Chapter 2 – THE ROLE OF LIFE CYCLE COSTING

2.1 GENERAL

The use of life cycle costing should, in each phase of the programme, support the process by which managers can make the best decisions on options presented to them. These options may include evaluation of future expenditure, comparison between alternative solutions, management of existing budgets, options for procurement and evaluation of cost reduction opportunities. Life cycle costing is also used for affordability assessment and determining the cost drivers associated with the Key Performance Indicators or Key User Requirements.

Life cycle costing must be used as a benchmark against which options can be measured for 'value for money' during the acquisition/production and in-services phases. However, it must be appreciated that the greatest opportunities to reduce life cycle costs usually occur during the early phases of the programme (as shown in Figure 2-1). It follows therefore that life cycle costing is used as a decision and optimisation criterion in the search of the best compromise between performance, cost and time.

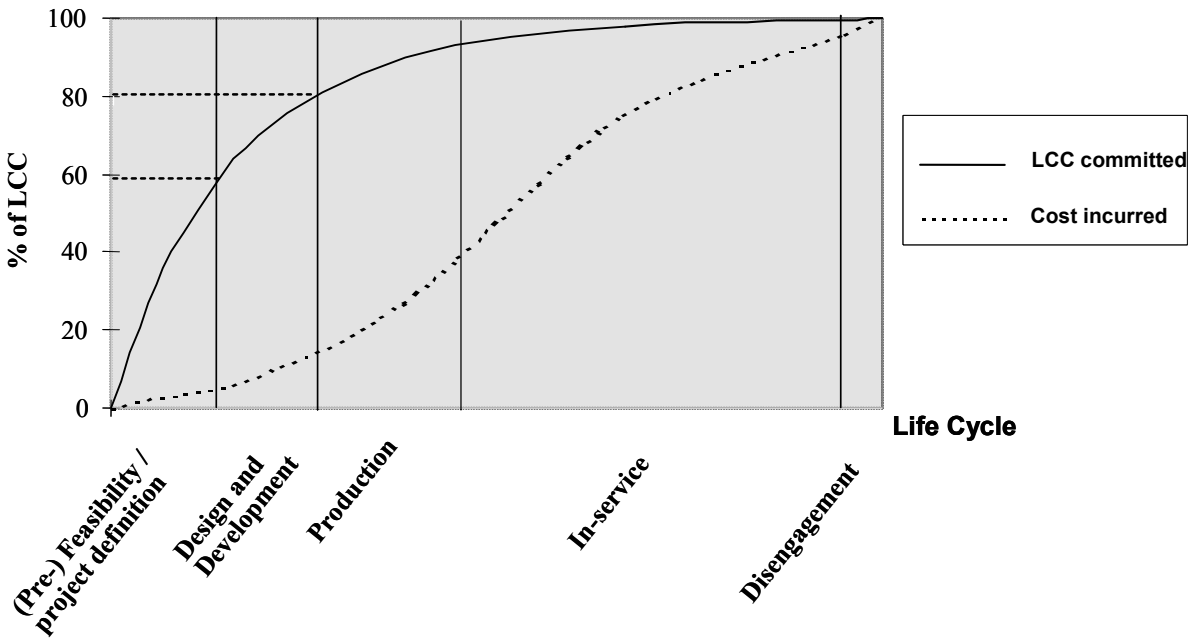


Figure 2-1: Traditional LCC Committed versus Incurred Cost Curve.

Life cycle costing should not be considered as a one-off task, but should be recognised as an ongoing activity throughout the life cycle to evaluate all programme changes and exploit cost saving opportunities.

Although this report focuses on the importance of conducting life cycle cost analysis, it should be recognised that there are limitations of such an analysis. Some of the limitations are (Reference: LCC Tutorial by Paul Barringer and David Weber):

- Life cycle costing is not an exact science. A life cycle cost analysis does not provide an exact number of the costs; it merely gives an insight in the major cost factors and an insight into the magnitude of the costs.
- The life cycle cost estimate is only an estimate. Estimates can never be more accurate than the inputs and the inputs are often estimates themselves or expert opinions.

- Life cycle cost models require volumes of data and only a few handfuls of data is likely to exist when conducting the estimate. Therefore many assumptions have to be made. The life cycle cost estimate therefore only counts given the assumptions used. If one of the assumptions changes, it is possible that the cost estimate will change too.
- Life cycle cost results are used for several purposes and, in some instances, are not compatible. For example, the life cycle cost used for a comparison or a trade-off study may not always be suitable for budgeting purposes.

These limitations should be carefully considered when conducting a life cycle cost analysis.

2.2 PHASES AND THE USE OF LIFE CYCLE COSTING

It is recognised that individual nations may use their own nomenclature for these early phases (e.g. user requirement, system requirement, etc.) and may conduct their own pre-feasibility or early conceptual work to assess the level of their capability gap. For clarity and consistency the NATO nomenclature has been used throughout. However, the processes and techniques described here are equally applicable to national and multi-national programmes.

Early in the project life cycle, studies need to address the capability gap, the numbers of equipment or platforms required and the technologies that can help to fill the gap at lowest cost. This requires a 'strategic' approach that can provide a capability to look at the 'big picture'. 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 holistic[1] values (i.e. the whole is more than the sum of its parts) in terms of the primary cost breakdown structure elements and the uncertainty surrounding these figures is required. The level of life cycle costing at this phase will support the NATO MND (Mission Need Document) and ONST (Outline NATO Staff Target). It is important to recognise in these early phases that only broad estimates or a range of estimates will be available – it is more important to ensure that they are as complete as possible (e.g. nothing large is missing).

Once the NST (NATO Staff Target) has been developed, the focus turns to the performance, cost and time envelope of various options that will meet the NST. Forecasts of the likely life cycle costs for new equipment(s) and platform(s) are needed so that the cost breakdown structure can be developed and extended to reflect the acquired knowledge of the expected system characteristics and associated costs. The life cycle costs at this phase will support the NSR (NATO Staff Requirement) by providing reasonably accurate estimates of development and production costs. However, due to the likely lack of design data the in-service costs will be more uncertain. During the project definition phase the usage patterns and system design will mature to provide a much improved basis for establishing more accurate in-service costs.

When the preferred options are identified, industry is generally asked to provide information and compete for its supply. Assessments of the bids are conducted on a life cycle cost basis and need to address all the economic and financial requirements set out by each nation. At this stage the cost breakdown structure should be fully developed such that all the cost elements are identified.

For in-service equipment a forecast of the costs for the remaining life is required. This will assist in any budget adjustment studies and provide a realistic baseline upon which to measure and compare with the effect of change due to utilisation, incremental updates, overhauls or even the procurement of new equipment.

[1] The literal meaning of "holistic" is that all the properties of a given system cannot be determined or explained by the sum of its component parts alone. Instead, the system as a whole determines in an important way how the parts behave.

In summary, it is not possible or desirable to collect and analyse information at the same level of detail throughout the life cycle although there should be a common thread in terms of programme phases, cost breakdown structure grouping and resource consumption. What should be seen is a life cycle cost estimate that evolves, in terms of detail, as the programmes progresses through the different phases.

Further discussion on the processes and methods applicable to each phase of the project life cycle is given at Chapter 3.

2.3 APPROACH TO LIFE CYCLE COSTING

Prior to any costing activity it is essential to define what is to be estimated and understand what the estimates will be used for (e.g. setting budgets, options evaluation, pricing, etc.). The system under consideration could range from a large turnkey project (e.g. a major capital investment including buildings and infrastructure), a stand-alone system (e.g. individual platforms such as a ship, aircraft or tank), or a worldwide application (e.g. theatre(s) of operation and use). The approach to be adopted needs to be tailored to suit the questions to be answered, the costing requirements and the availability of suitable data.

With some variation (to the level of detail), the same basic approach to life cycle costing can be applied to all projects regardless of their specifications. This approach encompasses the following steps that are more fully described in the subsequent sub-sections. The steps are:

- Define the aims and objectives of the study.
- Establish the programme content, the costing boundary and the assumptions for the study.
- Develop the structure of the life cycle cost framework.
- Establish the data and populate the life cycle cost framework.

Once the scope of the study has been established the overall cost estimating process can commence as shown in Figure 2-2. It may be necessary to undertake several iterations following the first set of results due to the availability of more data, clarification of the assumptions or just general refinement. The process is completed with the presentation of the results, assumptions and financial implications.

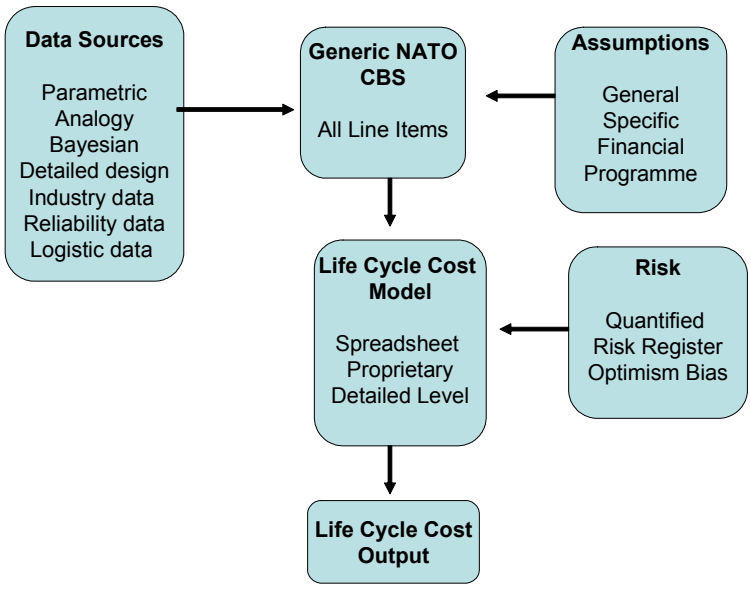


Figure 2-2: Generic Life Cycle Cost Estimating Process.

2.3.1 Define the Aims and Objectives

The aim and the objectives of the study will have a major impact on the way a study is conducted. A different type of question will result in a different way of conducting the study. This will often be implicit in the type of study being undertaken, but it needs to be clearly and unambiguously defined if the life cycle cost study is to provide useful and meaningful results. An overview of the type of studies to be conducted can be found in Section 2.6. Early procurement phases will concentrate on assessing affordability, option analysis, etc., when the level of data to support a life cycle cost analysis is sparse. It is essential therefore to undertake several iterations of the process due to clarification of the assumptions and general refinement of the data. This stage would also include the definition of the systems and/or options to be studied.

2.3.2 Establish the Costing Boundary and Assumptions

The Costing Boundary defines exactly what cost elements will be included in the study and the level of detail in which they will be considered. The level of detail of the study is also dependent of some external factors, like the maximum duration of the study, the financial means available to conduct the study, the availability of qualified personnel to conduct the study, the availability of experts to provide information and the availability of data.

There are three boundaries to consider. The first boundary relates to the definition of the system itself particularly the elements for costing. It is worth describing the total system and then agreeing with the stakeholders those elements that are outside the scope of the study. In this way a clear picture is drawn which helps to avoid any confusion later in the study.

The second boundary definition addresses the timescale aspects so as to establish which programme phases have to be included, e.g. phased procurement, phased implementation, incremental build standards, in-service date and the likely operating life of the proposed system (see Sub-section 2.8.3 for details of the time period consideration to be made).

The third and last boundary consideration defines what will be included within the scope of the study. This can range from the simple cost of buying a piece of equipment to the total cost to the government or industry of developing, procuring, operating, supporting and disposing of a complete range of such equipment.

To ensure completeness, a full list of all possible cost elements should be first drawn up which covers all phases in the project life cycle. These cost elements should then be reduced by elimination of those falling outside the specified cost element boundary. This costing framework should be based on the NATO generic cost breakdown structure (Reference: RTO-TR-058 report). In Chapter 10 some enhancements to this cost breakdown structure are suggested.

Figure 2-3 shows an example (taken from ANEP-41) on how the costing boundary expands firstly from just considering an equipment purchase (equipment buy) to the involvement in a development and production programme (procurement programme) and then into inclusion of the in-service costs. Further costs such as capability upgrades, etc., are included if the intention is to provide a forecast of future cost expenditure over the life of the programme. The costing of the final element shown is dependent upon each national requirement. Typically, an apportionment based on the expected use is agreed with the respective stakeholders and is added to the cost estimates for completeness.

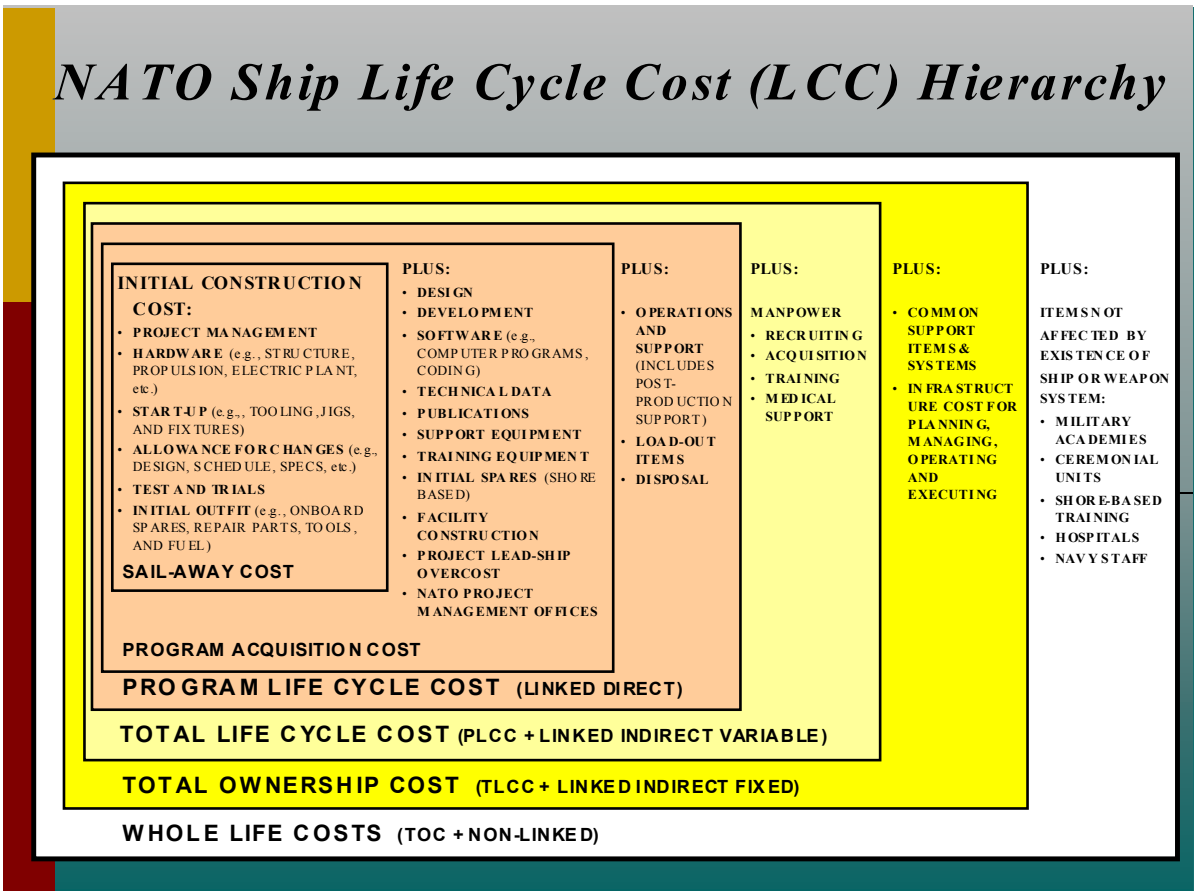


Figure 2-3: Typical Life Cycle Cost Boundary.

Whenever an estimate is undertaken, it is necessary to create a series of statements that define the conditions upon which the estimate will be based. When conditions are directed upon the estimator, they become the ground rules by which the estimate will be conducted. In the absence of a firm ground rule the estimator can define assumptions. Because of the potentially significant cost implications of key assumptions and ground rules, it is good practice to undertake a sensitivity analysis of them.

It is essential that all the data, ground rules and assumptions are captured and recorded so that there is a complete audit trail to the estimate. There is no NATO document that reflects this requirement. The next sub-sections describe how the UK and the US capture and record this.

2.3.2.1 UK Master Data and Assumptions List

The UK Ministry of Defence use and recognise a MDAL (Master Data and Assumption List) (Reference: www.ams.mod.uk). This is a comprehensive document that records all the data used in compiling the estimate and all the respective stakeholders are expected to sign that they agree with the data and assumptions recorded in the document. The process can be considered as laborious and time-consuming (but is essential) and in rapidly changing studies (e.g. pre-feasibility and concept) the requirement for a fully completed MDAL becomes cumbersome and constraining. This is overcome through the development of an abbreviated form of MDAL which may only be a few pages, but will contain all the salient points. This will be developed by the life cycle cost analyst and presented to the stakeholders for agreement. Developing the document in this manner ensures that the estimates can be produced rapidly and consistently to support option analysis and affordability assessment studies.

2.3.2.2 US Cost Analysis Requirements Description

In the USA a process is adopted to establish the costing boundary; this provides the basis for the cost estimate. For major acquisition programmes, the CARD (Cost Analysis Requirements Description) is used to formally describe the acquisition programme (and the system itself) for the purposes of preparing both the programme office cost estimate and the US Department of Defense Component[2] cost position, if applicable and the OSD CAIG independent cost estimate[3].

The CARD is prepared by the programme office and approved by the DoD Component Programme Executive Officer (PEO). For joint programmes, the CARD includes the common programme agreed to by all participating DoD Components as well as all unique programme requirements of the participating DoD Components[4].

The CARD typically provides both narratives and tabular data, roughly following the following outline:

- All ground rules and assumptions to be used in developing the cost estimates.
- System description and characteristics.
  - System work breakdown structure.
  - Detailed technical and physical description.
  - Subsystem descriptions, as appropriate.
  - Technology maturity levels of critical components.
- System quality factors.
- Reliability/Maintainability/Availability.
- Project Managers' assessment of programme risk and risk mitigation measure.
- System operational concept.
  - Organisational/unit structure.
  - Basing and deployment description (peacetime, contingency, and wartime).
- System support concept.
  - System logistics concept.
  - Hardware maintenance and support concept.
  - Software support concept.
  - System training concept.
- Time-phased system quantity requirements.
- System manpower requirements.
- System activity rates (OPTEMPO or similar information).
- System milestone schedule.
- Acquisition plan or strategy.

[2] A "Component" is a military department or a defence agency.

[3] DoD Instruction 5000.2, Enclosure 3 specifies that for major defence acquisition programmes the CARD will be provided in support of major milestone decision points.

[4] DoD 5000.4-M, DoD Cost Analysis Guidance and Procedures, Chapter 1 provides further guidelines for the preparation of the CARD.

For each topic listed above, the CARD should provide information and data for the programme to be costed. In addition, the CARD should include quantitative comparisons between the proposed system and a predecessor and/or reference system for the major topics, as much as possible. A reference system is a currently operational or pre-existing system with a mission similar to that of the proposed system. It is often the system being replaced or augmented by the new acquisition. For a programme that is a major upgrade to an existing weapon platform, such as an avionics replacement for an operational aircraft, the new system would be the platform as equipped with the upgrade, and the reference system would be the platform as equipped prior to the upgrade.

Clearly, much of the information needed for the CARD is often available in other programme documents. The CARD should stand-alone as a readable document, but can make liberal use of appropriate references to the source documents to minimise redundancy and effort. In such cases, the CARD should briefly summarise the information pertinent to cost in the appropriate section of the CARD, and provide a reference to the source document. The source documents should be readily available to the programme office and independent cost estimating teams, or alternatively can be provided as an appendix to the CARD. Figure 2-4 illustrates the process.

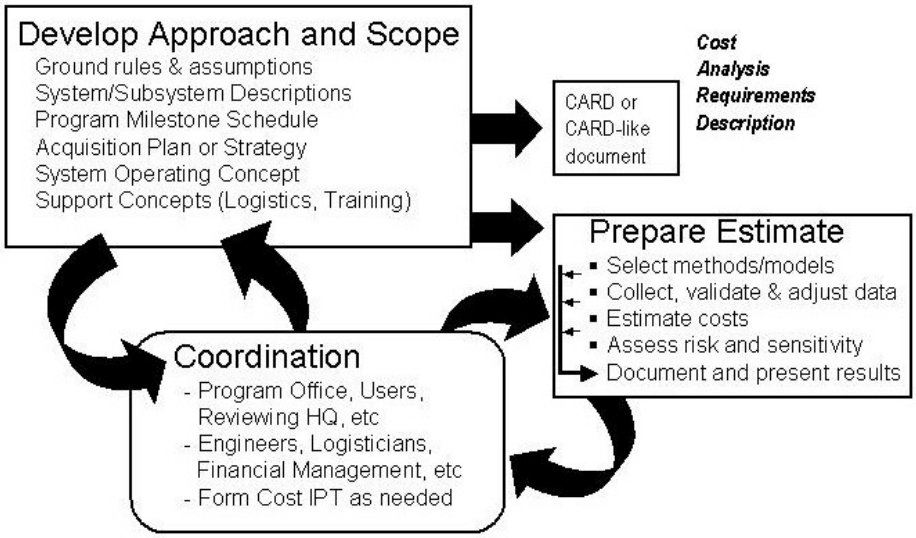


Figure 2-4: USA Cost Analysis Process.

It is recommended that all the assumptions used and recorded be questioned by an independent technical team.

2.3.3 Develop the Structure of the Life Cycle Cost Framework

Having established the costing boundary this will set the requirements for the life cycle cost framework (e.g. the implementation could be a spreadsheet or more advanced modelling techniques). The costing framework should take account of both the immediate needs of the current phase and also to be adaptable to the developing needs of later phases.

The structure of the framework will be based on the requirements previously discussed at Sub-sections 2.3.1 and 2.3.2. A typical outline for a generic life cycle cost model is shown at Figure 2-5.

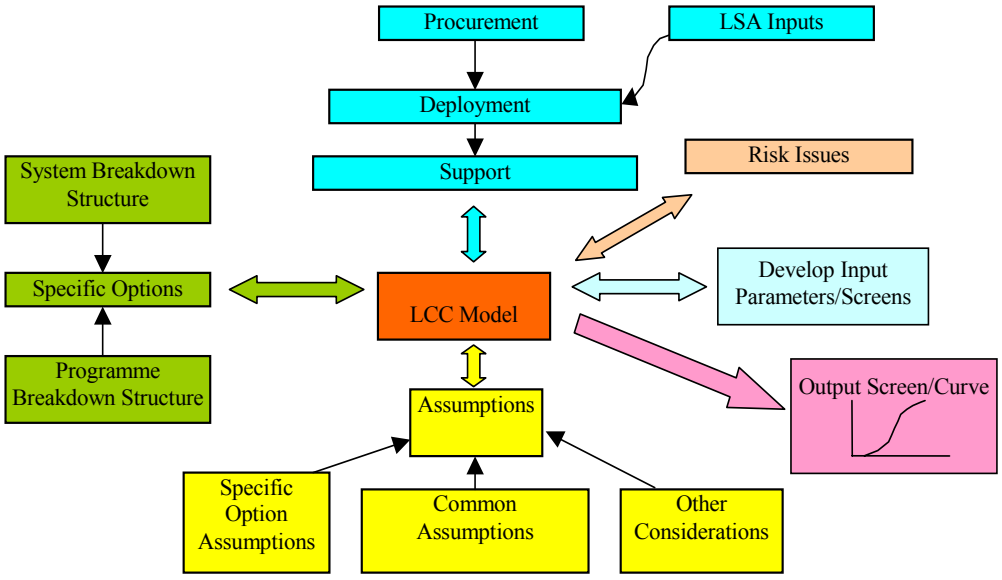


Figure 2-5: Example of a Typical Life Cycle Cost Framework Structure.

The figure shows the framework broken down into a number of areas. On the left (in green) would be the cost breakdown structure reflecting the system, any specific options relating to the system and details of the programme timescale. On the top (in blue) would be the programme documentation relating to procurement strategy, how the system will be deployed in operational and peacetime use and how it will be supported in these environments. The ILS (Integrated Logistic Support) and the LSA (Logistic Support Analysis) inputs would support the understanding of the proposed deployment. At the bottom (in yellow) would be the ground rules and assumptions. These would be recorded in a document and the information would be used to populate the areas of the model where no hard data was available. On the right hand side, the risk issues could be included within the model so as to obtain a 'risk adjusted' cost. To avoid an over complicated implementation it may be necessary to develop some suitable input and output screens to assist the user.

It is essential that all life cycle cost models are robustly tested and validated to ensure the correct operation of the equations in relation to the input attributes.

2.3.4 Establish the Data and Populate the Life Cycle Cost Framework

Once the structure of the life cycle cost framework has been established, the cost breakdown structure needs to be populated. The cost breakdown structure will comprise a number of cost elements. These cost elements will need to be estimated. The method of establishing the estimate will depend on the availability of the data. An overview of the methods to estimate costs can be found at Chapter 4.

Typical methods employed to gather data are:

Market Survey

This is usually good for gathering technical data, but limited in obtaining prices. Any costs obtained are likely to have a large margin of error and will have little or no substantiation.

Industrial Visit

This will produce information and data on the product, but it is unlikely that the companies will provide anything more than broad order cost and again with no substantiation.

Data for Direct Use Within the Study

This would be actual costs or estimates directly relating to the breakdown of the system. Actual equipment procurement costs, published data for equipment and services, etc., could fall directly into this category. A considerable element of these costs will be based on current records and may be held by specialist cost estimating departments or consultancies.

Data on Analogous Systems

This could be low level, technical and other data on the system under consideration for use in parametric or other modelling methods to derive the required information. Size, weight, complexity, reliability could be examples of this kind of data.

Data from Logistic Analysis

This would be information and data from ILS (Integrated Logistic Support) studies to provide data on component reliability, maintainability and supply chain information. The cost estimator should be aware of the following essential ILS information to support the life cycle costing (accepting that some of these will not be available in the early phases of the programme).

The work frame and interfaces of the ILS Programme for a generic defence system are described in an ISP (Integrated Support Plan). This is the main ILS management plan. Specific plans are applicable to the ILS Programme, for example (but not exclusively) the following:

- LSAP (Logistic Support Analysis Plan).
- Reliability and Maintainability Programme Plan.
- LCC (Life Cycle Cost) Plan.
- MANPRINT (Manpower and Personnel Integration) Plan.
- LORA (Level of Repair Analysis) Plan.

The LSA (Logistic Support Analysis) constitutes the on-going iterative analytical process that is employed to:

- Assess a given or assumed configuration in terms of its inherent supportability characteristics.
- Identify the ultimate support requirements for that configuration.

It should be emphasised that the results from the LSA contribute to life cycle cost in two distinct ways:

1) The application of the analysis provides data from which life cycle costs are derived; and

2) LSA results contribute to the reduction of life cycle costs by indicating the support cost drivers for the system and thus providing feedback for the ILS design influence.

The life cycle cost evaluation (see Figure 2-6) is based on the life cycle cost modelling effort, which in turn takes advantage of the Use Study to establish the full range of operational parameters necessary for the calculation of realistic costs.

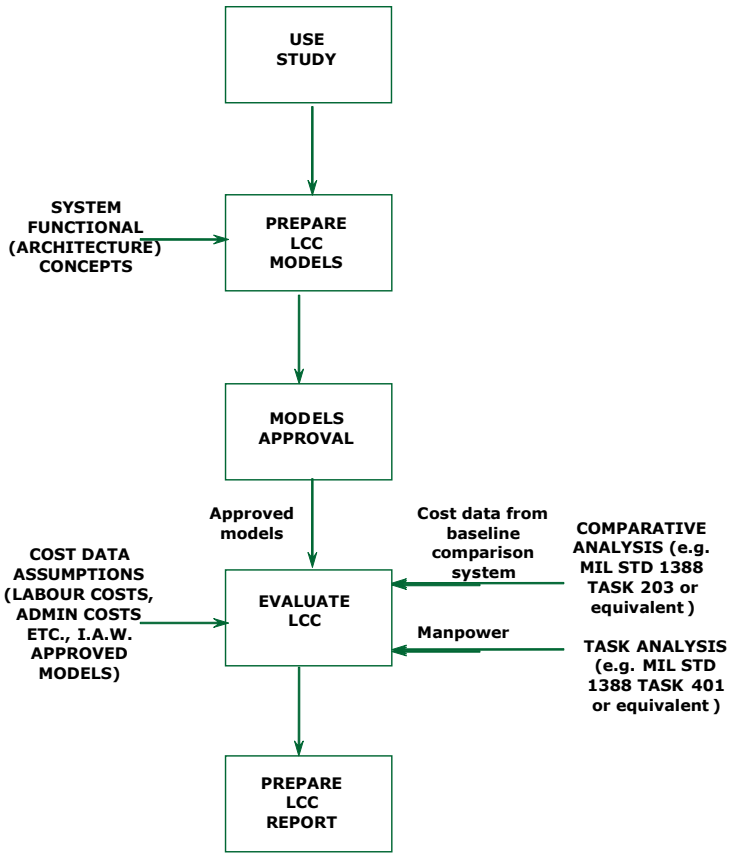


Figure 2-6: Process Flow for Determining LCC Support to Logistic Analysis.

Additional inputs to the life cycle cost evaluation can come from the execution of LSA Task 203 (Comparative Analysis) and Task 401 (Task Analysis).

The purpose of Task 203 is to identify, by using comparative elements, supportability problems that have arisen in the employment of systems already in service and to identify supportability, cost and readiness drivers that must be considered as critical in the comparative system design.

As regards Task 401, its purpose is to focus on potential critical support elements and to influence the system design in order to reduce the impact of critical support elements.

The LSA task results are documented in the LSAR (Logistic Support Analysis Record) to identify and develop logistic support resources.

The LSAR database is initiated early in a programme to capture logistic requirements, identify functional logistic breakdown structure and document the initial results of the LSA tasks. Prior to the production phase, the LSAR database is used to: identify the complete logistic breakdown structure; control logistic performance of the system; identify operating and maintenance tasks, logistic support resources and transportability characteristics. During the production phase, the LSAR database is used to update the identification data due to configuration changes, document the LSA task updates and document the results of validation of the technical documentation. During the in-service phase, the LSAR database is used to capture R&M (Reliability and Maintainability) data related to the use and support of the system, update logistic data due to configuration changes, manage obsolescence and the effect from any maintenance organisation changes.

Figure 2-6 illustrates how the information flow from various documents and studies are combined in order to provide the life cycle cost to support logistic analysis studies.

2.4 CONDUCTING THE COST ANALYSIS

The level of analysis required by different studies varies considerably. In some circumstances, simple accountancy calculations involving discounted cash flow may be all that is required. Cost analysis would traditionally include the testing of parameters and assumptions by means of sensitivity analysis. Testing of alternative assumptions by means of "what if" analyses should also be conducted. It is essential that any life cycle cost model has the ability to support these types of analyses so that the decision-makers have a full understanding of the costs and the financial implications.

Quantitative cost risk analysis may also be employed to either gain more insight into specific risk areas or to evaluate a programme's overall exposure to risk. A key feature of this approach to analysis is that it should provide forecasts and insights based on complex combinations of risks and uncertainties, as could occur, for example on major projects. Commonly used techniques include Monte Carlo analysis and System dynamics. Figure 2-7 shows the benefit of conducting cost risk analysis in addition to the more traditional accountancy methods of establishing financial outcomes.

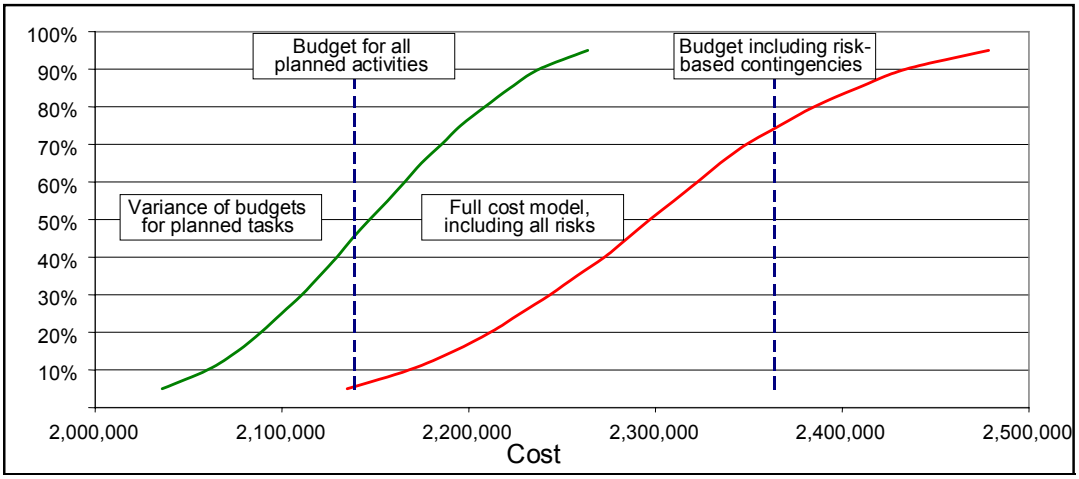


Figure 2-7: Cost Risk Analysis Outputs Example.

The first curve (green) represents the uncertainty in the cost estimate arising from uncertainty in the data and methodology employed in developing the estimate. The second curve (red) represents the extent of the risk in the programme arising from the relevant risks recorded in the programme risk register. In examining both curves the decision maker can establish the level of acceptable financial risk dependent upon the confidence in the cost estimate. More details on uncertainty and risk analysis can be found in Chapter 7.

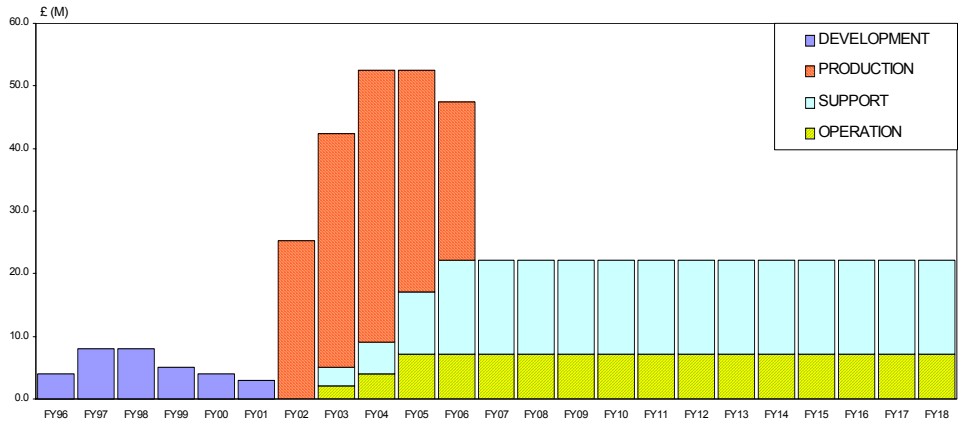
2.5 PRESENTATION OF THE LIFE CYCLE COST RESULTS

Summaries of the life cycle cost outputs and the underlying assumptions should be discussed with the stakeholders at the earliest opportunity. This will allow for changes and refinements to be incorporated prior to the issue of a final report. The objective at all times is to ensure the life cycle cost study is meaningful and fully meets all the stakeholders' needs.

The results of cost studies can be presented in a wide range of tabular and graphical forms. The favour is to include graphical presentations of the results wherever possible. This enables the widest possible

audience to have a clear picture of the overall results while retaining the detailed tabular presentations for those that require them.

Two common form of graphical presentation (the spend profile and cost allocation pie chart) are shown as Figures 2-8 and 2-9. These figures indicate costs at a high level, but can also be used to present a more detailed level as required. For presentation purposes these costs have been truncated at Financial Year (FY) 18.



£ (M)	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
DEVELOPMENT	4.0	8.1	8.1	5.1	4.0	3.0																	
PRODUCTION							25.3	37.4	43.4	35.4	25.3												
SUPPORT								3.0	5.1	10.1	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2
OPERATION								2.0	4.0	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1

Figure 2-8: Example of a Baseline Life Cycle Cost Spend Profile.

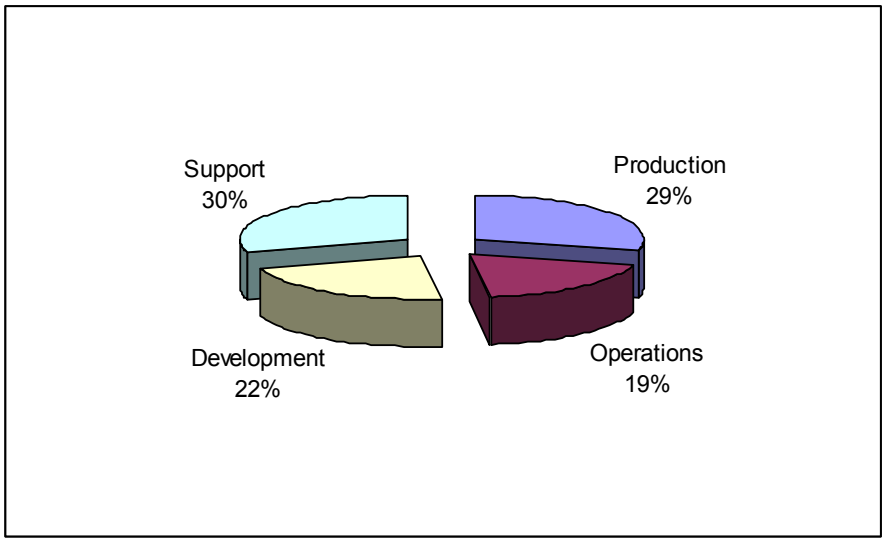


Figure 2-9: Example of a Life Cycle Cost Allocation.

Note: The cost allocation percentage shown in the example above should not be considered as being representative of all life cycle cost estimates.

The product of the life cycle cost study should be a report incorporating the results and conclusions as well as a presentation on the basis of those results. It should include a full definition of the aims and conduct of the study, the definitions of the options studied, the costing boundary considered and the assumptions underlying the cost elements. This work should also be continuous to support the life cycle management of the programme.

The figures above represent single point estimates with no consideration to the presentation of uncertainty and risk. ***Figure 2-10 presents a recommended approach for communicating results of a life cycle cost estimate to senior decision makers.***[5] The top line shows a three point range of estimates, and conveys the idea that a cost estimate is not a single number, but rather a continuum or distribution of possible values.

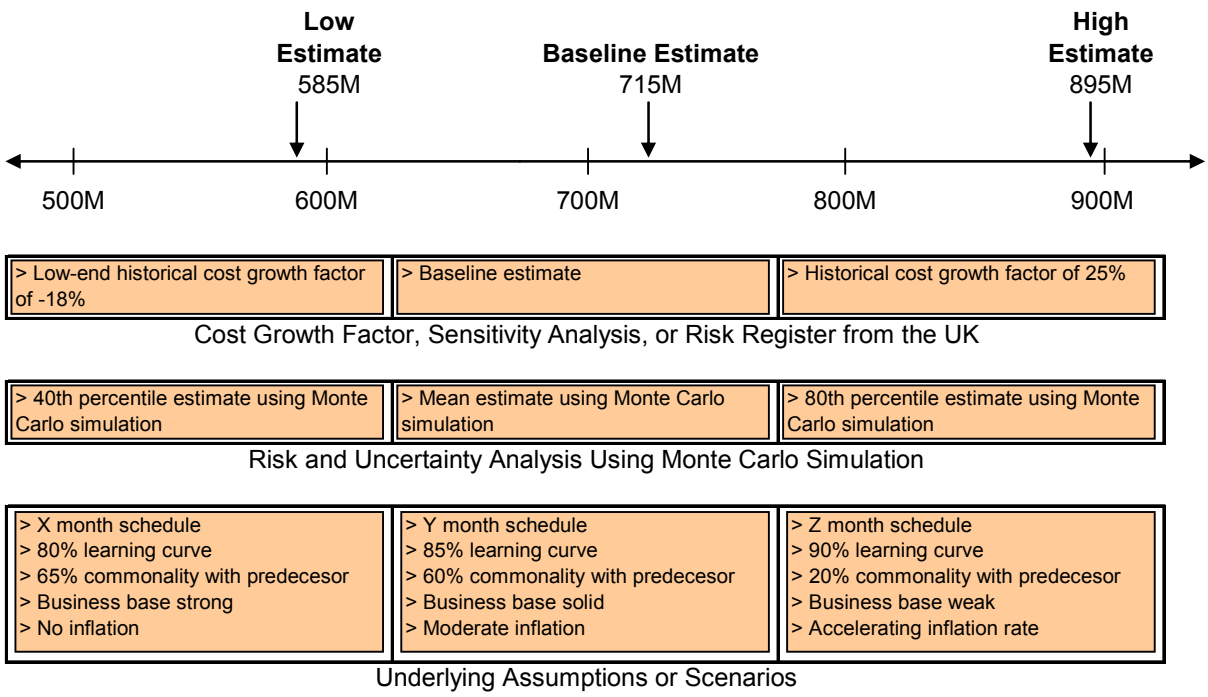


Figure 2-10: Recommended Presentation of Cost Estimating Risk Analysis.

Analysts can use one or more estimation techniques in performing risk and uncertainty analysis. Some of these are shown in the top two bars or sections of the figure. The bottom section, which should always be included in the presentation of the estimate, shows all of the assumptions or scenarios associated with the low, baseline, and high estimates. Including this section enables decision makers to see clearly the cost implications of events that can influence the outcome of an acquisition programme.

This approach will lead to the establishment of a sound, well-structured methodology for the conduct of and presentation of life cycle cost estimates.

2.6 FINANCIAL THRESHOLD

Some nations have set a financial threshold for conducting life cycle costing studies. For example, in The Netherlands a life cycle cost analysis (as part of the defence materiel process) is performed for all projects with a total budget in excess of €5 M. Others have no limits, but are determined by:

[5] U.K. Ministry of Defence and **Impossible Certainty**, RAND, 2006, pages 84-86.

- The level of detail required.
- The benefit the life cycle costing study will bring to the programme.
- The rigor necessary to support the business/programme investment.
- The likely effort to be expended.

It is recommended that each nation sets its own threshold value and that it should be determined in terms of total programme cost, political requirements and timeliness.

2.7 ORGANISATION AND OWNERSHIP OF THE LIFE CYCLE COST

The life cycle cost analyst or manager should be the owner of the development of any life cycle cost estimate and the configuration management of the supporting documentation.

The role of the life cycle cost analyst is to ensure the smooth running and facilitation of the total life cycle cost management process. In summary, the analyst should be responsible for:

- Ensuring that an appropriate life cycle cost management plan is in place and updated where necessary.
- Supporting the programme by providing robust and credible life cycle costs in a timely manner.
- Ensuring that the life cycle costing process is appropriate, workable and supports the programme requirements.
- Eliciting life cycle cost information from both the government and contractor project teams.
- Reviewing all assumptions and contractual change notices from the project teams and advising the programme manager of any points of issue.
- Providing guidance and assistance for the cost risk analysis and associated reports.
- Ensuring the smooth running and facilitation of the total life cycle cost management process, including the regular reporting procedures.

To achieve the above in the most practicable, auditable and robust manner it may be necessary to conduct the life cycle cost analysis using multiple methods and/or independent experts. This will depend on the overall value of the likely programme costs and the level of robustness needed for the government approval process.

2.8 TYPICAL APPLICATIONS OF LIFE CYCLE COSTING

One of the principal objectives of life cycle costing is to reduce or control the life cycle cost by assessing the financial impacts of the decisions taken about the complete system.

Three broad classes of applications rely on the output from life cycle costing and are discussed in detail below. These are:

- Determining the forecast of future spending.
- Examining comparisons between alternative solutions (e.g. alternative assets, design trade-off, supply chain analysis, etc.).
- Supporting the tender evaluation process.

In all cases, the output of the life cycle costing provides information to support the decision making process. Note however, that cost is just one of many criteria that could influence the decision. Other criteria such as operational effectiveness, technical risk, political and industrial policy constraints, etc., also have to be considered in the decision making process and are sometimes more important than cost.

2.8.1 Determine the Forecast of Future Spending – Defence Budget Planning Applications

Budget planners are often confronted with choices between several distinct systems (e.g. aircraft or UAV or missiles; ships or forward bases, etc.). The life cycle cost estimate can help the decision process by addressing the following typical questions:

- In consideration of long term planning applications (~10+ years):
  - What will be the cost of the systems currently being designed (both in terms of money spent annually and of the number of service personnel required to man the systems)?
  - What is the best ratio between money spent on investment (new systems or upgrades of 'old ones') and that spent in order to keep the readiness of currently available systems?
- In consideration of short term planning applications (~next 1 to 4 years):
  - How many systems (or individual platforms) can we afford (now) and still maintain some flexibility in future budgets (considering their estimated in-service costs)?

2.8.2 Examining Comparisons between Alternative Solutions

Comparative studies are particularly valuable in the early stages of planning when the primary objective is to establish an efficient and economical course of action. Comparative studies are, actually, used throughout all phases of a system's life cycle; they are also used in selecting in-service options such as in-house or contractor support.

An analytical comparison of the operational effectiveness, suitability and life cycle cost of alternative programmes that satisfy established capability needs is referred to as AoA (Analysis of Alternatives). An AoA broadly examines multiple elements of programme alternatives including technical risk, design maturity and cost. AoAs are intended to:

- Illuminate the risk, uncertainty and the relative advantages and disadvantages of the alternatives being considered.
- Show the sensitivity of each alternative to possible changes in key assumptions.
- Help decision makers in determining whether or not any of the proposed alternatives offer sufficient operational and/or economic benefit to be worth the cost. As a general rule, the preferred alternative is the alternative that provides the greatest amount of benefits in relation to its cost.

2.8.3 Supporting the Tender Evaluation Process

In the tender evaluation process the life cycle costs can be used to ensure that the contract award is made to the tenderer who offers a system that meets all technical and availability requirements at minimum life cycle cost. The cost of investment in reducing maintenance resources and the cost of lifetime support will be weighed against the cost of investment in the overall system. The resulting life cycle cost will therefore be beneficial to the overall tender evaluation process.

To establish a cost-effective in-service phase it is essential to consider operating and maintenance issues at the same time as the procurement of the system. The life cycle cost from the evaluation process can often be used as a baseline for negotiation on contractor logistic support contracts.

The choice of a proper time period (system life) in the life cycle cost evaluation process must be considered. For example, many parameters can influence the selection of a well balanced time-period. Very often the total technical life of a system may not be the most appropriate time period for the life cycle cost evaluation. A shorter time-period takes more consideration of the initial acquisition costs, and a longer time-period takes more consideration of the recurrent ownership costs.

Figure 2-11 presents the life cycle costs for two competing systems A (green) and B (red). The initial acquisition price for System B is less expensive than for System A. However, System A has lower annual cost for ownership than System B. At year 10 the cost-lines intersect, and after year 10 System A has a lower life cycle cost compared to System B. The example shows the complexity of choosing the "correct" time period to include in a tender evaluation. This example clearly demonstrates that the selection of a life cycle time period must be tailored and well balanced to fit its purpose.

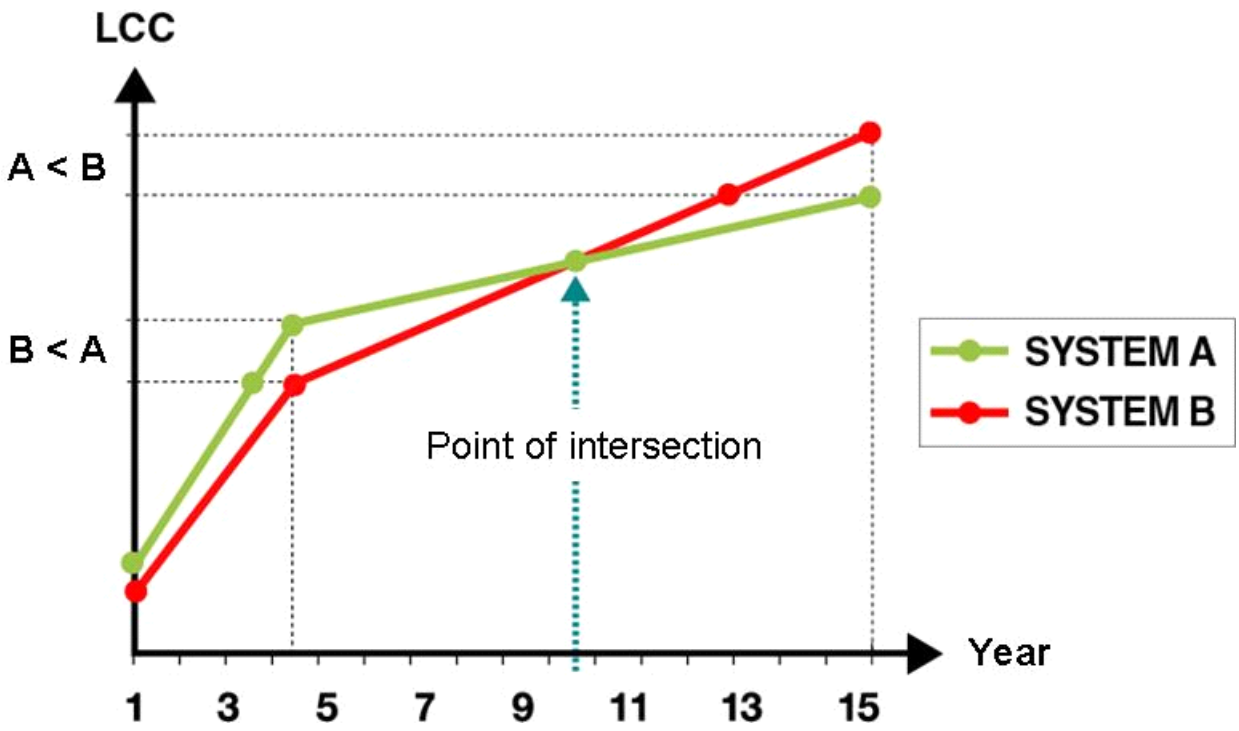


Figure 2-11: Example of Time-Period Consideration.

To ensure that all the tenders are impartially evaluated it is vital that the cost breakdown structure is defined by the procurement agency. This should include a definition of all the cost elements. Sufficient data on the likely use of the system should also be included in the request for quotation. This will improve the prospective supplier's ability to independently assess and possibly improve their offer.

It is recommended that a life cycle cost questionnaire is issued with the request for quotation so that the procurement agency can conduct an independent comparative life cycle cost evaluation on all the tenders. This will improve the understanding of the tender offer and provide a degree of credibility in the life cycle cost results.

However, before the request for quotation is issued, it is important that all the preparatory work has been independently conducted and that the Key User Requirements are well balanced between functionality and likely costs.

A life cycle cost evaluation starts with the quality of the submitted tender data. In most cases it is necessary to iterate the process several times in order to obtain clarification and to explore opportunities for improvements. Figure 2-12 shows the tender evaluation process with specific feedback to the tenderers in order to exploit opportunities for cost reduction. The tender evaluation process is completed by documenting the LCC results in an evaluation report before the contract can be awarded.

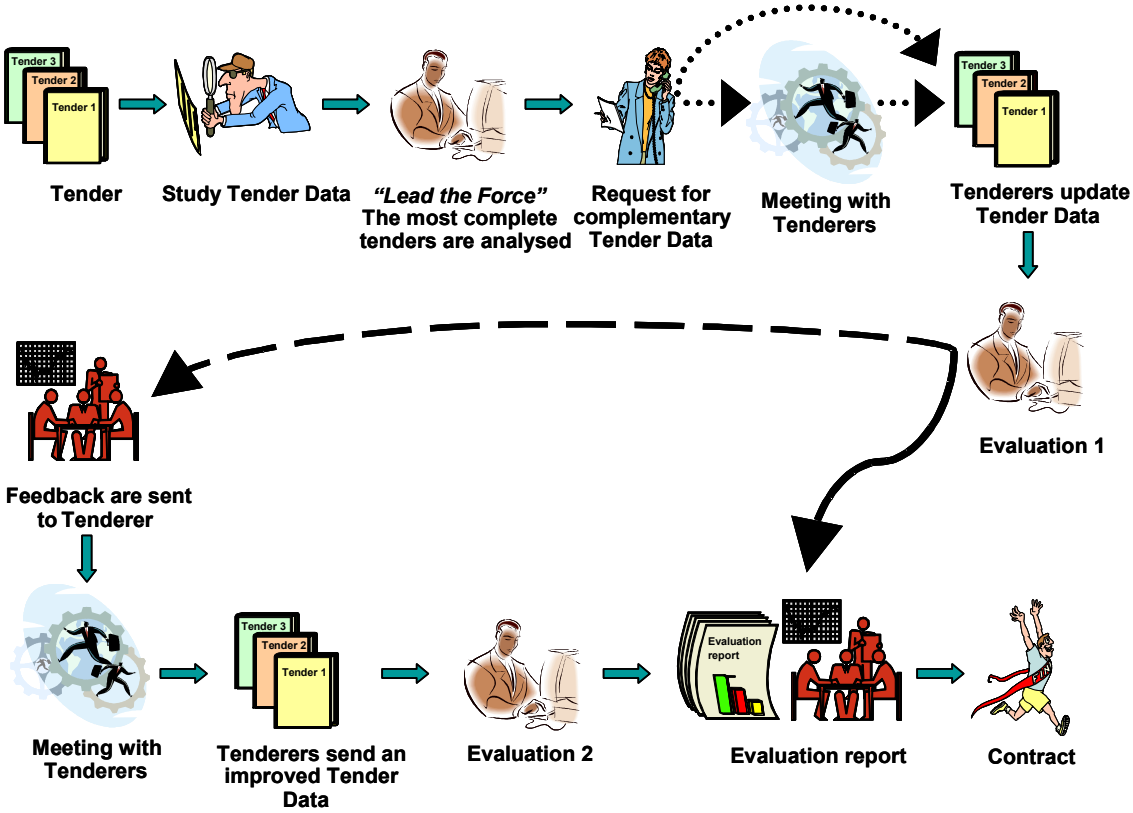


Figure 2-12: LCC and the Tender Evaluation Process.

2.9 ASSESSING AFFORDABILITY

This is not common practice in all nations, but it is one that we recommend should be conducted.

By definition, affordability can be considered as the degree to which the life cycle cost of an acquisition programme is **in consonance** with the long-range investment and force structure plans of national defence administrations. Affordability procedures establish the basis for fostering greater **programme stability** through the **assessment** of programme affordability and the **determination of affordability constraints**. In this context:

- **In consonance** means delivering systems that meet the customer's needs and budget.
- **Programme stability** means working towards sustainable opportunities.
- **Assessment** means creating a programme management strategy that guarantees programme viability.
- **Determination of affordability constraints** means bringing affordability to the foreground to avoid misconceptions in management and engineering which may ultimately lead to unaffordable design solutions.

Affordability plays an important part in programme decisions throughout the life-cycle. Even before a programme is formally approved for initiation, affordability plays a key role in the identification of capability needs. Programme affordability is part of the process which balances cost versus performance and in establishing key performance parameters.

The exact approach to the affordability assessment can vary, depending on the nature of the programme. However, in general, the assessment should address programme funding and manpower requirements over the whole life period. The assessment also should show how the projected funding and manpower fits within the overall plan for simultaneous programmes. The assessment should highlight those areas where the projected funding or manpower share exceeds historical averages, or where the projected funding or manpower exceeds zero real growth from the last year of the programming period. For the issues highlighted, the assessment should provide details as to how excess funding or manpower demands will be accommodated by reductions in other mission areas, or in other (e.g. non-modernisation) accounts. To illustrate this approach, this section provides a notional example of the type of analyses that could be incorporated in an affordability assessment. Although this example only addresses modernisation funding, the approach for manpower would be similar.

In this hypothetical example, a major defence acquisition programme is nearing government approval. For discussion purposes, this programme arbitrarily is assumed to be a mobility programme. A first step in the programmes affordability assessment is to portray the projected annual modernisation funding (Research, Development, Test and Evaluation plus procurement, measured as total authority obligation) in constant dollars for the six-year programming period, and, in addition, for an additional twelve years beyond that. Similar funding streams for other acquisition programmes in the same mission area (in this example, mobility) also would be included. Figure 2-13 is a sample chart for this first step.

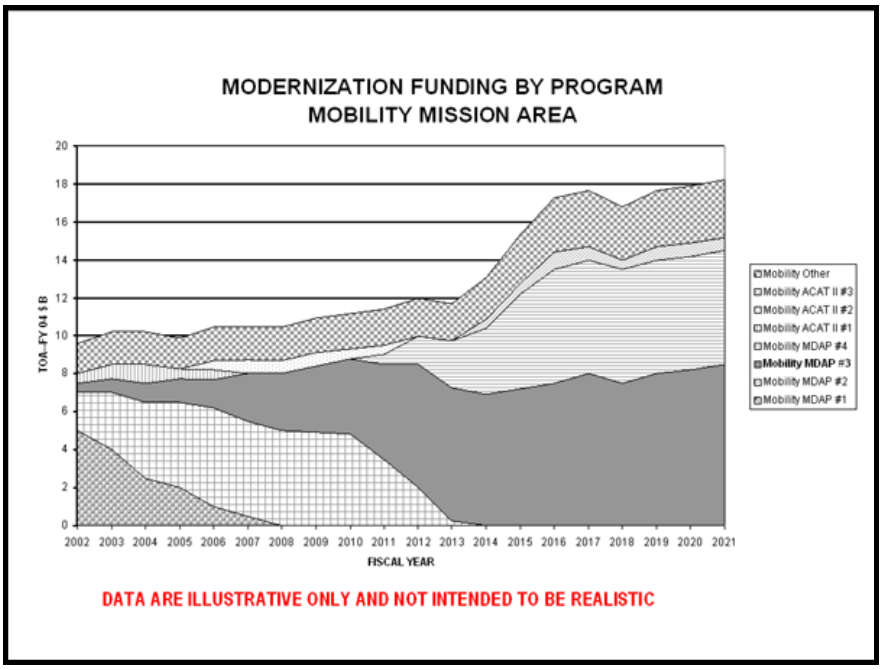


Figure 2-13: Sample Chart of Funding Streams by Programme.

In this example, the acquisition programme nearing approval is labelled "Mobility MDAP #3." Funding also is shown for the other modernisation programmes in the same mission area, consisting of three other major defence acquisition programmes, three other (Acquisition Category II) programmes, and one miscellaneous category for minor procurement. In this example, there appears to be a significant

modernisation bow wave beginning around 2014, which would then be subject to further analysis and discussion in the assessment. The term "bow wave" refers to a requirement for excess modernisation funds during a period beyond the programming period, resulting from acquisition decisions made earlier.

The second step in this assessment is to portray the modernisation funding stratified by mission areas, rather than by individual programmes. Figure 2-14 shows a notional example of this second step. The choice of mission areas will vary depending upon circumstances. Clearly, an analysis by an individual Component[6] would portray funding only for applicable mission areas. Also, for a Component like the Army, where almost all of its modernisation funding is in a single mission area (Land Forces), the mission area should be further divided into more specialised categories (such as digitisation, helicopters, ground combat vehicles, etc.).

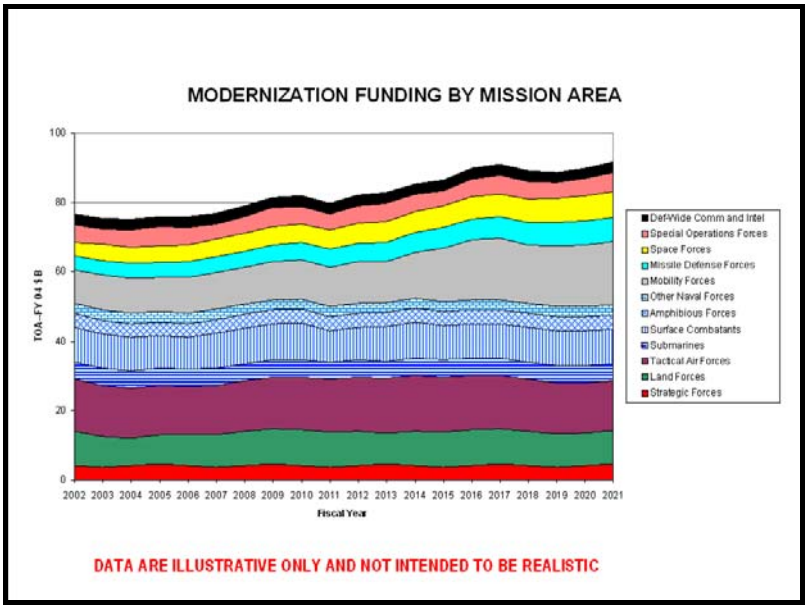


Figure 2-14: Sample Chart of Funding Streams by Mission Area.

For this example, Figure 2-14 shows funding growth in three mission areas (space, missile defence, and mobility). What remains to be determined is whether this projected growth is realistically affordable relative to the Department's Component's most likely overall funding (top-line). The third step in this assessment is to portray annual modernisation funding compared to the Department's Component actual or projected funding top-line, as shown in Figure 2-15. There are three distinct time periods considered in this figure. The first is a twelve-year historical period, the second is the six-year programming period, and the third is the twelve-year projection beyond the programming period. What this chart shows for this example is that the assumed mobility programmes are projected to require a significantly higher share of the Department's Component funding in the years beyond the programming period. In such a circumstance, the Department's Component would be expected to rationalise or justify this projected funding growth as realistic (by identifying offsets in modernisation for other lower priority mission areas, or perhaps by identifying savings in other accounts due to business process improvements or reforms).

[6] A "Component" is a military department or a defence agency.

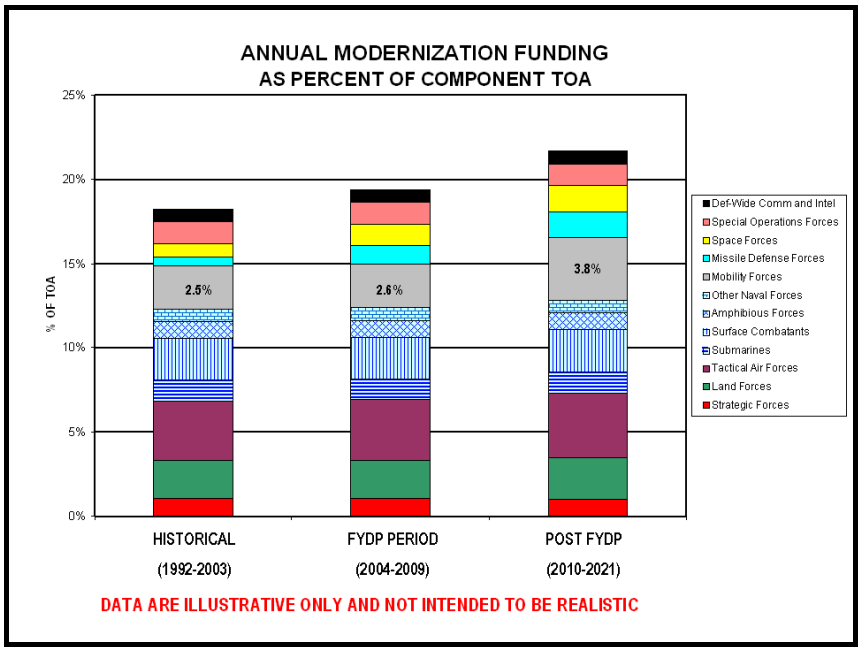


Figure 2-15: Sample Annual Modernisation Funding.

2.10 SPECIAL REQUIREMENTS FOR MULTI-NATIONAL PROGRAMMES

The life cycle cost studies for multi-national programmes follow the same principles as defined in the previous sub-sections. Nevertheless, there are some specifics that should be taken into account in terms of organisation, studies, model(s) and in the presentation of the results.

2.10.1 Definitions

Multi-national programmes involve at least two nations who have agreed upon the main principles of co-operation in a MoU (memorandum of understanding), or an equivalent arrangement, for one or several phases of the entire lifetime of that programme.

2.10.2 Specifics of Multi-National Programmes

2.10.2.1 Framework

A programme becomes multi-national as soon as a MoU is agreed and signed between the participants. In the NATO environment, it is assumed that such a MoU would normally start with the feasibility phase, at the earliest[7]. This means that the life cycle cost studies undertaken during the first phases (Mission Need Evaluation and Pre-Feasibility phases at least) are done at a national level.

2.10.2.2 Added Value

A significant added value of a multi-national programme is the possibility of setting up common solutions for procurement and support. This results in reduced life cycle cost due to research for greater commonality across the participants.

[7] Reference AACP-1 Allied Acquisition Practices Publications.

Another mutual benefit of a NATO collaborative programme is the economic saving that accrues due to cost sharing. In a NATO collaborative programme, the principal area of cost sharing occurs in the common non-recurring cost elements and the operation of the international programme office. Cost shares may be determined or allocated to the participating nations in a number of ways (e.g. costs may be allocated based on quantities procured during production, capital outlay of the respective nations, or other agreed means).

The co-operation of several nations within a multi-national programme may result in higher absolute costs – due to additional expenses for travel, accommodation, communication, information exchange, standardisation agreements, approval of procedures, etc., than the case of a national programme. Nevertheless, when sharing this higher total amount, the share per nation will usually be lower than for the same cost elements of a national programme thus resulting in overall programme savings from a national perspective. Some of these initial additional efforts such as developing a common methodological approach, standardisation agreements, etc., may be incurred only once and then be made available to future programmes at minimal additional cost.

2.10.2.3 Taking into Account "juste retour" (Fair Return on Investment)

Although common solutions reduce an overall life cycle cost, it is obvious that the participants will require a balance of financial and technological demands against the industrial benefit that flow from the programme ("juste retour" or fair return). This last requirement (industrial benefit) should also be taken into account in the life cycle cost studies.

This consideration implies the definition of a work sharing methodology to be utilised in future NATO programme cost estimating applications. The methodology requires an equitable distribution of work share for engineering, manufacturing and service related activity across the participating nations according to the capital outlay of the respective nations or as they otherwise may agree. The goal is to achieve an overall sharing balance through an optimum mix of development and management work, centrally procured major equipment, domestically procured miscellaneous material, land based facilities, and national construction activity. Additionally, offsets may be necessary in some cases and cost-effectiveness must be considered.

An objective evaluation is necessary to determine the optimum mix (technical requirements met and cost-effectiveness within work sharing constraints) of centrally procured equipment. This process involves assessing bids from participating national industries to establish an optimal distribution based on technical, cost, and work sharing considerations. Due to the large number of possible combinations, a computer assisted evaluation model is helpful if not essential.

2.10.3 Organisation

2.10.3.1 Multi-National Management Structure Models

There are basically three models for setting up a management structure for multi-national programmes in a NATO environment. These are:

- **The pilot nation model**, where the responsibilities for the day-to-day management of the programme, under the direction of a joint steering committee are exercised by one of the participants on behalf of all.
- **The integrated model**, where day-to-day management of the programme is secured either by an IPO (international programme office) under the authority of a joint steering committee or by an executive agency of a NATO organisation under the authority of a board of directors, having international status as a legal entity under a NATO charter in accordance with C-M(62)18[8].

[8] C-M(62)18 is related to the NATO council resolution on regulations for NATO production and logistic organisation.

- **The decentralised model**, where the joint steering committee has minimum power of decision, serving mainly as a medium for co-ordination and information.

2.10.3.2 Consequences on Life Cycle Costing Organisation

In the case of the first and second models of multi-national management structures, the pilot nation or the IPO or the NATO agency could be responsible for the life cycle cost estimates and comparison of alternatives within a scope to be defined by the participants (see Sub-section 2.10.4). One or more participant(s) could perform a peer review including a verification and validation of the life cycle cost studies performed above. The basic principle is that these studies should be based on an agreed common life cycle cost model (see Sub-section 2.10.6).

In the case of the third organisational model of multi-national management structure, the participants could agree on choosing one of them for the performance of the life cycle cost studies. Therefore the same organisation scheme as described above could be applied.

2.10.4 Scope of the LCC Studies in Multi-National Programmes

There are two main parts in undertaking life cycle cost studies for multi-national programmes. These are:

- Life cycle costing related to national specifics. For example, government furnished equipment acquisition, national programme management team.
- Life cycle costing related to the development of commonality part where different alternatives have to be compared and evaluated.

The first part is mainly a national responsibility. Nevertheless, if the participants want the pilot nation or the IPO or the NATO agency to perform a complete study, then the outputs of the life cycle cost relating to the national specifics should be inserted into the common model.

The second part is in the scope of the life cycle costing studies in multi-national programmes. Here it is necessary to identify the areas in which alternatives could be defined and assessed. Figure 2-16 below shows a process for the selection of the areas and the definition of the related scenario.

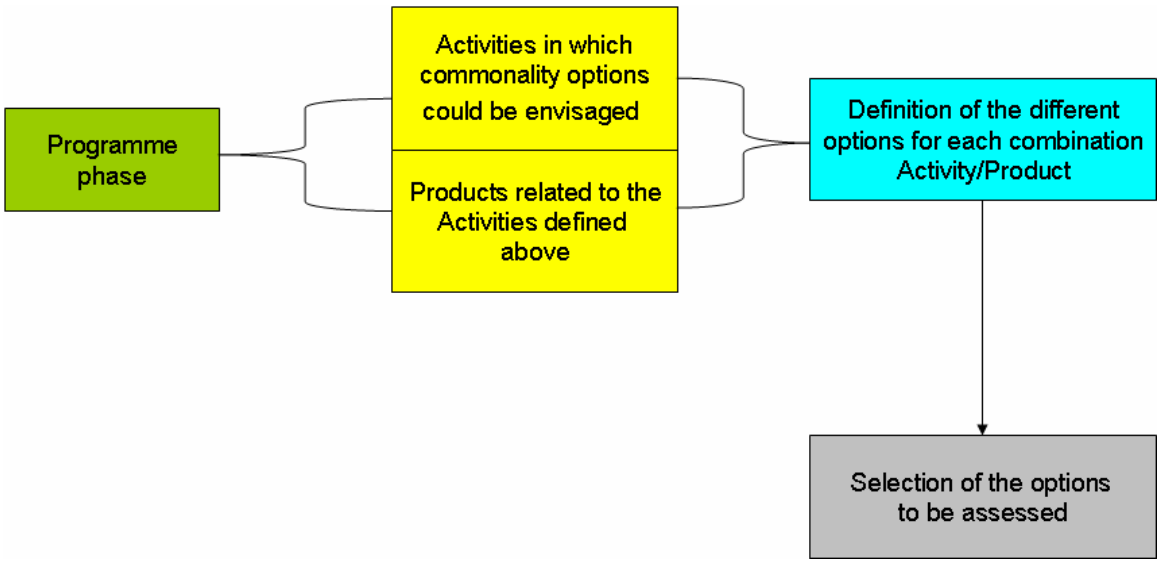


Figure 2-16: Identification of the Options to be Assessed.

2.10.5 Example

The different options to be considered could therefore relate to the management of support during the in-service phase particularly over the maintenance activities and of the support equipment. The life cycle costs would therefore have to consider the effects of the following activities:

- Common maintenance by participant nations.
- National maintenance on behalf of other nations.
- Common contractor logistic support.
- NATO maintenance.
- National maintenance.

Based on the results from the life cycle costing the selection of the options to be pursued would be based on the respective savings, opportunities, operational policy, etc.

2.10.6 Setting up a Common Life Cycle Cost Framework

Setting-up a common life cycle cost framework includes the following steps:

Step 1: The selection of the different models that will be used in common for the programme;

Step 2: The definition of the Programme Cost Breakdown Structure (CBS) and the way of aggregating the results of the different models into one framework;

Step 3: The definition of the assumptions to be applied for the LCC calculation and to be used for data collection; and

Step 4: The collection of the data.

Step 1: Selection of Common Life Cycle Cost Models

All interested parties in the life cycle cost calculation have to agree on the use of common models. This will ensure that all subsequent calculations can be compared on an equal basis. The models should be either programme specific or COTS (commercial off the shelf), as required by the need of the programme. The functionalities of such models must allow an easy interface with those models eventually defined at a national level.

Step 2: Definition of a Common Cost Breakdown Structure and Output Aggregation

Together with the selection of the models, a common CBS (cost breakdown structure) must be defined for the programme. This CBS should be based on the NATO generic cost breakdown structure (Reference: RTO-TR-058 report). It should also allow the insertion of the cost elements relating to national specifics if required (see Sub-section 2.10.4).

The results from the different models selected in step one should be aggregated following the CBS defined above. Figure 2-17 shows this aggregation.

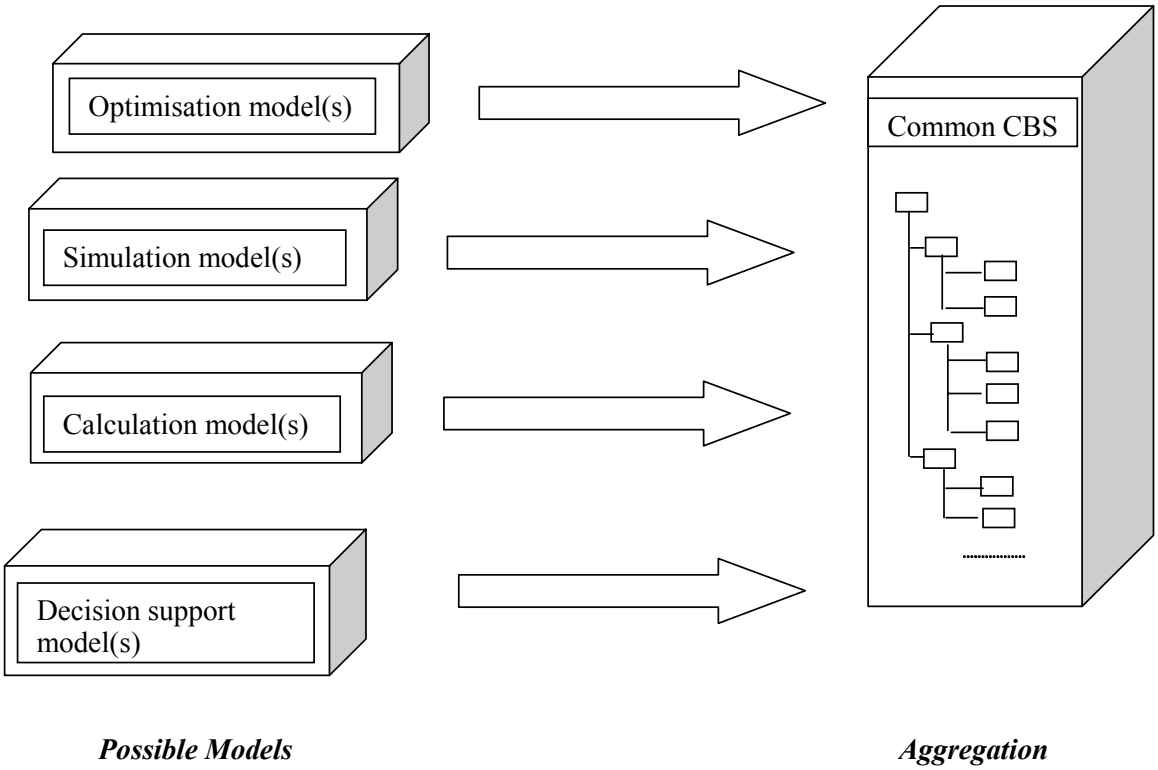


Figure 2-17: Models Output Aggregation.

Step 3: Assumptions (see also Sub-section 2.3.2)

Once the models (with the way of aggregating their outputs) and CBS have been defined, the assumptions necessary to define the cost data should be commonly determined and agreed. The pilot nation or IPO or NATO agency should build an MDAL or CARD or equivalent where all the assumptions necessary to the definition of the cost elements are included. It is acceptable (and in some instances, inevitable), that different nations will use different assumptions. This should, however, be reflected in the MDAL, CARD or equivalent document.

Great care must be particularly applied to the assumptions of deployment. It is likely that each nation may have slightly different deployment and supportability considerations than are usually reflected in the memorandum of understanding or similar arrangements. These should be taken into account in the MDAL, CARD or equivalent document while a consensus for a multi-national scenario is to be defined. In this way, optimised solutions can be evaluated to address both national and multi-national concerns.

Step 4: Data Collection (see also Sub-section 2.3.4)

Based on the agreed CBS and MDAL, CARD or equivalent, the data required to feed the models will have to be collected. The source of that data can vary between programmes, but it will generally include participating nations, industry and the pilot nation or IPO or NATO agency.

2.10.7 Presentation of the Results: Currency Issues

Generally, the cost data utilised as input to a multi-national programme is initially specified in the currency of the supplier nation. For non-domestic work and items subject to international influence of the participating nations, exchange rates between the national currencies are utilised as the currency conversion mechanism to

develop national cost estimates. Application of escalation formulae using indices from the supplier nation allows for changes due to national inflation prior to conversion to other currencies.

With the advent of the European Union, more and more nations have adopted the Euro instead of their former national currencies and the Euro has become the reference currency for expression of multi-national cost estimates and cost targets. Such a reference currency may be useful for performing design trade-offs or pricing the average cost for comparison against an established cost target.

Some past programmes have utilised Purchasing Power Parities (PPP) as the currency exchange mechanism for domestic work under the direct control of the respective nations, e.g. labour. PPP are rates of currency conversion that equalise the purchasing power of the different national currencies. Variations in PPP over time are mainly governed by the difference of inflation rates between countries. PPP vary slowly in contrast to currency exchange rates that are subject to market stresses. PPP may be useful when comparing costs between specific nations and may provide insight useful to planning purposes of the respective nations or for trend forecasting associated with NATO collaborative programme cost estimates.

Despite the need for a reference currency and the issues of currency exchange that must be agreed upon, ***it is recommended that each nation apply its own cost model and applicable data (Cost Estimating Relationships, labour rates, etc.) to arrive at its national cost estimate.***

The choice of the currency should be made before the launch of the life cycle cost studies and the evolution of the exchange rates taken into account in the model. ***It is highly recommended that the life cycle cost analyst seeks economic advice that is pertinent to the particular programme to be evaluated.***

See also Sub-section 6.5.4 for more details on exchange rates and currency issues.