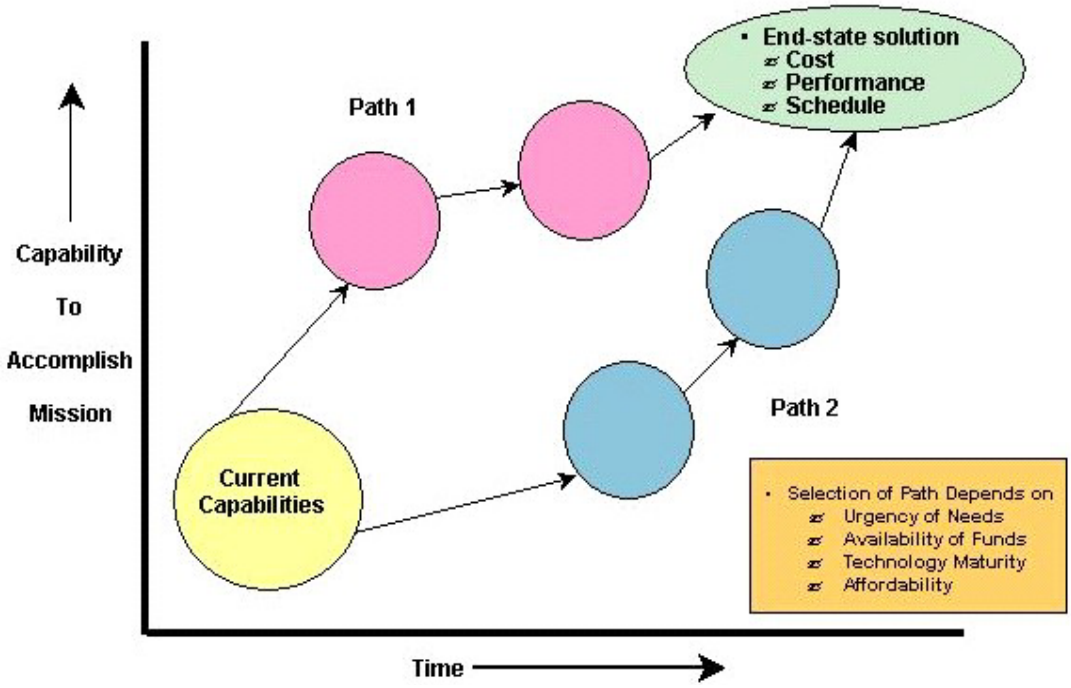


Figure 3-8: End-State Solution.

Given that several, different, potential technological solutions are typically examined, and given that user requirements are still very fluid, the method of choice for performing life cycle cost estimates in this phase is usually parametric. This allows for rapid analytical response to changes in technologies and user needs.

To take a concrete yet simple example (see Figure 3-9), assume a new satellite needs to be developed to detect stealthy enemy sea mines in very shallow water (VSW), in the littoral. The user community is unsure of their specific requirement concerning the size of enemy sea mines that it needs to detect. The range of user values is from one to three cubic metres. This requirement, in turn, drives the size and power of the sensor and, consequently, the size of the satellite bus and the number of thousands of sources

lines of code (KSLOC) to develop. Note that detecting a relatively small enemy sea mine requires a relatively powerful sensor and hence more lines of code and a bigger bus (to carry a bigger sensor).

CER Input Variables	User Requirements		
	A	B	C
Sensor Fidelity (size of sea mine)	1 cubic metre	2 cubic metres	3 cubic metres
Software (KSLOC)	250	150	100
Bus Weight (pounds)	1500	1100	1000

Figure 3-9: Example Sensor Fidelity to Software Size.

Three CERs are use to generate a cost estimate for development for each of the three cost elements:

- Payload (sensor)
  - Expected Cost = 3,568,510*(size of sea mine in cubic meters)$^{-0.87}$
- Software
  - Expected Cost = 435,216*(KSLOC)$^{0.91}$
- Bus
  - Expected Cost = 87,450*(Bus Weight)$^{0.79}$

Similarly, cost estimates for production and for operating and support are generated using parametric techniques. Finally, costs for each phase are rolled-up to produce life-cycle cost estimates for the three alternatives.

3.4.10 References

[13] Handbook on the Phased Armaments Planning System (PAPS), Allied Administrative Publication (AAP-20) PAPS, NATO Defence Support Division, 1989.

[14] UK MoD, Operational Analysis – Foundation for the Business Case, November 2003, Director General (Scrutiny and Analysis) [unpublished MoD Documents/Reports].

[15] www.ams.mod.uk

3.5 DESIGN AND DEVELOPMENT PHASE

3.5.1 Summary Definition of Phase

This phase of the programme calls for sufficient design engineering work to be conducted to ensure that full validation of the technical approach can be achieved. Also, the complete system integration is assessed to the point where production contract action can be taken.

3.5.2 Inputs

This phase commences with the NADDO (NATO Design and Development Objective) and is the phase where the earnest work on life cycle costing is performed. In this phase the design and development of the system being considered is well under way. An equipment, a system or a platform has been chosen and the

next step is to develop a final design and to choose a supplier. A lot of information from earlier phases may exist; in-house historical data, results from early tests and technical demonstration.

Ideally in this phase, a RFI (Request for Information) can be initiated and discussions can be held with several potential suppliers without commitment. This can provide several advantages. Information received from these contacts can provide a better understanding of the programme and introduce the opportunity to influence the life cycle costs by using market competition. The process also provides an opportunity to further develop the cost breakdown structure (greater transparency and higher precision). This approach to gaining data and information is also applicable in situations where only a single supplier is available.

In addition, the CONOPS (Concept of Operations) document should be used in conjunction with the ARM (Availability, Reliability and Maintainability) information provided by the supplier to refine the operating and support costs.

3.5.3 Outputs

On completion of this phase the life cycle costing will be sufficiently comprehensive and complete to support the NAPO (NATO Production Objective) and provide a realistic forecast of the likely total whole life cost.

3.5.4 Life Cycle Cost Benefits

The main purposes of life cycle costing in this phase are to:

- Influence the alternative solutions by evaluating the balance between life cycle costs and military capability.
- Support the system choice through using the results of the life cycle costing.
- Establish the logistic support requirements for the chosen solution to minimise the life cycle costs.

It is an established fact that many of the cost drivers are influenced by design decisions. The challenge for the system engineers is to balance the acquisition and support cost to provide the minimum life cycle cost. The life cycle costing activity plays a very significant role by providing data for systems engineering trade studies aimed at minimising the life cycle cost.

3.5.5 Types of Life Cycle Cost Studies

Entering the design and development phase concludes a decision to whether to make or buy a system off-the-shelf to meet the requirement capability. Since the design and development phase is a part of the “make track”, there is a relative large extent of freedom in designing the end product.

The types of life cycle cost studies to be employed can be described in many dimensions. A split can be made between:

- A life cycle cost analysis that aims toward costing the production and operation of the system(s), and
- Costing the alternative effects of introducing the system into the organisation in addition to or incrementally replacing the first.

Experience shows that up to 80 % of the life cycle costs relating to the system can be influenced in the design phase. This demonstrates that significant resources should be allocated to the life cycle costing work to be conducted during this phase.

The life cycle costing studies should be performed as an iterative process with each cycle providing greater levels of completeness, granularity and clarification. Any changes to the design should be aimed at minimising the life cycle costs whilst meeting all the desired requirements. The life cycle costing work should focus on both the principal system and all supporting infrastructure.

Cost savings are often found during this iterative cost estimating process. It is therefore essential that a thorough analysis of all the cost elements is conducted at this phase.

3.5.6 Methods Employed

There are no limitations to what type of methods can be employed in this phase. For example, engineering, parametric, and analogy are all still applicable and can be used to produce a life cycle cost analysis of high quality. It is often found that a combination of these methods is useful particularly when used together with expert opinion.

However, in order to provide a high quality input to these methods, a close working relationship will need to be maintained with the system design team.

3.5.7 Life Cycle Costing Process

Previous life cycle costing studies will have been conducted by government departments or their agents using a variety of methods, various assumptions and predictive system design data. At this phase it is appropriate to firm up as much as possible on the assumptions and predictions by gaining further information from industry. The major steps to developing the life cycle costing further during this phase are:

- Issue a RFI (Request for Information), based on the cost breakdown structure, to several prospective suppliers requesting all the data to support a life cycle cost study of their proposed system.
- Conduct a life cycle cost study to identify the key cost drivers, the costs that can be influenced and the costs that differ between the alternative solutions.
- Validate the system specification based on a cost/benefit analysis and the associated risk and uncertainty.
- Evaluate the life cycle cost analysis to support the procurement decision.
- Iterate the process to resolve any conflicts between system performance and cost.

Each of these 5 steps is described in more detail below.

3.5.7.1 RFI and CBS from Vendors – LCC Comparison

During this phase, it may be possible to have a dialogue with several prospective suppliers in order to gain information to support the life cycle costing process. This can provide a better understanding of their systems and increase the possibility to influence the life cycle costs by making the cost breakdown data more transparent and with greater precision. This approach is also applicable in situations where there is only a single supplier. By using this approach, different product designs can be assessed in terms of a minimum life cycle cost solution.

To enable comparisons between different product designs, it is crucial to ensure that the costing boundary is consistent. For example, using the same definition for personnel cost in the cost estimates given by the suppliers or ensuring whether the personnel cost has been included or not. The Operating and Support cost

elements should be determined using an agreed CONOPS (Concept of Operations) to highlight all the deployment requirements.

It is also essential to understand how the life cycle costing has been conducted by the suppliers and the models they have used to conduct the analysis.

A risk register together with a quantitative risk assessment should be provided by each of the prospective suppliers. This should be based the suppliers ability to meet the requirements detailed in the NADDO (NATO Design and Development Objective).

All the data and information gathered from the prospective suppliers should be benchmarked against empirical data either from internal or external sources. This should diminish the risk of a biased life cycle cost analysis.

3.5.7.2 Cost Drivers – Influencing the LCC

When receiving the completed cost breakdown structure from the prospective suppliers the focus of the life cycle cost analysis should be on identifying the major cost drivers and avoiding becoming embroiled with too much detailed data. The focus on major cost drivers is needed in order to reveal potential areas of product design changes that could have a significant influence in minimising the life cycle cost at the earliest opportunity.

The focus of the analysis should also be on the cost drivers that enable comparability between the different product designs. It is more crucial to reveal the cost differentiation between differing product designs than estimating the likely total cost.

3.5.7.3 Validate the System Specification

The cost drivers are further analysed to understand the effects on both benefits (capabilities) and the cost of any possible changes. This would include requesting the suppliers to clarify data on the identified cost drivers. In the original data analysis, risk premiums with regards to new technology should be included and the suppliers risk analysis should also be reviewed together. The resulting analysis will support the decision making process and could result in adjustments being made to the final specifications in order to achieve a lower life cycle cost.

3.5.7.4 Evaluation and Iteration

In practice, life cycle costing should be part of the iterative process of the system design. The costing boundary defines exactly what elements should be included and the level of detail in which they will be considered. The life cycle costing activity during this phase should be sufficiently robust to support a ‘value for money’ decision. To achieve this level of confidence it may be necessary to iterate the life cycle costing process several times during the phase. It is essential to ensure that life cycle costing is not just a one-off activity. To be at its most efficient it needs to be integrated into the design process, be able to identify opportunities for cost savings and be accurate in terms of providing a robust and defendable life cycle cost.

Figure 3-10 provides a simple illustration of the life cycle costing process. It shows that at this PAPS phase the source data to support the life cycle costing is likely to be very mature in terms of system engineering design therefore there should be detailed design data (structure and ARM) available from industry. Logistic information providing support analysis and stockholdings should also be available. All this information will allow a detailed population of the cost breakdown structure. It should now be possible to populate all the line items in the cost breakdown structure.

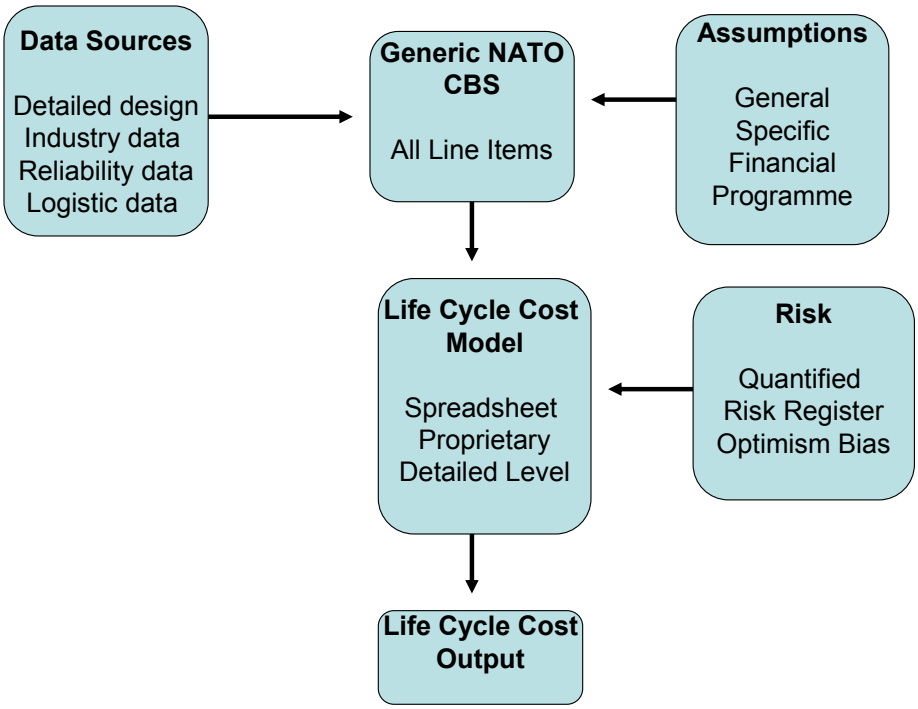


Figure 3-10: Simplified Design and Development Phase Life Cycle Costing Process.

All the risks should now be captured and quantified within a risk register to provide the basis for conducting the cost risk analysis. There should also be mitigation plans for all the major risk areas and the costs of undertaking these should also be included in the cost estimates.

At the completion of this phase the life cycle cost output should be a detailed account of all the line items contained in the cost breakdown structure. A comprehensive risk analysis in terms of Cost and Schedule impact should also be available.

In summary, the key considerations to the life cycle costing process for this phase are:

- The principal data sources are likely to be design and logistic information from industry supplemented by military data on likely deployment and staffing numbers.
- All design data and a comprehensive CONOPS report is likely to be available to refine the estimates and provide an established baseline for the acquisition, operating and support costs.
- The life cycle costing is likely to be conducted using in-house models and the results cross-checked and supplemented using an alternative method. A further independently generated estimate would provide a third view and provide the assurance and robustness of the life cycle cost estimate.
- All the ground rules will have been agreed. There will be few assumptions to be recorded and assessed. Although, it can be expected that the reliability and maintainability modelling will have been conducted using predictive data. The criticality of this data should be measured using sensitivity analysis.
- The risk will be measured at a detailed level utilising a quantified detailed risk register and recognised risk simulation models.
- The life cycle costs are likely to be determined at all the line items in the cost breakdown structure.

3.5.8 Risk Assessment

During these phases the identification of risk should be conducted at a very comprehensive level to fully understand the level of risk exposure to cost and time. All the mitigation plans should have been developed and programmed. The cost of conducting the risk mitigation actions should be included in the life cycle cost estimate.

The risk analysis should comprise pre and post risk mitigation scenarios as well as developing the time line for undertaking and completing the mitigation actions.

At completion of the phase the results of the risk analysis should provide a clear indication on the level of financial and timescale risk exposure to the programme.

3.5.9 Examples

A number of examples are shown that relate to the types of studies to be undertaken before and after contract award. It is important to distinguish these as the added value provided to this and the next phase is invaluable.

3.5.9.1 Analogy Cost Estimating

This cost estimating method is accomplished by forecasting the cost of the future based on the historical cost of a similar or analogous item. The costs of the historical item must first be normalised for both content and historical price differences. Normalising for content entails deducting the cost of components that are not comparable to the new design and adding estimated costs of the new components. Normalising for inflation entails converting historical cost to an appropriate base year value and applying the proper escalation indices to achieve then-year costs. Estimating by analogy involves comparing your system and/or cost breakdown structure elements to comparable current and or historical systems or cost breakdown elements. This involves understanding the programme and how it derives its history, for example, what programme it is based upon. It is important to interact with programme engineers to ensure the validity and credibility of candidate analogous programme to the future system; once comparable programmes are considered, it is necessary to seek out those specific systems if possible to obtain necessary data and cost information. The estimator will also need to talk to the programme engineers to understand differences between the future system and the comparable analogous system(s).[2]

Figure 3-11 is a simple example of estimation by analogy for military personnel pay systems. System A is old and system B is new. The objective is to estimate the software development effort for the new system. This is done using system A as an analogy, or more specifically, using man-months of effort per function point on A as the analogous ratio or multiplier, to be applied to the new system, B.

[2] NAVSEA 2005 Cost Estimating Handbook, p. 4-11.

System	Software Development Effort (Number of Manmonths)	Size of Software (Number of Function Points)
A	986	15,800
B	?	12,800

System	Manmonths Per Function Point
A	0.06

System	Software Development Effort (Number of Manmonths)
B	.06 x 12,800 = 799

Figure 3-11: Example of Analogy Cost Estimating.

Finally, complexity factors have often been used to adjust analogous estimates. However, they can often undermine the credibility of the future estimate if they have not been substantiated. For example, engineers might suggest that a new programme is twice as complex as an analogous programme, and that, therefore, the new programme's cost should be twice the cost of the old programme. In reality, the relationship between complexity and cost might be unknown. It could be proportional, linear, or exponential. Without hard data, a subjective adjustment will negate the credibility of the estimate.

3.5.9.2 Parametric Cost Estimating

Parametric estimating requires that a statistically valid relationship be established among the dependent variable, such as cost, and independent variables, such as costs of other elements, and or various physical and performance characteristics of that system. This parametric CER (cost estimating relationship) is then used to estimate the cost of a new system with different values for the same physical and performance characteristics.[3]

Provided below is an example, based on a dozen historical observations on number of man-months required for lead ship construction and the displacement tonnage of that ship. Note, that construction for the first ship in a class is typically a development contract, and includes non-recurring design effort.

First, a CER is estimated using least-squares regression analysis.

$$Y_i = 10.3 + 100.7X_i + e_i$$
$$(4.3)\ (3.2)$$
$$n = 12$$
$$R^2 = 0.87$$
$$F = 17.1,$$

where n = the number of historical observations used to estimate the equation.
Y_i = number of man-months required to construct the ith ship (in millions).
X_i = displacement tonnage of the ith ship (in thousands).
e_i = the ith regression residual.

[3] NAVSEA 2005 Cost Estimating Handbook, p. 4-11.

R^2 = The coefficient of determination, or the proportion of variation of Y (dependent variable) that can be attributed to the variation of the explanatory or independent variables (X's). It is a measure commonly used to describe how well the sample regression line fits the observed data. Note that $0 <= R^2 <= 1$.

F = measures the overall power of the regression equation in explaining changes in the dependent variable. More specifically, it is used in testing the null hypothesis of no relationship between the set of X's (explanatory variables) and Y (the dependent variable).

and where t-statistics are shown in parentheses.

Then, a value for displacement tonnage for the new system is input into the estimated regression equation to give an estimate of man-months of effort required to design and construct the new ship.

3.5.9.3 Historical Trend Analysis

In addition to the estimating techniques discussed above conducting a historical trend analysis provides the estimator with the ability to set estimated costs and time schedules either separately or together in the context of historical costs for similar or related programmes. This is distinct from any cost estimating models themselves. Its uses are:

- To provide supplementary background information of a kind that can assist an estimator by giving a wider context to their work upon an individual programme.
- Similarly, by providing context and background to a study, it facilitates the work of those responsible for the scrutiny of estimates prepared by others e.g. as in auditing and due diligence work.

Figure 3-12 illustrates the estimated cost of a new programme in the context of historical trends as exemplified by the actual outturn costs of a substantial number of similar programmes completed in the past. All the costs having been normalised to common economic conditions and due allowance made for differences in scale. How well the estimated costs of the new programme fit into this context is both seen by the user in readily-understood graphical form and can also analysed statistically.

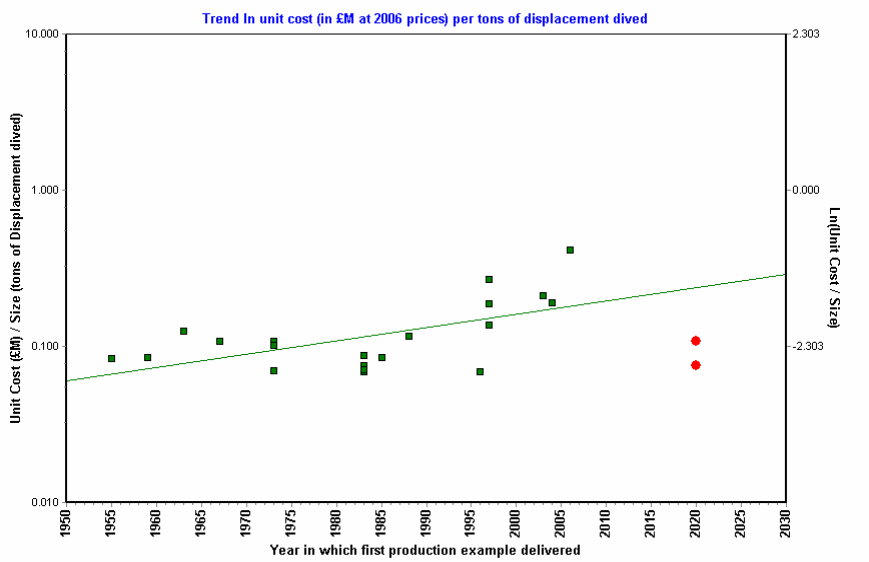


Figure 3-12: Example of Historical Trend Analysis.

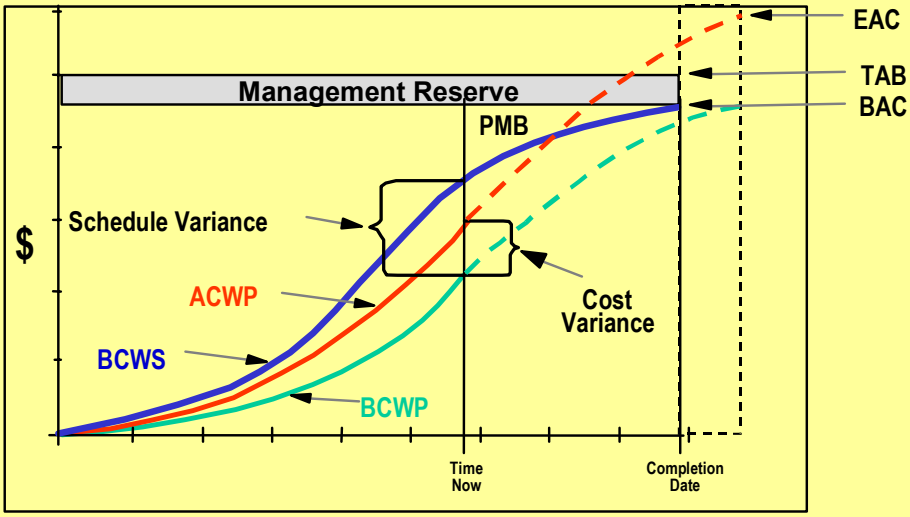
3.5.9.4 Example of Evaluation of Contract Performance

Once a contract has been awarded for design and development, or production, data from an EVM (earned value management) system can be employed as an aid to decision making. EVM is an integrated management control system for assessing, understanding, and quantifying what a contractor is achieving with programme funding. More specifically, EVM:

- Integrates technical, cost, and schedule information with risk management.
- Allows objective assessment and quantification of current project performance.
- Helps predict future performance based on trends.

Earned value provides an objective measurement of how much work has been accomplished on a programme. Using the earned value process, the management team can readily compare how much work has actually been completed against the amount of work planned to be accomplished. All work is planned, budgeted, and scheduled in time-phased 'planned value' increments constituting a PMB (Performance Measurement Baseline), or BCWS (Budgeted Cost of Work Scheduled) curve, as shown in Figures 3-13 and 3-14, which have been taken from the US Defense Acquisition University EVM Gold Card.

Defense Acquisition University
Earned Value Management Gold Card



VARIANCES *(Favorable is positive, Unfavorable is negative)*

- Cost Variance — CV = BCWP – ACWP — CV % = CV / BCWP
- Schedule Variance — SV = BCWP – BCWS — SV % = SV / BCWS
- Variance at Completion — VAC = BAC – EAC

PERFORMANCE INDICES *(Favorable is > 1.0, Unfavorable is < 1.0)*

- Cost Efficiency — CPI = BCWP / ACWP
- Schedule Efficiency — SPI = BCWP / BCWS

OVERALL STATUS

- Percent Complete = $\frac{\text{BCWP CUM}}{\text{BAC}}$
- Percent Spent = $\frac{\text{ACWP CUM}}{\text{BAC}}$

TO COMPLETE PERFORMANCE INDEX (TCPI)

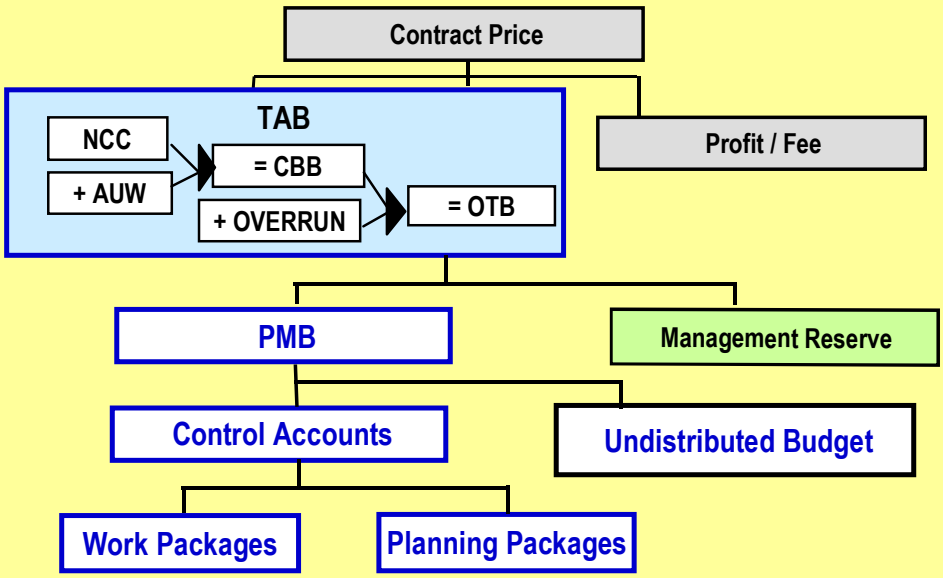
$$\text{TCPI}_{(EAC)} = \frac{\text{WORK REMAINING}}{\text{COST REMAINING}} = \frac{\text{BAC} - \text{BCWP CUM}}{\text{EAC} - \text{ACWP CUM}}$$

ESTIMATE AT COMPLETION (EAC = ACWP + Estimate for Remaining Work)

$$\text{EAC}_{CPI} = \frac{\text{BAC}}{\text{CPI CUM}}$$

$$\bullet\ \text{EAC}_{Composite} = \text{ACWP CUM} + \frac{\text{BAC} - \text{BCWP CUM}}{(\text{CPI CUM}) \bullet (\text{SPI CUM})}$$

Figure 3-13: Example EVM Calculations.



TERMINOLOGY

NCC	– Negotiated Contract Cost	Contract price less profit / fee
AUW	– Authorized Unpriced Work	Work authorized to start, not yet negotiated
CBB	– Contract Budget Base	Sum of NCC and AUW
OTB	– Over Target Baseline	Sum of CBB and recognized overrun
TAB	– Total Allocated Budget	Sum of all contract budgets - NCC,CBB or 0TB (includes MR)
BAC	– Budget At Completion	Cumulative BCWS - total end point of PMB (excludes MR)
PMB	– Performance Measurement Baseline	Contract time-phased, budgeted work plan (excludes MR)
MR	– Management Reserve	Contractor PM's Contingency budget
UB	– Undistributed Budget	Broadly defined activities not yet distributed to CAs
CA	– Control Account	Contractor key management control point - CWBS element
WP	– Work Package	Near-term, detail-planned activities within a CA
PP	– Planning Package	Far-term CA activities not yet defined into detail Work Packages
BCWS	– Budgeted Cost for Work Scheduled	Value of work scheduled -- PLAN
BCWP	– Budgeted Cost for Work Performed	Value of work completed -- EARNED VALUE
ACWP	– Actual Cost of Work Performed	Cost of work completed -- ACTUAL COSTS INCURRED
EAC	– Estimate At Completion	Estimate of total contract costs

EVM POLICY (DOD 5000.2-R)

ALTERNATIVE EV MANAGEMENT APPLICATIONS

LEVEL 1. EVMS Industry Standards Management Application

Contractor management system certified as meeting Industry Standards

- Required for non-FFP contract exceeding $73M RDT&E or $315M in procurement (CY00$).
- PM may apply to contracts below-threshold —consider benefits, risk and criticality.
- Contractor must establish, maintain, and use a system that meets the the 32 Industry Standards.
- Cost Performance Report (CPR) delivered as a CDRL item.
  - 5 Formats (WBS, Organization, Baseline, Staffing, and Explanations)

LEVEL 2. C/SSR Management Application

Contractor Management system not certified

- Required for non-FFP contract exceeding $6.3M (CY00$) and 12 months in length.
- 'Reasonably objective' EV methods acceptable, traceability at higher level (CA vs WP)
- The CPR or the Cost/Schedule Status Report (C/SSR) delivered as a CDRL item.

EVM Home Page — http://www.acq.osd.mil/pm/
DSMC EV E-Mail Address — EVM@DSMC.DSM.MIL
DSMC EV Phone No. — (703) 805–2848/2968 (DSN 655)

June 2000

Figure 3-14: Example EVM Process.

As work is performed, it is 'earned' on the same basis as it was planned, in monetary or other quantifiable units such as labour hours. Comparing earned value with the planned value measures the monetary value of work accomplished versus the monetary value of work planned. Any difference is called a schedule variance.

Earned Value – Planned Costs = Schedule Variance (SV)

The value earned for the work performed compared with the actual cost incurred for the work performed (taken directly from the contractor's accounting systems), provides an objective measure of cost efficiency. Any difference is called a cost variance.

Earned Value – Actual Costs = Cost Variance (CV)

A negative variance means more money was spent for the work accomplished than was planned. Conversely, a positive variance means less money was spent for the work accomplished than was planned to be spent. Finally, as the figures indicate, cost and schedule variances can be used to generate estimates of contract cost at completion (EACs).

3.5.10 References

[16] NAVSEA 2005 Cost Estimating Handbook, http://www.navsea.navy.mil/sea017

[17] Earned Value Management Implementation Guide, Defense Contract Management Agency, October 2006; available from http://guidebook.dcma.mil/79/evmigoldversion.doc

[18] U.S. Defense Acquisition Guidebook available from http://akss.dau.mil/dag

[19] DoD Instruction 5000.2 "Operation of the Defense Acquisition System", May 2003 available from http://akss.dau.mil/dag

[20] UK MoD, General Instructions and Guidance on IAB and Delegated Approvals, Edition 8, March 2003 [unpublished MoD Documents/Reports].

3.6 ALTERNATIVE PROCUREMENT PHASE (MAKE OR BUY DECISION)

3.6.1 Summary Definition of Phase

As described in Section 3.2.9 this alternative procurement phase replaces a design and development phase and the production phase to represent a situation where an off-the-shelf buy (instead of a make) decision is made. In this situation, only a limited number of activities can be expected.

3.6.2 Inputs

The input for the alternative procurement phase is the agreed and fully documented NATO Staff Requirement. However, the level of detail required (in terms of performance and supportability) from industry would be far more substantial. This would be gained from formal approaches such as an RFI (Request for Information) or a more contractual RFQ (Request for Quotation). If there are more than one potential suppliers then a tender competition may be conducted and the ITT (Invitation to Tender) could comprise a life cycle cost questionnaire (see Annex C for an example) for completion by the contractors.

3.6.3 Outputs

The life cycle cost outputs should be sufficient to fully understand, on a year by year basis, all the acquisition, operating and support costs over the life of the programme.

The output of the alternative procurement phase will be a product or system that complies with the NATO Staff Requirement.

3.6.4 Life Cycle Cost Benefits

The main purposes for conducting life cycle costing on an off-the-shelf procurement programme is to provide the decision maker with a full understanding of the financial commitment over the life of the programme.

3.6.5 Types of Life Cycle Cost Studies

The type of life cycle cost studies to be conducted in this phase can be summarised as follows:

- Supporting the tender evaluation process.

  In the tender evaluation process the life cycle costing methodology can be used to ensure that the contract is award to the tender offering a system that meets all technical and availability requirements at minimum life cycle cost. The cost of investment in maintenance resources and the cost of lifetime support will be weighed against the cost of investment in the technical system. The resulting life cycle cost will be included in the overall tender evaluation period.

- Comparing alternative solutions or options on costs, in order to choose the best solution.

  As part of the alternative procurement phase various alternatives need to be compared. In some cases, the tender evaluation process may have to evaluate several options provided in the tender response all of which may meet the requirements (including direct procurement or a lease option). Or it may be that a nation would like to compare various types of support: e.g. own maintenance organisation versus outsourcing. In this case it is not necessary to estimate all cost elements. It may be sufficient only to estimate the cost elements that will show differences between the options. These relative comparisons however, will not provide a complete picture of the life cycle costs, but would be an aid to the decision making process.

- Determining the total life cycle costs

  In order to make a fair decision in the procurement phase, a nation would need to have an overview of the total life cycle costs, not only to determine the forecast of future spending, but also to assess the affordability of a procurement programme. In this case, all the cost elements have to be estimated and a detailed cost study is required.

3.6.6 Methods Employed

Dependent on the data available, many methods may be used in this phase:

- Engineering method.
- Parametric method.
- Analogy method.
- Expert opinion.
- Rules of thumb.
- Catalogue.

For more details on these methods see Chapter 4.

3.6.7 Life Cycle Costing Process

The major steps to follow are similar to the process described in Section 3.5.7. However, in an alternative procurement phase it is conducted in less detail.

- Based on the system requirements described in the NATO Staff Requirements an RFI/RFQ/ RFP/ITT is compiled and sent to several companies and they are asked to answer cost related questions and fill in data in an agreed cost breakdown structure format. This will include a statement on the definitions and the basis of the cost estimate.
- Gathering data from internal sources in order to complete the cost model.
- Data analysis to find cost drivers, costs that can be influenced and costs that differ between the alternative solutions.
- Evaluate the result, either to support the procurement decision or to iterate the process until the basis for decision is clearly understood and agreed.

More details are provided at Sub-section 3.5.7. Figure 3-8 can also be used for the alternative procurement phase.

3.6.8 Risk Assessment

During the tender evaluation the identification of risk should be conducted at a very comprehensive level in order to fully understand the level of risk exposure. All the risk mitigation plans should have been developed and programmed and assigned to owners. The cost of conducting the risk mitigation actions should also be included in the life cycle cost estimate.

The risk analysis should comprise pre and post risk mitigation scenarios and should develop the time line for undertaking and completing the mitigation actions. At completion, the results of the risk analysis should provide a clear indication on the level of financial and timescale risk exposure to the programme prior to contract negotiation.

3.6.9 Example

The multi-national NSHP (Nordic Standard Helicopter Programme) is an example of how the life cycle costs can support the tender evaluation process.

All the participating nations' requirements were implemented in a common Nordic Requirements Document. This document defined those requirements that were considered common and those which were specific to a particular nation. The request for quotation required prospective contractors to provide detailed data to enable the evaluation of performance and reliability. In addition, this information would be used to estimate the life cycle cost. The evaluation of system availability and life cycle cost were performed for each participating nation's individual life cycle cost model.

Figure 3-15 represents a summary of user data and tender data that was included in each nation's life cycle cost model. The figure also shows how the calculated estimates for cost of spare parts were used as input to the model. All the nations' specific life cycle cost models were then combined in a total life cycle cost model, representing a combined life cycle cost for all the participating nations.

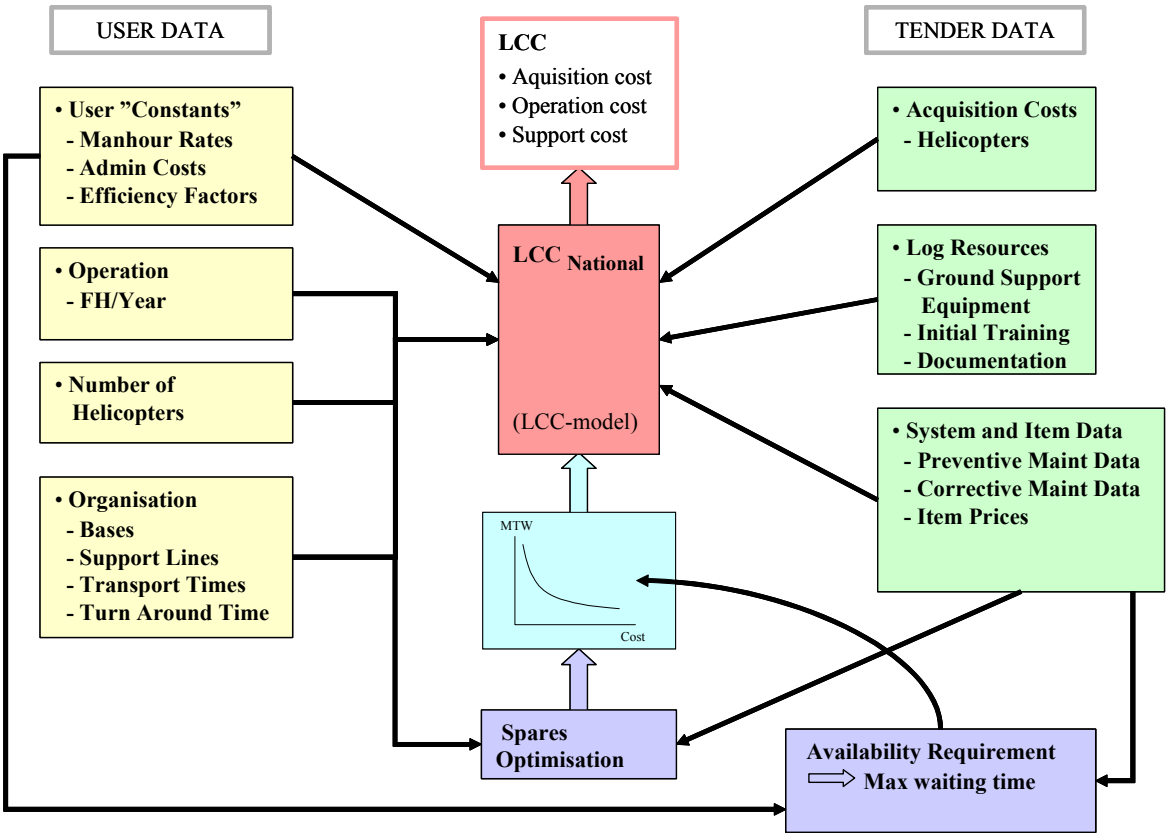


Figure 3-15: LCC Data Process.

The requirement for spares was calculated, by the procurement agency, using a logistics and spares optimisation model, based on the individual nation's operational profile. The criterion for the cost modelling was based on the MWT (Mean Waiting Time) for spare parts together with the unavailable time due to preventive and corrective maintenance. The system availability requirement was given as 80% (see Figure 3-16). By using this approach all the tenders were normalised and compared using the same performance level. The calculated costs for spare parts were used as an input to the life cycle cost evaluation.

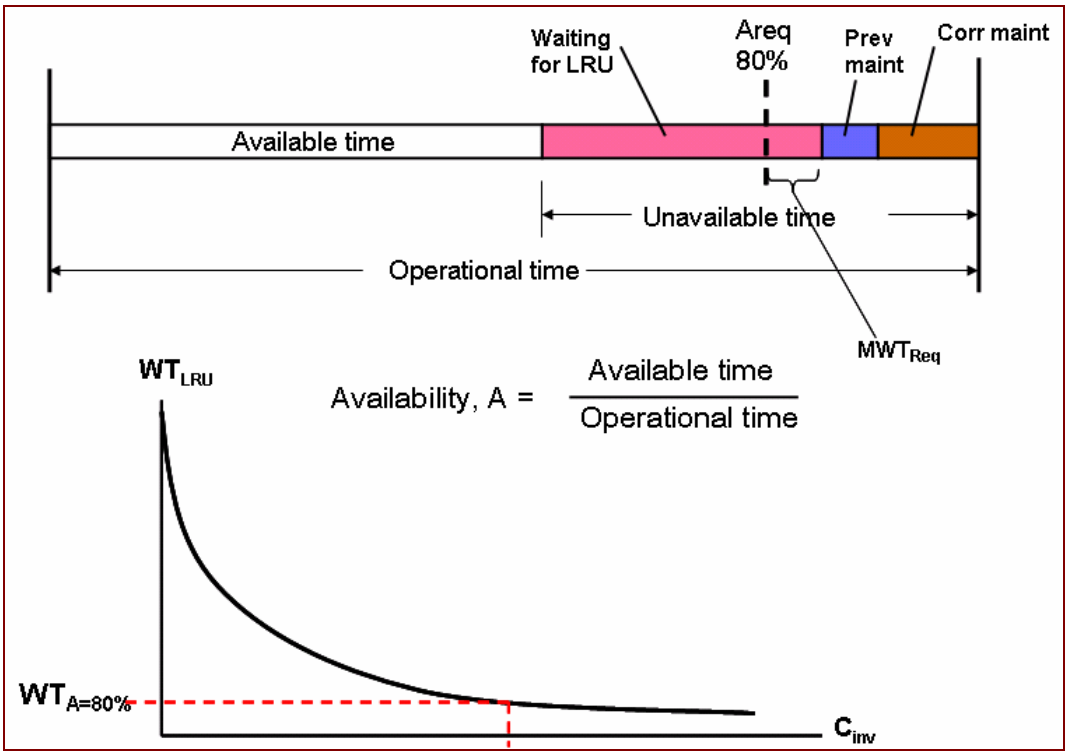
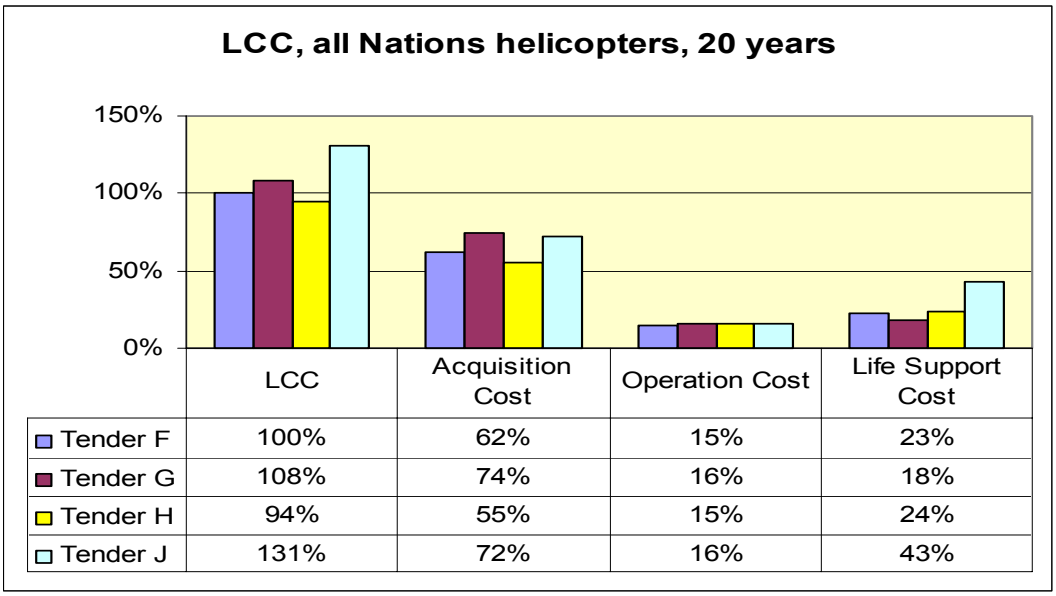


Figure 3-16: Availability Precedence.

Some of the results from the life cycle cost tender evaluation are presented below. Figure 3-17 shows the sum of all the participating nations' life cycle costs per tender. The cost for total life cycle cost, acquisition, operation and life support have been normalised to Tender F to provide a relative comparison. The life cycle cost tender evaluation process generated many different diagrams that presented different aspects and the cost drivers for each tender.



	LCC	Acquisition Cost	Operation Cost	Life Support Cost
Tender F	100%	62%	15%	23%
Tender G	108%	74%	16%	18%
Tender H	94%	55%	15%	24%
Tender J	131%	72%	16%	43%

Figure 3-17: LCC Evaluation Results.

When analysing the LSC (life support costs) (Figure 3-18) in more detail it became clear that the investment in spare parts differed significantly between the tenders. The difference was explained by the different maintenance concepts offered by each contractor.

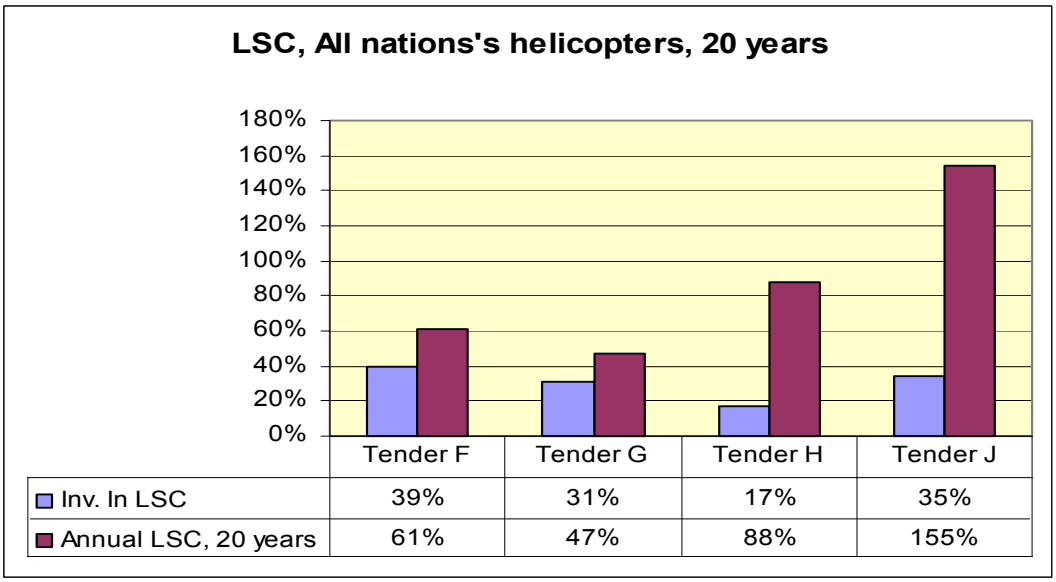


Figure 3-18: LSC Evaluation Results.

Figure 3-17 shows that Tender H has the lowest costs, however Tender F was selected as the winning tender due to other considerations. The life cycle cost analysis results were used as a baseline for negotiating the contract. In addition, the life cycle cost analysis is now being used to establish a support cost baseline prior to negotiating a contractor logistic support contract.

3.6.10 References

[21] Handbok för driftsäkerhet (H DriftSäk), 2006, (M 7740-714001 H Driftsäk), Swedish Armed Forces and Swedish Defence Materiel Administration. (in Swedish).

[22] Stappenplan voor het Analyseren van Levensduurkosten binnen de Defensie Organisatie (SALDO), FEL-93-A337, december 1993, B. Bhola and J.A.M. van Wees (in Dutch).

[23] Aanwijzing DGM inzake levensduurkosten bij materieelprojecten, aanwijzing 98-4 d.d. 11 december 1998 (in Dutch).

3.7 PRODUCTION PHASE

3.7.1 Summary Definition of Phase

This phase starts with the approval of the NAPO (NATO production objective). The NAPO is an outline statement of the manufacturing process, personnel and facilities required for production of the equipment, including an outline production programme based on cost plans, quality control requirements, and the stated production specifications. This phase includes the manufacture of a system, sub-system or equipment in a plant or factory using series manufacturing techniques.

3.7.2 Inputs

Assuming that the project does not include a combined design and development and production phase the inputs can be defined as:

- The project has achieved a level of maturity that will enable the final delivered product to satisfy the documented capability as defined in the NATO Staff Target and NATO Staff Requirement.

3.7.3 Outputs

Assuming that the project does not include a combined design and development and production phase the outputs can be defined as:

- At the end of production phase the product complies with NATO Staff Requirement Document or is supported with an incremental plan achieve the NATO Staff Requirement.

3.7.4 Life Cycle Costing Benefits

During the production phase the life cycle cost estimates made on the product components will change either because of component obsolescence, change in design or integration with other components/ systems. All of these factors will have a direct impact on the Systems Life Cycle Management Plan[4]. Therefore it is essential that any revised data is collected so that budgets and plans can be amended accordingly.

3.7.5 Types of Life Cycle Cost Studies

During the production phase the only related life cycle costing study is the review and update of the financial element of the systems life cycle management plan. Other life cycle costing studies may be initiated if there is radical change brought about by the failure to achieve the forecasted plan or a change in policy or procurement strategy by the participating nations in the joint project.

3.7.6 Methods Employed

3.7.6.1 Prior to Start of Production

To ensure that there is a sound basis for tendering/contracting the programme must have completed its design and development phase and a full production requirements specification is available. The arrangement for work share between participating nations must also be defined.

To enable suppliers to estimate costs and gain an understanding of the full requirements the acceptance standards must also be defined and documented.

To form a sound basis for both industry and government (including the commitment by the Armed Services during tests and trials) to plan their commitment to the project, the participating nations must supply a document that defines the equipment and specialist support they intend to supply free of charge (government funded equipment and the government funded support known collectively as GFX).

If there is no competition for the programme (single source supply) government investigating departments must be provided with adequate information from the suppliers to enable an assessment to be made of the reasonableness of the quotation. Therefore the invitation to tender document should be used to detail all the deliverables and acceptance criteria that will enable the authority to make an assessment of the contractors bid submission. A typical request for information is shown at Annex B.

[4] Policy for Systems Life Cycle Management C-M(2005) 0108-AS1, January 2006.

To provide assurance and programme control the bid submission must be soundly based, with key risks to performance, cost and timescale identified, and actions planned to monitor, mitigate and control those risks. Depending on the circumstances and the number of participating nations consideration should be given to the combining of the risk registers prior to tendering. ***If this cannot be done prior to tendering then it is recommended that a joint risk register should be developed as soon as the contract is agreed***.

The contract must meet the national and international requirements for contract law.

Experience has also shown that in a series production environment a correlation can be established between the reduction of production time and the quantities produced. Details on the theory and application are given in the example at Section 3.7.9.

The learning factor here equates to both the production quantity and the spares. Care must be taken to ensure that all cost benefits arising from increased quantities (learning) must be taken into account.

3.7.6.2 During Production

The primary focus here will be to assess how the forecasted costs compare to the actual cost, particularly those that relate to the in-service element.

The cost element of the systems life cycle management plan should be refined during the course of production to reflect refined product and sub component life cycle information (e.g. MTBF, MTTR, etc.).

Regular joint reviews of the systems life cycle management plan must take place to ensure that impacts can be assessed.

Review the integrated test, evaluation and acceptance plan. This will ensure you that there are adequate means to demonstrate that the equipment is fit for service.

The supplier shall provide progress reports either by EVM (Earned Value Management) or equivalent reports.

Regularly review the risk register and risk mitigation plans.

3.7.6.3 Post Production

To inform follow-on projects a post stage evaluation report should be prepared to ensure that best practice is captured and any weaknesses for future redress are exposed.

It is recommended that all actual costs incurred by the contractor are certified. This data can subsequently be used to refine and calibrate future cost forecasting models.

3.7.7 Life Cycle Costing Process

Figure 3-19 provides a simple illustration of the life cycle costing process. It shows that at this PAPS phase the source data to support the life cycle costing is likely to be very mature in terms of system engineering design. Quotations for production should be available together with all the logistic information required to model the supportability of the system over the expected lifetime. The cost breakdown structure should now be fully populated to provide a comprehensive view of the life cycle costs.

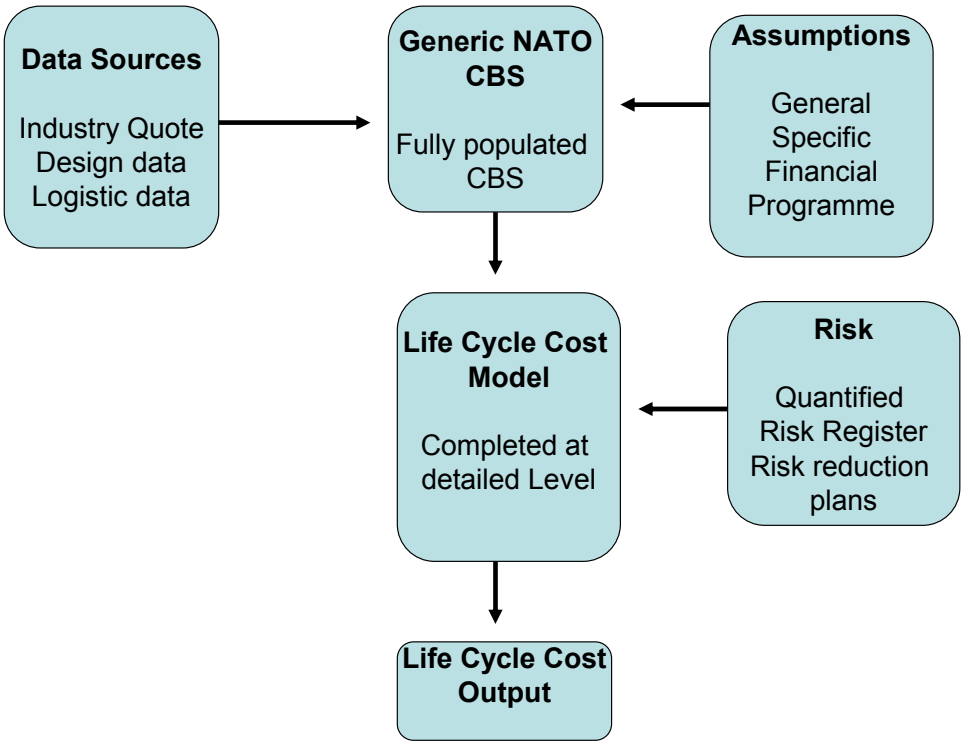


Figure 3-19: Simplified Production Phase Life Cycle Costing Process.

All the risks (both government and industry) should now be captured and quantified within a joint risk register to provide the basis for conducting the cost and schedule risk analysis. There should also be mitigation plans for all the risk areas and the costs of undertaking these should also be included in the life cycle cost estimates.

During this phase the life cycle cost output should be a detailed account of all the line items contained in the cost breakdown structure. It can be used to support the population of the production activity plan and subsequent cost control processes such as earned value management. A comprehensive risk analysis in terms of cost and schedule impact should also be available. In summary, the key considerations to the life cycle costing process for this phase are:

- The principal data sources will be firm/fixed price quotations from prospective suppliers supplemented by military data on likely deployment and staffing numbers.
- All design data and a comprehensive CONOPS report is likely to be available to refine the operating and support cost estimates and provide a robust baseline for supportability assessment and long term financial budgeting.
- The life cycle costing will be done at a detailed level.
- There will be very few assumptions to be recorded and assessed. Although, it can be expected that the reliability and maintainability modelling will have been conducted using predictive data. The criticality of this data should be measured using sensitivity analysis.
- The risk will be measured at a detailed level utilising a quantified detailed joint risk register.
- The life cycle costs are likely to be determined at all the line items in the cost breakdown structure.

3.7.8 Risk Assessment

During the production phase all the risks will be reviewed and managed on a regular basis. Mitigation plans will be put into action and their progress monitored. This will be a comprehensive management and analysis activity and will regularly report the possible outcomes in cost and schedule to the project manager.

3.7.9 Example

An example of cost analysis activities conducted at this phase include the use of cost improvement curves also referred to as the learning curve theory.

According to this theory, as the cumulative production quantity increases, unit production costs decrease. This can be due to an increase in workers skill levels, improved production methods, and/or better production planning. This effect can be quantified in production cost estimates using a product improvement curve, or a learning curve. A 90 % learning curve means that, each time the cumulative production quantity doubles, the production time (or, comparatively, the production cost) will be 90 % of its value before the doubling occurred. The standard measure of organisational experience in the learning curve formulation is the cumulative number of units produced, which is a proxy variable for knowledge acquired over production. If unit costs decrease as a function of such knowledge, organisational learning in some form is said to occur.

In actuality, unit (or Crawford's) learning curves may vary considerably depending on the expected magnitude of the cost savings estimated for the 2nd unit and so on. Because of the product complexity, an 80 % unit cost reduction may not be realised until the production of the following units. Cost analysts should evaluate the complexity of tasks in the production process and attempt to determine the type of unit learning curve that is most appropriate for the specific situation.

The equation used in Crawford's model[5] is:

$$\mathbf{Y = aK^{b}}$$

where:

a	=	time (or cost) required to produce the first unit.
Y	=	the incremental unit time (or cost) of the lot midpoint unit.
K	=	the algebraic midpoint of a specific production batch or lot.
b	=	percent change in cost divided by the percent change in quantity.

The unit cost of the mid-point unit is the average unit cost for the production lot.

Sometimes, in the application of learning curves, it may be more appropriate to use a cumulative average learning curve. If it turns out that the projected average cost of producing the first 20 units is 80 % of the average cost of producing the first 10 units, then the process follows an 80 % cumulative average learning curve.

[5] The theory of the learning curve or experience curve is based on the simple idea that the time required to perform a task decreases as a worker gains experience. The basic concept is that the time, or cost, of performing a task decreases at a constant rate as cumulative output doubles. Learning curves are useful for preparing cost estimates.

There are two different learning curve models. The original model was developed by T. P. Wright in 1936 and is referred to as the Cumulative Average Model or Wright's Model. A second model was developed later by a team of researchers at Stanford. Their approach is referred to as the Incremental Unit Time (or Cost) Model or Crawford's Model.

In Wright's model, the learning curve is defined as

$$Y = aX^b$$

where:

a	=	time (or cost) required to produce the first unit.
Y	=	the cumulative average time (or cost) per unit.
X	=	the cumulative number of units produced.
b	=	percent change in cost divided by the percent change in quantity.

Figure 3-20 gives an example of a learning curve.

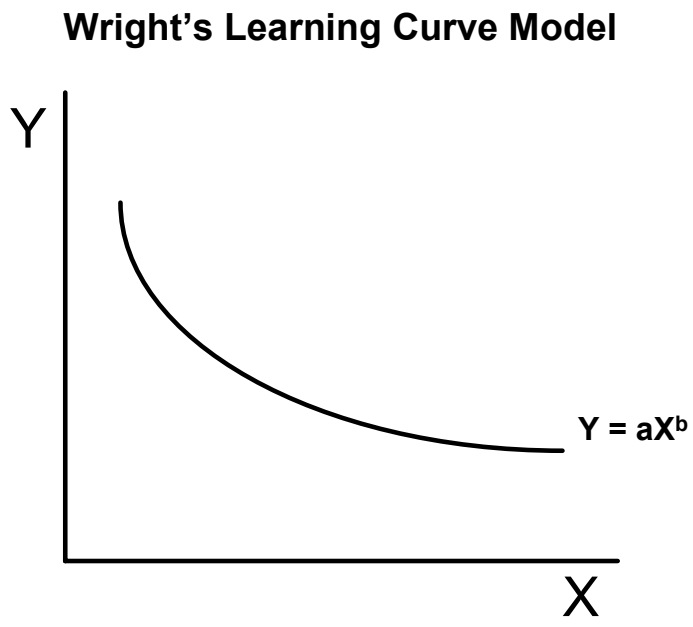


Figure 3-20: Learning Curve Example.

3.7.10 References

[24] www.ams.mod.uk

[25] Life Cycle Cost Policies Based on Learning Curve Concepts, Lt Col Massimo Pica, Ministry of Defence, Directorate General of Land Armaments, Rome, Italy.

[26] US Air Force Analyst's Handbook, Christopher A. Feuchter, January 2000.

[27] The "Mother of all Guesses", A User-Friendly Guide to Statistical Estimation, Francois Melese and David Rose, Armed Forces Comptroller, 1998.

[28] Unit Cost – a Financial Management Tool for Today and Tomorrow, Comptroller of the Department of Defense, 1990.

[29] U.S. Air Force Life Cycle Management Plan (LCMP) Guide, March 2005 https://acc.dau.mil/GetAttachment.aspx?id=32631&pname=file&aid=6197

[30] Statistical Methods for Learning Curves and Cost Analysis, Matthew S. Goldberg and Anduin E. Touw, 2003.

3.8 IN-SERVICE PHASE

3.8.1 Summary Definition of Phase

This phase starts with the NISEG (NATO in-service goals). The NISEG is a statement of the general utilisation intentions for equipment including reference to national or co-operative logistic and training arrangements.

The NATO PAPS defines the in-service phase as "the operational utilisation of equipment by nations". This utilisation phase is executed to operate the product at the intended operational sites to deliver the required services with continued operational and cost effectiveness.

3.8.2 Inputs

According to a suitably determined CBS (cost breakdown structure), data related to the operation and maintenance activities of a considered system must be collected. An illustrative CBS is shown thus:

- Operation
  - Personnel
  - Training
  - Infrastructure/Facilities
  - Consumables
  - Others
- Maintenance
  - Personnel
  - Training
  - Facilities
  - Spares
  - Repair Parts
  - Documentation
  - Test and support
  - Infrastructure
  - PHST
  - Modification/Upgrading

Various data formats are used to gather cost and non-cost (e.g. technical) data. Databases which are specifically designed for automated information and reporting systems are examples. More information on the collection of data can be found in Chapter 6. After data is obtained, data analysis and normalisation process must be performed to have a consistent data set (adjustment/normalisation of data).

3.8.3 Outputs

The essential output of in-service phase life cycle cost studies is the gathering of actual costs occurring during the operation and maintenance activities. However, it should be recognised that there will be differences in the expected data due to the approach adopted by the users to maintain the availability of the

system during its life. Care is needed therefore to ensure that the gathered data is correctly interpreted and properly used in any life cycle cost analysis.

3.8.4 Life Cycle Cost Benefits

One of the main objectives of life cycle costing is to provide suitable data in order for the decision makers to forecast future costs, manage existing budgets and undertake options analysis where necessary. The forecasting of future expenditure requires a sound knowledge of the actual in-service costs. Therefore, the collection of actual costs during the in-service phase helps:

- To analyse differences between forecasting and actual costs.
- To help to identify potential areas of cost saving.
- To feed cost databases.
- To identify cost drivers.
- To implement management control.
- To plan to phase out the system and reduce stockholding.

Life cycle cost studies during this phase are also used to achieve the following objectives:

- One of the main objectives of life cycle cost studies is to provide a forecast of future spending on operating and maintenance costs. This will determine the likely financial commitment to support the system in-service.
- Monitoring costs: to identify cost growth and inaccuracies. This can be achieved by comparison between actual cost and earlier estimates. If unpredicted cost growth is identified, more detailed studies that focus on the identified differences has to be undertaken. This is in order to find the reasons behind the unexpected cost growth, it may stem from a different actual utilisation than was used in earlier cost modelling estimates. This is particularly important if a logistic support contract has been awarded with a mechanism of penalties and incentives.
- The life cycle cost studies give operational planning departments the opportunity of estimating the costs of activities to be performed and selecting between them, particularly when activity based approaches for cost control are followed. Therefore, in-service phase costing enables the discard of activities in a cost-effective manner.
- Data collection activities on systems in an operational area supply factual historical data about those systems performance. This data can subsequently be used to support future life cycle costing studies.
- Involvement in a new investment analysis process anytime there is a significant change to the planned in-service programme.
- The in-service life cycle costs also enables staff to address such questions as:
  - Consider a buy or lease option on the services to be provided?
  - Determine the level of stock to be held and where are they best placed?
  - What maintenance operations should be undertaken at the various support organisations?

3.8.5 Types of Life Cycle Cost Studies

The in-service phase gives the cost analyst the opportunity of verifying the estimates with the actual costs. Because of that, the life cycle cost activities during this phase concentrate on the data collection of actual data and information. Data collection processes can be accomplished using manual techniques and/or

automated information/database systems. Some data analysis must be performed in order to prepare the data for use in cost estimating models or cost estimating relationships.

During the in-service phase, studies are performed in order to refine the life cycle cost estimate of the systems in use by using actual recorded data. Further analysis may be done in order to determine the failure rates of a system in use and measure the effects of those failures against the predicted values. Therefore, it is important to capture system related reliability parameters such as MTBF (mean time between failures) and MTTR (mean time to repair) so that the operating and support calculations used in the life cycle costs are properly calculated on an engineering rather than a budget controlled basis.

In addition to the traditional studies conducted during this phase on evaluating cost reduction opportunities, studies on the likely costs and implications on the phasing out of the systems are likely to be conducted. This will include stock reduction and disposal considerations such as scrap, resale or recycle.

3.8.6 Methods Employed

For determination of the in-service phase costs, quantitative expressions of the costs must be specified. It falls into three categories. These are:

- Cost of platform/system life-cycle operation.
- Cost of platform/system life-cycle support.
- Cost of platform/system modifications.

Methods employed during the in-service phase include system dynamics and discrete event simulation to provide predictive outcomes, but also the parametric method is used (see Chapter 4 for details). In order to capture actual costs methods like activity based costing can be used. As activity based costing provides actuals and does not provide any estimates, this methods is not considered in this report. However, both type of methods are complimentary and provide the ability to conduct “what-if? scenarios”.

3.8.7 Life Cycle Costing Process

Figure 3-21 provides a simple illustration of the life cycle costing process for this phase. It shows that at this PAPS phase the source data to support the life cycle costing is likely to be the actual costs arising from operating and supporting the system. This information can be used to refine the estimates and provide realistic simulation of future spending patterns. The cost breakdown structure should now be fully populated to provide a comprehensive view of the life cycle costs.

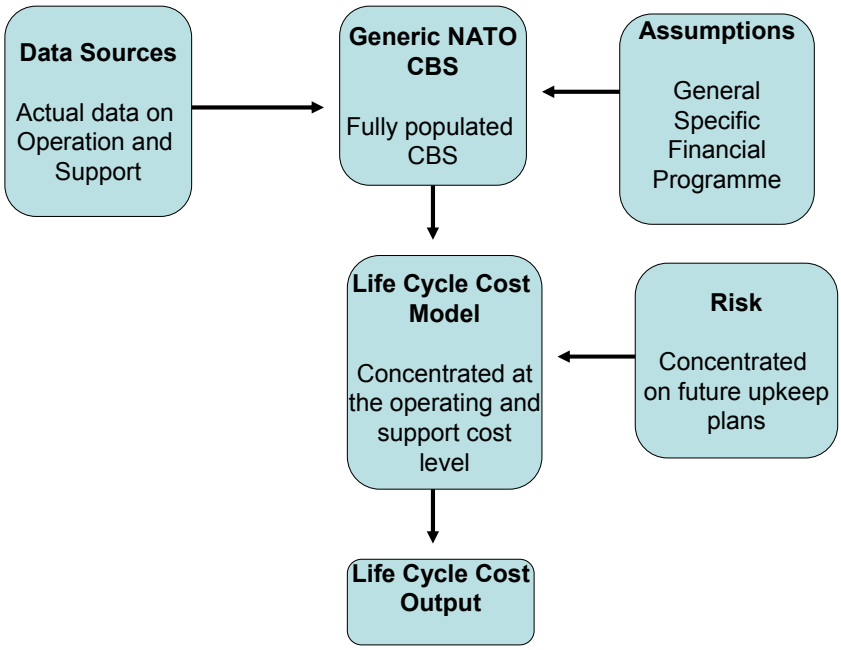


Figure 3-21: Simplified In-Service Phase Life Cycle Costing Process.

Life cycle cost studies will concentrate on future upkeep or upgrade plans as well as providing future cost spending profiles.

Any risk analysis activity at this phase will concentrate on future support plans such as alternative support solutions or planned upkeep/update programmes. As previously, these risks would be captured and recorded in a risk register and analysed with respect to the effect on future planning.

During this phase the life cycle cost output should mirror that of the actual expenditure. The output will therefore be used for future budgeting and feedback to support analysis on improving the estimating capability and the forecasting of future systems. In summary, the key considerations to the life cycle costing process for this phase are:

- The principal data sources are likely to be the actual costs incurred in the operation and support of the equipment. This can then be measured against the planned budget and use of the equipment.
- The reliability, availability and maintainability targets can be analysed against the actual effort incurred. This will provide a basis for adjusting the supportability plans.
- The life cycle costing activities are likely to be conducted using detailed cost analysis models concentrating on the operation and support functions.
- There will be very few assumptions to be recorded and assessed. Previous assumptions will have been superseded by actual data. However, financial assumptions on future escalation, exchange rates, etc., will still be made.

3.8.8 Risk Assessment

The risk assessment during the in-service phase will more likely support any studies of alternative support scenarios. The principles and practice discussed earlier are still valid for this phase. Care will be needed however, to counter any over-optimistic predictions when comparing the alternative solutions. It would be unwise to introduce any risk into an in-service programme without a comprehensive analysis of the possible outcome.

3.8.9 Example

ABC (Activity Based Costing) is a good example of an in-service life cycle cost study for determining actual costs.

ABC is an accounting technique that determines the actual cost associated with products and services produced by an organisation without regard to the organisational structure. The method has its roots in the manufacturing sector and was developed as a model to identify activities that add value and those which are non-added value with the aim of removing waste.

Activities can be defined as a named process, function or task that occurs over time and has a recognised result. Activities use up assigned resources to produce services or products for life cycle costing. These can be activities such as repair of equipment, training personnel, and in some cases a combination of military activities.

The system requires a high level of investment in developing recording schemes and element definitions.

Cost analyses are performed using an in-house model named Educational Cost Effectiveness Analysis Model (EDCAM). The interface and menu components of the model are illustrated in Figure 3-22. As shown in the figure, the model requires resources, activities, products and the allocation of resources and activities to activities and products reciprocally to be defined. The main output of the model is the cost of any defined activity based on the resources used, and the product total costs. The model also includes an effectiveness estimation module which works on multi-criteria basis. The functional capabilities of the model enable the educational planners to select the most cost-effective training programmes.

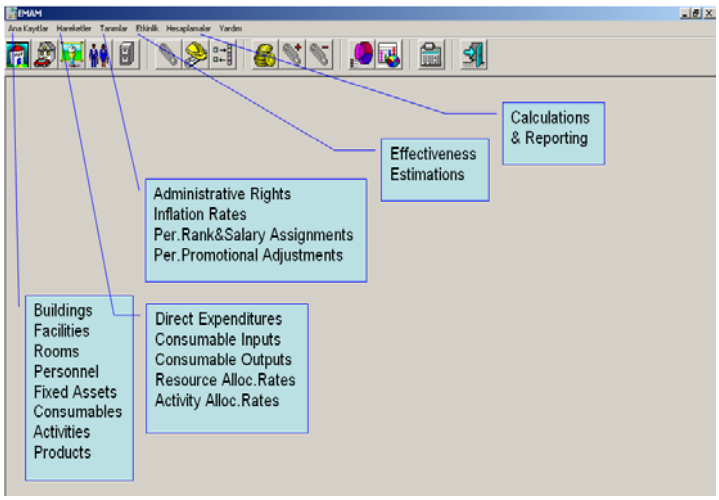


Figure 3-22: The Interface and Menu Components of EDCAM.

3.8.10 References

[31] RTO-TR-058 “Cost Structure and Life Cycle Costs for Military Systems” Technical Report.

[32] Turkish Armed Forces Logistics Concept.

[33] Turkish Navy ILS Guide.

[34] www.ams.mod.uk

[35] FAA Life Cycle Cost Estimating Handbook, Investment Cost Analysis Branch ASD-410, June 3, 2002.

3.9 NATIONAL DISENGAGEMENT

3.9.1 Summary Definition of Phase

This phase starts with a NADI (National Disengagement Intention). The NADI is a statement of a decision to withdraw equipment from operational utilisation, including forecast dates, quantities and other relevant information such as age, condition of equipment, and availability of spare parts.

However, in some NATO nations, cost estimates for this phase are conducted in the project definition phase. The estimates for the likely disengagement cost are required at the early phases in order to meet the needs of a government accounting practice whereby a funding provision (included in the life cycle cost estimate) accrues annually over the project's life to equal the value of the predicted financial liability at the end of the programme's life.

This difference of opinion (do it first – leave it till later) has caused some confusion with respect to what should be included in the life cycle costing boundary and when the cost estimates for this phase are best conducted.

For nuclear and other dangerous substances then it is clear that an estimate of the likely disposal costs should be included in the early life cycle costing analysis. For other substances where the likely financial liabilities are lower then it may be more appropriate to assess these costs at a later stage in the programme.

The following sub-sections present the view that cost estimates for this phase will be conducted at the Project Definition phase and will support an impact assessment using PESTEL (Political, Economic, Social, Technological, Environmental and Legal) analysis[6] or other similar techniques.

3.9.2 Inputs

For a preliminary assessment three primary criteria (viability, socio-political considerations and finance aspects) are defined, each of which will require evaluation on a range of issues. Examples of the criteria normally include:

- **Viability** to cover the following issues:
  - Technical feasibility.
  - Environmental Impact (technical considerations).
  - Legislation/Regulation.
  - Flexibility to change.
  - Time sensitivity.
- **Socio-political** considerations:
  - Response from Pressure Groups.
  - Public Acceptability/Concerns.
  - Acceptability to Parliamentary Groups.
  - Environmental Impact (site).

[6] PESTEL: **P**olitical factors, **E**conomic factors, **S**ocial factors, **T**echnological factors, **E**nvironmental factors, **L**egal factors. For each set of factors, you need to evaluate what is the situation and what developments are likely to take place in the next future.

  - Alignment with Government policy.
  - Alignment with International policy.
  - Historical acceptability.
  - Physical security constraints.

- **Financial** aspects including:
  - Overall cost.
  - Commitment and spend profile.
  - Risk of extra cost materialising.
  - Affordability.

3.9.3 Outputs

Each of these would have an associated critical success factor and the disposal options can then be measured and evaluated.

3.9.4 Life Cycle Cost Benefits

The long term plan should include the identification and consideration of a number of disposal options. By conducting life cycle cost analysis the following options can be assessed:

- Re-deployment (can the equipment be used for training/instructional use, as a heritage/museum asset, for spare recovery, etc.).
- Reclamation, recycling, re-manufacture (is there a possible other use as opposed to disposal).
- Sale (potential customers).
- Disposal at cost.

3.9.5 Types of Life Cycle Cost Studies

Some nations are conducting cost studies and developing estimates of the likely disposal costs during the concept and feasibility phases in order to inform and make budget provisions. The types of costing studies being conducted at this early phase are predominantly restricted to high-level estimates to support disposal option analysis and financial liability studies. In this instance, the life cycle cost would be one of the criteria measures in a rigorous assessment of the alternative options. For larger programmes where a PESTEL analysis is conducted at a later stage then the life cycle costing study would support the financial aspects taking cognisance of the results from the other measurement criteria.

3.9.6 Methods Employed

Predicting cost estimates for equipment disposal is not dissimilar to the methods employed at the pre-feasibility phase. The most common methods of estimating the likely disposal cost currently used is by analogy and parametric. These methods are well established and can calculate the negative and positive financial impact depending on the alternative disposal options being assessed. However, care should be exercised when employing both methods. To avoid error, it is essential that as much historical data as possible is gathered and evaluated to provide a degree of ‘normalisation’ such that a ‘like for like’ basis is achieved.

3.9.7 Life Cycle Costing Process

Figure 3-23 provides a simple illustration of the life cycle costing process. It shows that at this PAPS phase the source data to support the life cycle costing is likely to be immature therefore a greater reliance on the types of data sources indicated should be expected. In addition, there will be a high level of assumptions in terms of the likely performance/design parameters of the systems being evaluated. Risk is likely to be qualitative rather than quantitative.

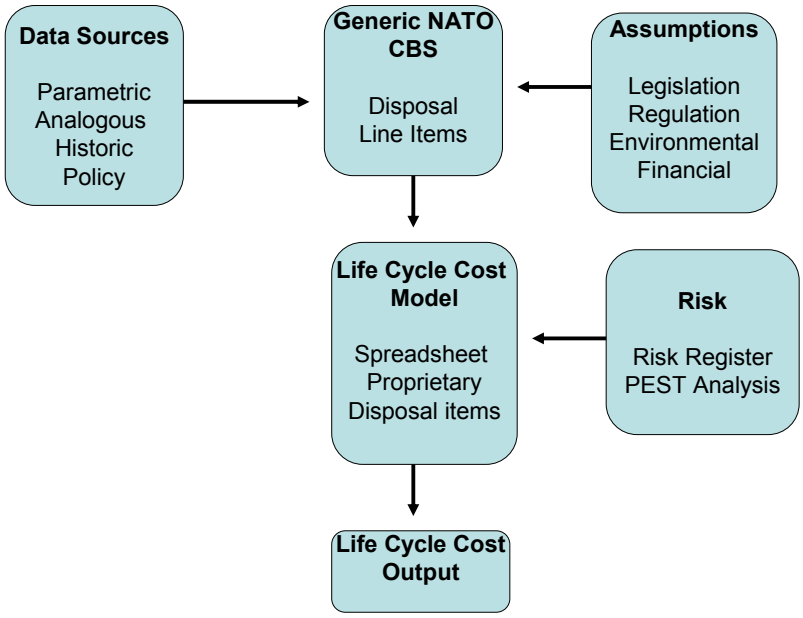


Figure 3-23: Simplified Disengagement Phase Life Cycle Costing Process.

It should be expected therefore that the life cycle cost output for the disengagement phase will be an understanding of the programme liability costs and the level of uncertainty surrounding them. In summary, the key considerations to the life cycle costing process for this phase are:

- The principal data sources are likely to be parametric based and for speed and ease of use a proprietary cost estimating model is likely to be employed.
- There will be many assumptions to be recorded and assessed.
- The risk will be measured at the very top level probably utilising some high level risk register and PESTEL techniques.
- The disposal phase costs are likely to be in the form of rough order of magnitude determined by legislation, regulation and market forces at the time.

3.9.8 Risk Assessment

The identification of risk for this phase will be conducted at a very high level. It is likely to be a combination of single line statements and will probably contain a mixture of issues as well as risks. The cost analyst will need to distinguish the difference between them in order to ensure that only those applicable risks are to be included in the cost estimate.

Where there is no risk register or risk record then another approach would be to employ an optimism bias technique. Here it could be employed to redress overly optimistic tendencies by making empirically based adjustments to the cost estimates (this technique is explained at Chapter 7).

At the very minimum, the life cycle cost estimate produced at this phase should include or indicate the level of financial risk exposure and liabilities.

3.9.9 Example

There are significant benefits and cost saving opportunities to be realised by reducing asset holdings. Current approaches include the use of marketing arrangements to examine the most cost effective disposal method.

The principal means of gaining a return on surplus inventory is either by scrap or sale. By definition, any surplus equipment or stores (excluding nuclear) will have been written off by the user organisation and therefore, in theory, are only worth their scrap value. In practice, they are a source of affordable and proven defence equipment for other countries and can provide the organisation with an additional source of income to offset any future spending.

As the costs of disposal is therefore determined by the market forces and opportunities at the time then the financial aspects of the PESTEL criteria should reflect the implication and cost associated with scrap value only.

During the in-service phase further opportunities such as re-deployment or sale may arise. These should be seen as an opportunity. A full cost benefit analysis (see Sub-section 3.3.9.2) should then be undertaken to support the decision process.

3.9.10 References

[36] Middleton, J., "The Ultimate Strategy Library", Capstone Reference.

[37] UK MoD, Operational Analysis – Foundation for the Business Case, November 2003, Director General (Scrutiny and Analysis) [unpublished MoD Documents/Reports].

[38] www.ams.mod.uk

3.10 NATO POLICY FOR SYSTEMS LIFE CYCLE MANAGEMENT AND THE FUTURE OF PAPS

3.10.1 General Comment

As stated previously, the PAPS life cycle phases have been adopted in this report because they represent a commonly accepted NATO standard. Furthermore, they are reasonably well defined and they form a natural framework for extending the process descriptions and guidelines given in PAPS to include costing activities.

It is recognised by the authors of this report, however, that while the subject and purpose of PAPS remains as relevant as ever, the document itself, though still in effect, is dated. Many references to NATO documents, agencies, etc., are no longer relevant. More importantly, NATO policy has evolved. NATO policy for standardisation now calls for the use of civil standards to the maximum practicable extent. Such a standard was published in 2002 as ISO 15288 on system life cycle processes. This standard has been adopted in NATO policy for SLCM (systems life cycle management).

At the time of writing this report, a working group under AC/327 NATO LCMG (life cycle management group) is working to update PAPS to comply with NATO policy for SLCM and the related AAP-48

on NATO life cycle stages and processes, which is a guide to implementing NATO policy for SLCM. (AAP-48 is, at the time of the writing of this report, in the draft stage.)

While it is therefore likely that the PAPS will be adapted to comply with ISO 15288, the original PAPS life cycle phase definitions are retained in this report. The rationale behind this is that the present definition is still NATO practice and that the focus of the original PAPS on the early part of the life cycle is more in line with objectives of this report.

ISO 15288 divides the system life cycle into six stages, defined later in this chapter, as opposed to the eight phases of the original PAPS. The main difference between them is that PAPS treats the earliest part of the life cycle in more detail, while ISO 15288 divides the in-service activities into utilisation and support activities. Note that mission need evaluation, the first phase of the PAPS life cycle model, is not considered part of the system life cycle in ISO 15288. A rough translation between the original PAPS life cycle phases and the ISO 15288 life cycle stages is provided in Figure 3-24.

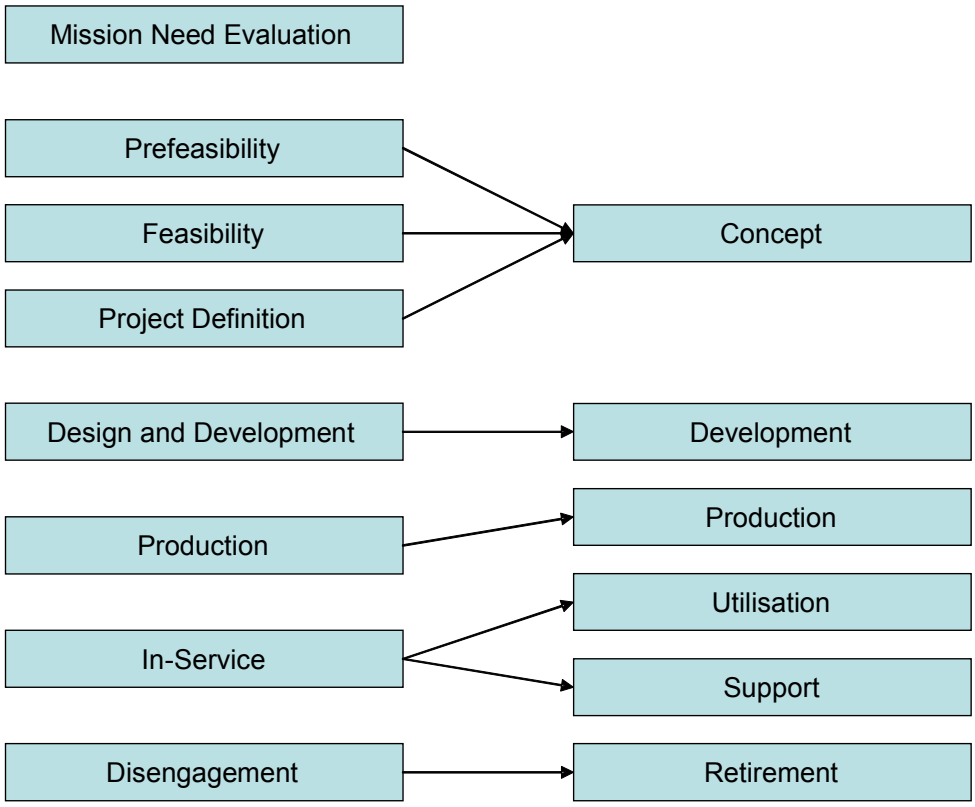


Figure 3-24: "Translation" from PAPS Phases to ISO 15288 Stages.

3.10.2 ISO 15288 Life Cycle Stage Definitions

AAP-48, NATO life cycle stages and processes is based on ISO 15288. The stages defined in AAP-48 are the same as those included in ISO 15288 AAP-48. The following definitions are therefore taken from AAP-48.

3.10.2.1 Concept Stage

The concept stage starts after the decision to fill a capability gap with a materiel solution and ends with the requirements specification for this materiel solution. The purpose is to evaluate the relative need, potential

risks, and cost benefit of a proposed system, or a major upgrade of an existing system prior to any commitment of resources. One or more alternative solutions to meet the identified need or concept are developed through analysis, feasibility evaluations, estimation (such as cost, schedule, market intelligence and logistics), trade-off studies, and experimental or prototype development and demonstration.

3.10.2.2 Development Stage

The development stage is executed to develop a SOI (system of interest) that meets user requirements and can be produced, tested, evaluated, operated, supported and retired. This stage also ensures that the aspects of future stages (production, utilisation, support, and retirement) are considered and incorporated into the design through the involvement of all stakeholders.

3.10.2.3 Production Stage

The production stage is executed to produce or manufacture the product, to test the product and to produce related supporting and enabling systems as needed.

3.10.2.4 Utilisation Stage

The utilisation stage is executed to operate the product at the intended operational sites to deliver the required services with continued operational and cost effectiveness. This stage ends when the SOI is taken out of service.

3.10.2.5 Support Stage

The support stage is executed to provide logistics, maintenance, and support services that enable continued SOI operation and a sustainable service. The support stage is completed with the retirement of the SOI and termination of support services.

3.10.2.6 Retirement Stage

The retirement stage provides for the removal of a SOI and related operational and support services and to operate and support the retirement system itself. This stage begins when a SOI is taken out of service.

3.10.3 References

[39] NATO International Staff – Defence Support Division, Allied Administrative Publication (AAP) – 20 – Handbook on the Phased Armaments Programming System (PAPS), February 1989.

[40] C-M(2000)54 – NATO Policy for Standardization, 20 September 2000.

[41] ISO/IEC (International Standards Organisation/International Electrotechnical Commission) 15288 “Systems Engineering – System Life Cycle Processes”, 1 November 2002.

[42] C-M(2005) 0108-AS1 – NATO Policy for Systems Life Cycle Management, January 2006.

[43] PFP(AC/327)D2006(0009) – Allied Administrative Publication (AAP) – 48 – on NATO System Life Cycle Stages and Processes (Draft Edition 1), February 2006.