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ALLIED LIFE CYCLE COSTS PUBLICATION

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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

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NATO LETTER OF PROMULGATION

23 May 2018

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Zoltán GULYÁS
Brigadier General, HUNAF
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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS

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RECORD OF SPECIFIC RESERVATIONS

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PREFACE

1. In September 2005 the Conference of National Armaments Directors stated the task of drafting a NATO Guidance for Life Cycle Costs[1].

2. ALCCP-1 defines the general approach for Life Cycle Costs estimation within System Life Cycle Management (SLCM) framework and provides guidance on the application and implementation of a method for costs calculation and estimation, ALCCP-1 also provides a common understanding of cost related definitions and a general guidance for cost data collection, processing, validation and presentation.

3. To support the implementation of the Life Cycle Costing within System Life Cycle Management, ALCCP-1 needs to be read in conjunction with additional publications (AAP-48,AAP-20 and ALP-10) of AC/327 (Life Cycle Management Group).

[1] PfP Decision Sheet – PfP (CNAD)R(2005)001

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1. INTRODUCTION

This publication provides a common understanding of Life Cycle Cost (LCC) and a common way of conducting a LCC-analysis for NATO Nations, agencies and bodies as a result of implementing the NATO Policy for System Life Cycle Management, C-M(2005)0108.

This guidance seeks to support NATO acquisition decision makers in taking into consideration Life Cycle Costs together with the acquisition time and the effectiveness of the SOI.[2]

This publication needs to be used in close conjunction with AAP-48 NATO System *Life Cycle Processes*, AAP-20 NATO Programme Management Framework (NATO Life Cycle Model)[3] and *ALP-10 NATO Guidance on Integrated Logistics Support for Multinational Armament Programmes*[4].

This publication drew extensively on the efforts of RTO TR-058 / SAS-028 *Cost Structure and Life Cycle Costs for Military Systems* and RTO-TR-SAS-054 *Methods and Models for Life Cycle Costing* [5].

1.1 Purpose

The purposes of the document are the following:

- To provide guidance on the application and implementation of a method for costs calculation/ estimation taking into consideration acquisition time and effectiveness
- To provide a common understanding of cost and definition (i.e. what kind of costs are to be considered in the life stages) based on the Generic Cost Breakdown Structure (GCBS)
- To provide guidance for adopting a common exchange mechanism and methodologies for cost data collection, processing, validation and presentation

The aim of this publication is to guide the Programme Managers to identify, quantify and control the costs associated with the Life Cycle of the System of Interest (SOI).

This publication is useful for Programme Managers in their pursuit to optimize NATO's capabilities minimising the Life Cycle Cost, mitigate the risks and reduce acquisition times. The publication is also useful for the Cost Analyst or the Cost IPT who should conduct the Life Cycle Cost analysis.

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[2] If not specified, costs are presented without regarding inflation or exchange rates fluctuations.

[3] AAP-20 focus is on all programme Life Cycle processes, while AAP-48 focus is on system fife cycle processes. AAP-20 includes processes of pre-concept stage, which are not covered by AAP-48.

[4] ALP-10 provides general guidance on the policy, implementation and responsibilities for the application of Integrated Logistics Support (ILS) in multinational armament programmes within NATO.

[5] Like the underlying guidance, RTO-TR-SAS-054 provides guidance for Life Cycle Costs, however RTO-TR-SAS-054 is based on the NATO AAP-20, whereas this guidance is based on AAP-48. Therefore, information from the RTO-TR-SAS-054 report had to be adapted to comply with AAP-48.

The publication is structured in accordance with the Life Cycle stages (as defined by AAP-20) and it is flexible in order to be applicable in different situations, cases and projects as the programmes need.

1.2 Applicability & Benefits

LCC consists of all direct costs plus indirect variable costs associated with the Life Cycle stages of the SOI.

NATO bodies and agencies, nations and industry, in their role as acquirer or supplier, may use this publication. It can be used by either a single party or in a multiple-party situation either within or among organizations. As there are benefits for several application areas, LCC gives support for the different stakeholders of a programme.

The publication is applicable for all Life Cycle stages described by AAP-20. The level of implementation depends on

- The System of Interest (SOI)'s scope and complexity
- Programme objectives and needs
- Boundaries, and
- Assumptions

The influence of the above mentioned and more factors will be detailed in Chapter 2.

There are several options regarding the use of LCC. This publication provides information to be used for

- Evaluating future expenditure
- Assessing the affordability of the programme in terms of the involved costs
- Evaluating alternative solutions (e.g. SOI, programmes, logistic support, bidders etc.)
- Planning and control of Life Cycle Cost
- Managing existing budgets
- Evaluating cost reduction opportunities
- Pointing out cost driver and
- Analysing capability packages

1.3 NATO framework for Life Cycle Cost

The evolution of the system in the timeframe from pre-concept to retirement represents the Life Cycle of the system. This Life Cycle of the system is divided by AAP-20 into seven stages: pre-concept, concept, development, production, utilization, support, and retirement.

Some years ago, Life Cycle Cost management and LCC related issues were already mentioned in a NATO document *Life Cycle Management in NATO*. *A report to CNAD, Edition 2, 2002.* In this document Life Cycle Cost Management activities are part of the Life Cycle Management in NATO. The activities that were identified were cost planning, cost estimating, cost budgeting and cost assessment and control. This report was one of founders of the Life Cycle Management Group; however, the report never led to a general guideline for Life Cycle Costs. A naval specific NATO document related to Life Cycle Costs was published: ANEP-41 *Ship Costing,* April 2006. The only NATO activity that led to general guideline was originated in the formerly NATO Research and Technology Organisation: RTO - SAS-028 that presented a common Cost Breakdown Structure and RTO - SAS-054 that led to the report “Methods and models for Life Cycle Costs”. Part of this report is a guideline for Life Cycle Cost in all Life Cycle stages.

The total of costs which are incurred for a system, facility or product during its Life Cycle represents the Life Cycle Cost. Life Cycle Costing is a process meant to determine the Life Cycle Cost.

Besides some general definitions such as “all costs from cradle to grave”, LCC is defined in each project by the list of all the cost elements to be considered in its calculation. This list is usually captured in a Generic Cost Breakdown Structure (GCBS). This GCBS may be tailored between nations or even between programmes in one given nation.

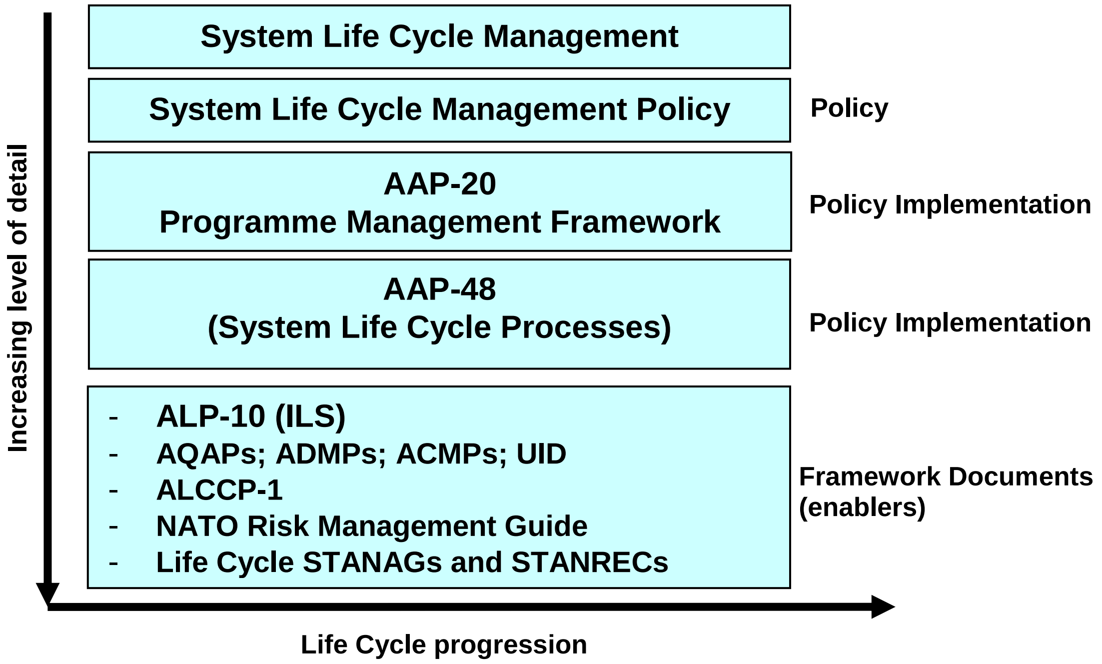

Figure 1.1: Conceptual Framework (adapted from AAP-20)

This publication is part of the conceptual framework defined by AAP-48 and AAP-20, setting up the Life Cycle Cost as an operational enabler. Within the System Life Cycle Management this publication can be considered as one of the various framework documents (enablers), as shown in Figure 1.1.

Apart of this framework, LCC is an important item in the capability delivery process. Cost transparency and the evaluation of financial aspects through the Capability Package (CP) process provide decision makers relevant key factors. The relationship between systems and CPs is described in AAP-20. LCC of CPs are determined by figures and budgets of capabilities and associated system(s) required. Taking in consideration that a capability could be fulfilled by several systems and some systems could serve more than a single capability, there may be the need to differentiate the LCC from a system to a capability. The relationship between these two levels has always to be assessed on case by case basis.

Whatever the stages or decision gates of the programme are, the Life Cycle Cost Estimation Process must provide reliable cost data by which the Programme Managers can optimise their decisions.

1.4 Summary of the publication

This publication consists of 8 chapters, as follows:

The first Chapter is a general introduction to the publication presenting the purpose and applicability and the place of this guidance within the general framework referring to the Life Cycle of systems.

The second chapter, *INTRODUCTION TO LIFE CYCLE COST ESTIMATION* PROCESS**,** is a general overview of the main activities involved in the Life Cycle Cost estimation process.

The approach to the Life Cycle Cost Estimation Process consists of a clear definition of the aims and objectives, the establishment of the programme content, costing boundaries and assumptions of the cost estimation, and the development of the structure of the Life Cycle Cost framework.

The Life Cycle Cost Estimation Process consists of a set of activities aiming mainly at the estimation of the Life Cycle Costs for a System of Interest. This process is influenced by the nature and complexity of the System of Interest, the Scope of the cost estimation, the stage of the Life Cycle, and the availability of cost data.

Chapter 3,

INPUTS FOR THE LIFE CYCLE COST ESTIMATION PROCESS, includes guidance elements of the main inputs to consider in order to develop the Life Cycle Cost Estimation.

Thus, the chapter details the first step of the Life Cycle Cost Estimation Process providing specific information for each stage of Life Cycle and, it ends with showing a model of possible distribution of costs over the Life cycle.

Chapter 4, *COST BREAKDOWN STRUCTURE PROCESS*, presents the process of generating the Cost Breakdown Structure, including the requirements of the process, the inputs and outputs and the steps to follow, the elements of the GCBS: Cost Element, Activity List, Resource List, and Product Tree.

The list of cost elements to be considered in a project is defined and organised in a Life Cycle Cost Breakdown Structure (LCCBS) also referred to as a Cost Breakdown Structure (CBS).

Chapter 5, *METHODS AND MODELS FOR LIFE CYCLE COST ESTIMATION*, is a short presentation of the methods and models to be adequately selected by the specialists involved in Life Cycle Cost Estimation activities.

For each individual cost element part of the CBS, the appropriate method or model needs to be chosen in order to estimate the costs.

Furthermore in this chapter a special attention is paid to the presentation of risk and uncertainties related to cost estimation. As a main result of the cost estimation, the LCC estimate is represented by a group of three figures: Low Estimate, Baseline Estimate and High Estimate. The quantification of risks and uncertainties related to cost estimate allows the direct transfer of the cost associated risks into the risk assessment of the programme, providing useful information regarding budgeting.

Chapter 6, *LIFE CYCLE COST ESTIMATION REPORTING*, sets up the main elements for reporting the outputs of Life Cycle Cost Estimation Process based on the rationale for data traceability, usability and accompanied by the need for transparency of the adopted models and methods.

The LCC report is important in two ways: it provides the cost data the Programme Manager needs for the decision making process, tender selection, budgeting etc. and presents a complete documentation of the costs estimation process so that further revisions should become possible due to changes in data availability, boundaries and assumptions.

Chapter 7, *LIFE CYCLE COST DATA COLLECTION AND PROCESSING*, provides information, on the various types of data used in the Life Cycle Cost Estimation Process, on the data collection process, including issues to consider in data collection and normalization, and reviews some typical sources of data. Life Cycle Cost data is the raw material of the Life Cycle Cost Estimation Process. Valid data may provide credibility, accuracy and defensibility to the Life Cycle Cost Estimate. Furthermore chapter 7 provides the guidance for setting up the right format in order to facilitate cost data exchange.

Chapter 8, *LIFE CYCLE COST DATA EXCHANGE* providing guidance for adopting the exchange mechanism for the data assumed by Product Life Cycle Support (PLCS). The important aspects of this mechanism are presented for the Programme Manager to formulate adequately the requirements for a specific Data Exchange Set (DEX) which may be used for cost data exchange.

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2. INTRODUCTION TO LIFE CYCLE COST ESTIMATION PROCESS

2.1 General

The Life Cycle Cost Estimation Process consists of a set of activities having as main purpose the estimation of the LCC for a SOI. The Programme Manager must clearly state if the programme is cost driven or it is time schedule driven. This statement has an important influence on LCC subsequent activities.

LCC estimation must fit of purpose, being consistent with the programme requirements.

However, many factors may influence the estimate. The main factors that influence the Life Cycle Cost Estimation process are listed below.

- **The nature and complexity of SOI** (tanks, carriers, aircrafts, communication systems, military facilities, software intensive projects etc.) influence mainly the product tree, and also logistics support requirements to ensure SOI quality in terms of Reliability, Availability, Maintainability (RAM) and the content of processes, activities and tasks to be considered in CBS.
- **The scope of cost estimation** influences the extension and deepness of cost element elaboration (granularity) in order to fulfil the assumed use of the cost estimates for analysis, assisting decision making process, budgeting etc.
- **SLC Stage** influences CBS through the content of processes, activities and tasks adopted as components of each stage during SLC tailoring process. For instance, the estimated low weight of a considered stage may conduct to a less elaborate breakdown of costs.
- **The data available or expected to be available (time factor)**. The cost data used to estimate LCC vary during the SLC from a rough estimation to an accurate recorded value. Accordingly, the evolution in time of stages involves dramatic changes in terms of data availability which make possible the further elaboration and refinement of CBS.

The characteristics[6] of high quality cost estimates are:

- **Accuracy**
  Cost Estimation relationships are the result of regression analyses with good curve fits and minimal error bands, making them valid predictors of cost. Estimates are unbiased, not over conservative and based on the assessment of most likely costs. The data have been correctly normalized for technical baseline, and for inflation using appropriate guidance. Time phasing of the estimate is logical and accurate.
- **Comprehensiveness**
  Estimate uses a CBS that is at a level of detail appropriate to ensure that cost elements are not omitted nor double counted. All cost–driving ground rules and assumptions are detailed in the documentation of the cost estimate.
- **Ability to Replicate and Audit**

[6] These characteristics are given in the International Cost Estimating and Analysis Association (ICEAA) Cost Estimating Body of Knowledge training programme module 1. They are replicated here by kind permission of the ICEAA Office.

Estimates are presented in CBS fully traceable to the system specifications. The estimate is thoroughly documented, including source data, significance and goodness of fit statistics for Cost Estimating Relationship (CER), clearly detailed calculations and results, and explanations for why a particular method or reference was chosen. A reviewer must be able to follow the estimate process, repeat the calculations and arrive at the same answer.

- **Traceability**
  Data is traceable back to the source documentation. CBS elements are traceable.
- **Credibility**
  Credibility is the single most important quality of a good estimate. Without the above mentioned characteristics the estimate will not be trustworthy.
- **Timeliness**
  The best estimate in the world will not be useful or good if it comes too late to provide decision makers the value insight they need.

Larger (more expensive) programmes will usually demand more effort and rigor. Sufficient time and effort should be allowed in order to provide a robust cost estimate. However, there should be a balance between the cost estimating effort and the value of the estimate to the decision to support the programme.

2.2 LCC Plan

Prior to any costing activity it is essential to establish a LCC plan in order to provide all stakeholders a clear and common understanding of the scope, following actions and responsibilities. This plan should be regarded as an updated agreement between the involved personnel and associated documents (e.g. user requirements, ILS plan, etc.).

For major materiel systems a Cost Estimation Requirements Document (CERD) must be prepared before the estimation starts. The CERD, among other things, documents assumptions; presents technical, functional, and physical descriptions of programme elements; specifies the number of items to be procured; provides a schedule for development and acquisition; describes the support concept and operational needs in terms of fuel, power, chemicals, labour, facilities, tools, security, and so on; and defines the Life Cycle length.

As the programme matures from identification of a mission need, to identification of alternatives, to publication of a request for proposals, the CERD must be updated to incorporate additional details and to present the most accurate picture of the programme. At any point in time, some parts of the CERD may contain details about cost elements that are well known and defined, while other parts may be subject to programme decisions, engineering research, or undefined external requirements. In a CERD following essential domains can be defined:

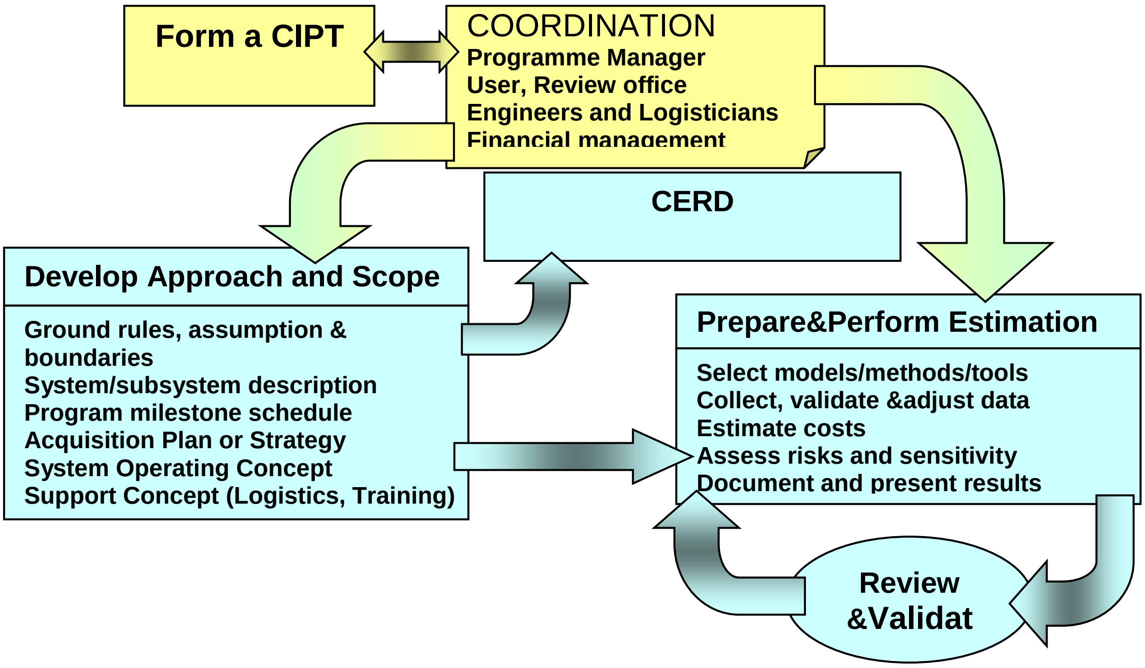

Figure 2.1: Analytical Approach for Life Cycle Cost Estimation Process

2.2.1 Scope of LCC

The cost estimation process is a long and iterative process involving the work of the Cost Integrated Project Team (CIPT) in close coordination with the Programme Manager and other teams. It is necessary to keep all efforts focused on the main scope and define the SOI.

2.2.2 Personnel

As in an organization usually executed, responsibilities should be clearly addressed. Within these responsibilities tasks concerning LCC and its related topics are deployed.

A CIPT or assigned cost analysts as part of the Integrated Project Team (IPT) coordinate with Programme Manager, user, review office, engineers and logisticians, financial management etc. as needed. All life cycle cost estimates should be prepared, conducted and analysed by suitably experienced personnel.

2.2.3 Groundrules and assumptions

Estimating future costs means to make assumptions in order to close a lack of information or data. This coherent set of assumptions has to be thoroughly documented and its validity has to be checked through the Life Cycle of the programme. By applying a sensitivity analysis the effect of the change of key assumptions (on the results of alternatives) may be highlighted.

2.2.4 Reporting and presenting

A LCC estimation will depending on the input data deliver a huge amount of output. This has to be structured and reported in order to support the decision aims and meet the scope. To make these efforts beneficial, a structure and schedule have to be developed and implemented.

2.2.5 Methods

The chosen method will be in most cases directly influenced by the scope and availability and quality of data. Which itself is determined by maturity of the programme. Depending on scope, aim, requested level of detail and the affordable effort of the estimation the stakeholders will be advised by the CIPT and have to agree on the best suitable method.

2.2.6 Data Collection and Analysis

The meaning of data management is an outstanding and all other points concerning issue. Availability and consistency will have a major influence on the estimation and therefore on the results too. There are several inputting sources with different quality, information and amount of data. Among stakeholders and management team an agreed approach of data management has to be established in accordance with the scope and aims of the LCC estimation.

2.2.7 Update process

The cost estimate should be updated and validated. While the model used to estimate LCC of the SOI should be calibrated periodically as the programme matures technically and schedules change. Validation and Calibration should take place within all the stages of the programme.

2.2.7.1 Validation and Verification

An estimate should be validated and verified against a set of independent estimating figures before being released. The main activities to be performed are the following:

- Evaluate the quality of the initial estimates
- Determine whether estimates are complete, consistent, and reliable
- Assess whether the estimates satisfy all constraints, especially cost and schedule. Adjust as suitable and required
- For estimates supplied to a customer, ensure estimate meets customer needs

2.2.7.2 Calibration

Calibration is the process of adjusting the parameter-values of a commercial or an in-house developed parametric model to the specific organization’s cost, and system history.
It has to be considered how well the model has been calibrated to the project’s process, reasonableness of the assumptions and levels of uncertainty.

2.2.8 Link to other activities

As being an integral part of programme management, LCC may have a lot of aims, functions and links to other tasks, such as Integrated Logistic Support (ILS), price negotiation, request management etc. These interfaces with in- and output relations have to be described, in order to structure tasks and results of the whole programme management team and other stakeholders.
The system under consideration could also be a group of systems that is integrated into one large System of Systems (SOS). A SOS requires expanded roles and activities, such as the Lead System Integrator. This is of particular interest to NATO, as NATO will undertake complex and costly programmes that single nations cannot afford.

2.2.9 Constraints

The identification and evaluation of constraints is required throughout the Life Cycle Costing process. The single constraints will differently influence the estimating. These factors itself will be influenced and controlled by all stakeholders in different ways and extents. Generally, constraints can be characterized in two types:

- External Constraints

Though the benefits of life cycle costing are recognised, the approach for its use and implementation could vary from nation to nation, due to

  - Time constraints imposed by decision makers
  - Potential high number of organisations involved
  - Limited and suitable resources to support Life Cycle Costing

- Internal Constraints

These constraints are inherent to

  - Data availability
  - Limited and suitable resources to conduct Life Cycle Costing
  - Maturity of requirements definition
  - Economic and Commercial conditions

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3. INPUTS FOR THE LIFE CYCLE COST ESTIMATION PROCESS

3.1 Introduction

Inputs for the Life Cycle Cost Estimation Process are highly dependent on the stage the SOI is in.

According to AAP-20 the Life Cycle of a SOI is divided into seven stages. In addition to this the Acquisition Process according to AAP-48 plays a major and overlaying role in the Life Cycle and so LCC, it is regarded in chapter 3.4:

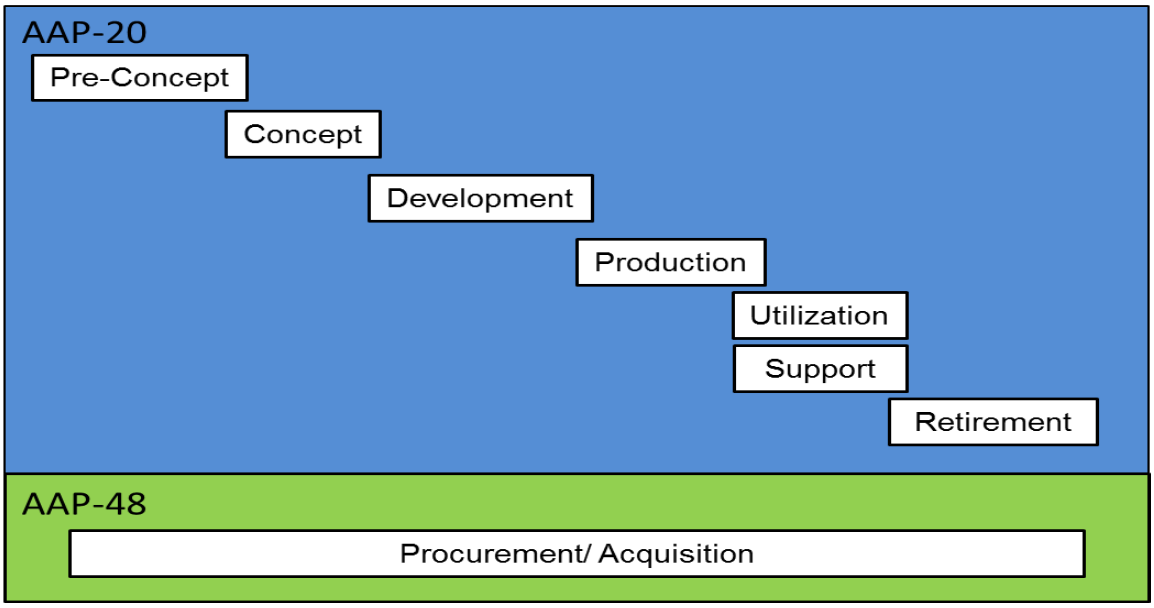

Figure 3.1: Stages in the Life Cycle of the SOI

Each stage represents one essential period of the life cycle of a SOI. The partitioning of the system life cycle into stages is based on the practicality of doing the work in small, understandable, timely steps. Stages, in addition, help address uncertainties and risk associated with cost, schedule, general objectives and decision making. Each stage has a distinct purpose and contribution to the whole life cycle. The transition between stages uses decision gates and entry/exit criteria.

This chapter describes each stage in further detail, also how costs can be estimated and how cost data can be collected.

The AAP-20 stages cover the life cycle of a programme from identification of a need for a new capability through specifications, design, production, use and eventually retirement of the system. It is general enough to cover most national and multinational life cycle models for this type of programme. However, in some specific situations, the typical life cycle of weapon systems and other materiel systems is substantially different, because systems are bought rather than developed and built (COTS/ MOTS products). This has wide implications for the whole life cycle management process, including life cycle costing, especially in some of the earlier stages 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, developing 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 “development” programme as described in AAP-20 stages is so great that it warrants a special treatment. This is given in section 3.4 which covers the specific LCC related issues derived from the decision between developing or buying a system.

3.2 Pre-concept Stage

In a capability driven defence planning process – such as NATO Defence Planning Process (NDPP) - first the requirements of the stakeholder(s) are to be identified. Defence Planning is the political and military process used by nations to provide assets and capabilities the Alliance requires to meet their defence commitments, enabling NATO to undertake the full range of missions it has set for itself. A NATO Capability is defined as: “the ability to perform actions to achieve desired objectives/effects”[7] and is achieved when the outputs of all the lines of effort have been delivered: Doctrine, Organization, Training, Material, Personnel, Facilities and Interoperability (DOTMLPFI).

In the pre-concept stage only frame conditions like affordable costs, timescale and generic risk assessment can be defined. At this point of the programme LCC can hardly be estimated because the decision towards one or several systems has not been made and costs can only be estimated on the base of one or more systems. As an output towards this direction the “identification of the most promising option” may be used as an uncertain base to give a rough order magnitude.

Furthermore the awareness of LCC being an integral part of Life Cycle Management (LCM) has to be developed. So the approach can be prepared according to chapter 2.

The aim of NDPP is to provide a framework within which national and Alliance defence planning activities can be harmonized to meet agreed capability targets in the most effective way.

Capabilities identified in the NDPP (Step 2) include national, multinational and common funded capabilities that will be developed on a later stage through the Capability Package (CP) process.

3.3 Concept Stage

The Concept Stage starts after the decision to fill a capability gap with a materiel or service solution is made and ends with the publication of the requirements specification for this materiel solution.

To fill the capability gap and meet the requirements certain capabilities are necessary. A capability requirement defines a CP, which consists of resources and SOI in order to close a capability gap.

[7] End-to-end rationalization review for all structures engaged in NATO Capability Development: PO(2011)0210 dated 30 May 2011

NATO CP Process is the primary process through which capability shortfalls are identified for common effort and fulfilled using NATO common funding.

The purpose of the Concept Stage is to evaluate the relative need, potential risks, and cost benefit of a proposed SOI, or a major upgrade of an existing SOI prior to any commitment of resources. One of the outputs of the concept stage are initial design solutions in the form of drawings, models, prototypes, including Life Cycle Costs estimate and human resource requirements estimates. One or more alternative solutions to meet the identified need or concept are developed through analysis, feasibility evaluations, estimations (such as cost, schedule, market intelligence and logistics), trade-off studies, and experimental or prototype development and demonstration. A Cost-Benefit-Analysis or Cost-Effectiveness-Analysis are widely used to evaluate and figure out the economic solution.

At the beginning of this stage 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 presuppose

- 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 (the main measurable characteristics) in representative operational or business situations

To support the activities above, a systematic, rigorous and auditable process needs to be adopted. Cost models that provide a holistic (e.g. whole) estimate of costs and time are essential for this stage. The cost models should also provide the estimates with defined confidence levels and have the ability to provide a ‘what if’ capability.

The greatest opportunity to reduce life cycle costs usually occurs during this stage. The concept stage is where decisions are made when the amount of supporting information is at minimum. The availability of cost data during this stage is very dynamic, imposing a permanent renewal of cost database and a continuous update of cost estimation. This is the most important stage 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. It is therefore extremely important that a high quality Life Cycle Cost estimate is constructed and updated during the whole duration of this stage and that it must be used to support the various decision making processes.

Typical methods used for developing a cost estimate at this stage are Parametric, Analogous, Expert Opinion or Rule of Thumb techniques. There are several proprietary estimating software-tools that can be used to build up a model.

Ideally, in this stage, a RFI (Request for Information) can be initiated and first conversations and discussions can be held with several potential suppliers. The purchaser gets to know interested partners without commitment. This provides several advantages. Information received from these contacts allow a wider view on potential technical solutions and the opportunity to influence the Life Cycle Costs by using market competition - although information and data given upon the RFI may differ from later tenders. 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.

3.4 Acquisition Process

At some point during the AAP-20 stages of a SOI a choice will be made either to develop or to purchase the SOI. The decision for one solution will be made, based on the comparison of different alternatives according to the evaluation of particular factors, such as system operational performance, proposal risk, offerors past performance, LCC, offset benefits, etc. As soon as the requirement is identified and validated, acquisition planning should commence. The complexity of requirements will dictate the extent of acquisition planning. Acquisition planning, including life cycle costs analysis, logistics, finance and other resources is essential for the effective and timely solicitation of bids or proposals, award of contracts and delivery of goods and services required.

At the conclusion of the Acquisition Planning Phase the contracting strategy is fully depicted with a clear identification of cost factors and risks related to the acquisition. The scope and depth of the analysis should be directly related to the overall value, importance, and complexity of the procurement, and be concluded before launching a formal solicitation. During the Acquisition Planning LCC shall be calculated and utilised to illustrate the ‘performance-to-cost’ ratio of the SOI.

The following list comprises some examples of issues that might have significant influence on the estimated LCC and need to be considered in the acquisition process

- Data exchange between purchaser and bidder
    - The purchaser has information related to utilization concept, boundaries, hour rate for own personnel etc., and establish the LCC model based on input from various sources, including the bidder
    - The bidder has information related to the supportability requirement of the system such as consumables, fuel, service, failure rates, maintenance cost, training cost, etc., and may establish its own LCC plan as a sub-plan of ILS plan.
    - The purchaser and the bidder could eventually develop together an LCC model as part of the contract negotiations

- The conditions stated in a Contractor Logistic Support (CLS) contract will influence the LCC. This means that, in order to be able to calculate and utilise LCC in the Acquisition Process, the CLS contract must be established simultaneously with the delivery contract of the materiel. The possible variants depend on the following:
    - The part of the maintenance which shall be performed by the contractor
    - The part of the maintenance which shall be performed by a third party and the contractor shall deliver documentation, test equipment, spare parts etc. only

- What techniques should be used by the purchaser to receive reliable cost estimates for utilization and support stages?
    - Requested options for different maintenance packages including at least an option based on a complete fixed price for all maintenance, given a specified mission concept
    - Evaluation of experienced operational data according to a specified contractual obligation
    - Tests
- How the exchange of LCC data is organized?
    - Contractual aspects related to the contractor (disclosure of confidential information)
    - Disclosure of classified military information
    - Definitions and nomenclature related to LCC data in order to prevent misinterpretations
    - Agreement on the format of the data to be exchanged

Whatever the acquisition procedure and bidding selection criteria, the above mentioned problems must be clarified in order to allow further development of LCC analysis during the entire Acquisition Process.

3.5 Development Stage

The Development Stage is executed to develop a SOI that meets user requirements and can be produced, tested, evaluated, operated, supported and retired, taking into account an ILS strategy. This stage also ensures that the aspects of future stages (production, utilization, support, and retirement) are considered and incorporated into the design through the involvement of all stakeholders.

A lot of information from the previous stage may exist; in-house historical data, results from early tests and technical demonstration. The Life Cycle Cost estimates will improve in quality by increasing maturity of data. With the development of the technical solution the detailed inputs become predictable. With more figures known an engineering method can be used (bottom-up) supported by analogy cost estimating, parametric cost estimating, historical trend analysis.

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

The results of operational tests and trials at the end of this stage represent a valuable source of actual cost data to be considered.

3.6 Production Stage

The Production Stage is executed to produce or manufacture the SOI, to test it and to produce related supporting and enabling systems as needed.

During this stage actual data becomes available. This may affect LCM in general, but also the LCC estimation. During the production detailed prices can be provided by the manufacturer, based on the consumption of resources. This information gives the CIPT a chance to validate its estimation in regard to the acquisition expenditures. This data provided by industry may be validated by own price respectively technical audits, in order to make these figures reliable also for price negotiations.

With existence of first detailed data and a CBS of the SOI, as primary estimating method in this stage an engineering approach shall be conducted.

Depending on complexity and number of produced systems, costs will underlie a learning curve of the manufacturer having impacts on the costs.

3.7 In–Service Stage

Taking in consideration that Utilization and Support Stages are logically connected and carried out together, the economical reflection is joined here as an In-Service Stage.

The Utilization Stage is executed to operate the SOI at the intended operational sites to deliver the required services with continued operational and cost effectiveness. The Support Stage is executed to provide logistics that enable continued SOI operation and a sustainable service. Both stages can be considered completed when the SOI is taken out of service.

Usually the In-Service Stage is the longest period within the lifecycle of a SOI, the expenditure profile for this stage is the highest within all stages in the LCM and in fact it plays a key role in the estimation of LCC. These costs are primarily driven by few factors determined by the stakeholders. The operational doctrine, assigned mission, the operational environment of usage, the operating rate (up-tempo) and the ability skills and the efficient training of the personnel are the most directly affecting ones. Connected with these, the ILS concept describes the support process and defines terms of maintenance.

To forecast LCC in this stage (for new scenario or another environment) a discrete event simulation or an optimization method seems to be the preferred solution.

3.8 Retirement Stage

This stage begins when a SOI is taken out of service. It is determined by the decision of the further handling of the retired SOI. There are several options:

- Re-deployment (SOI/ parts used for training/ instructional use, as a heritage/ museum asset, for spare recovery (further information can be found in Annex 4))
- Reclamation, recycling, re-manufacture, preservation and storage
- donation
- Sale (to second-hand user, further information can be found in Annex 4, maybe affected by limiting regulations of manufacturer/ nation)
- Disposal

Depending on the complexity of the SOI, specific situations may occur such as: disassembling the system into manageable elements to facilitate its removal for reuse, recycling, reconditioning, overhaul, archiving or destruction, reuse of the SOI or of some parts of it by turning to account, cost saving due to the sold of recyclable components of SOI etc.

Depending on the chosen option the arising costs or revenues will be subsumed in the content of the entire LCC. Success promising methods to forecast LCC can be analogy or parametric approaches.

3.9 LCC over stages: The bathtub curve model

The Life Cycle Costs of a SOI over the stages depend on its characteristics and various variables. But comparing different SOIs a significant similarity in regard to the distribution of the costs over lifetime can be observed.

The so-called "bathtub-curve" is a graph to illustrate the failure rate over the usage of a product family or SOI. It is a visual model that can be roughly divided into three periods:

- Infant mortality period with a Decreasing Failure Rate (DFR)
- Followed by a normal life period (also known as "useful life") with a relatively low and Constant Failure Rate (CFR); and
- Concluding with a wear-out period that exhibits an Increasing Failure Rate (IFR)

The observed failure rate is the combination of the early, constant, and wear-out failures.

Some parts/ functions will fail relatively early (infant mortality failures), others will start failing close to wear-out, and some will fail randomly, during the relatively long period typically called 'useful' life. The border between these periods is fluent and can vary depending on the SOI and other determinants.

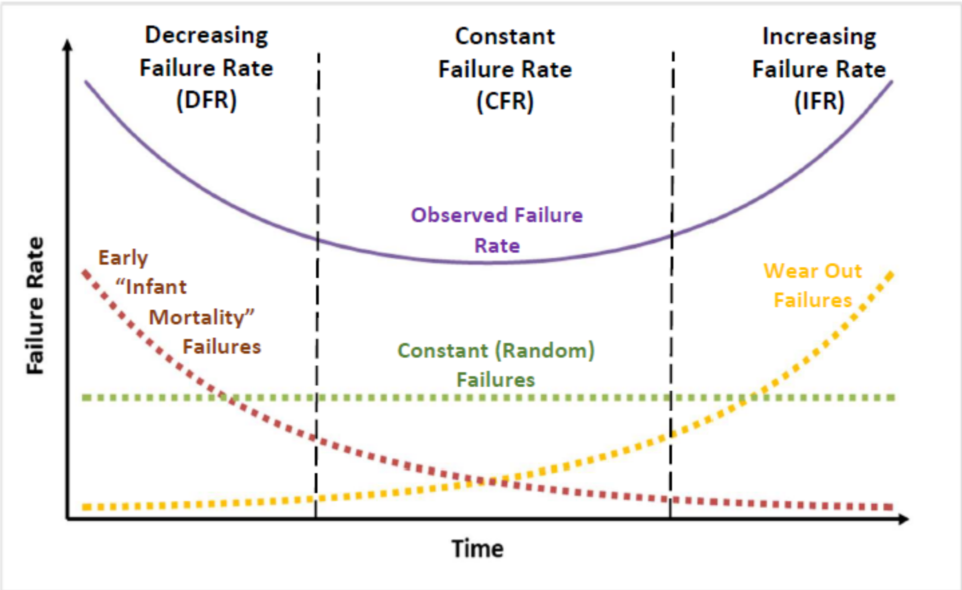

Figure 3.2: Bathtub curve - failure behaviour in utilization stage.

With a close relation between amount and gravity of failures and thereof following costs, this graph may be transferred into a generic LCC model to gain a statement about assumable expenditures.

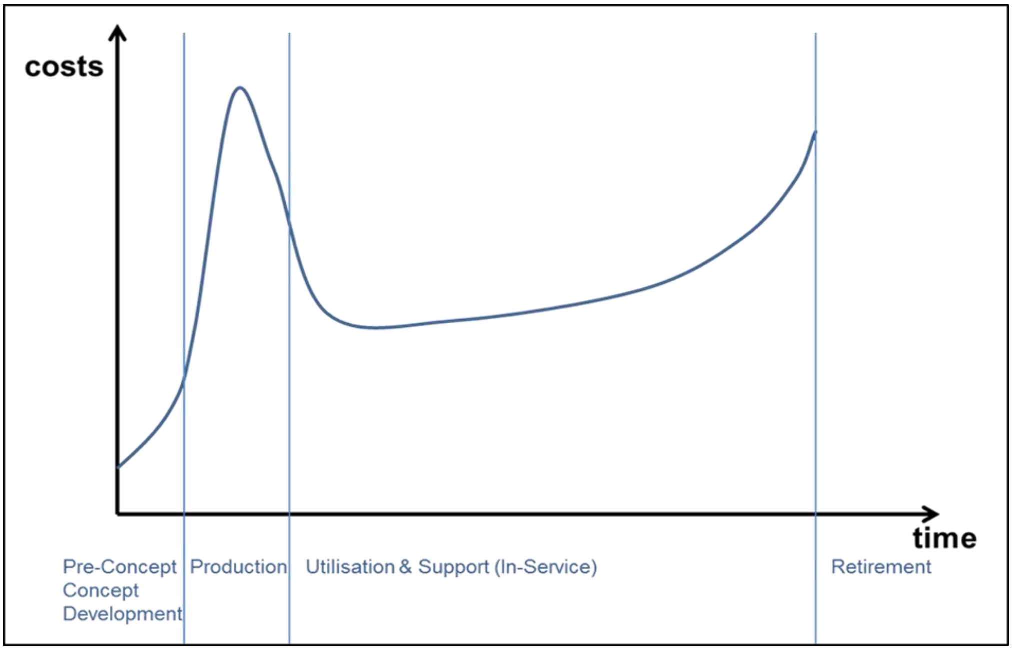

Figure 3.3: Generic LCC

The curve does not sketch the costs of the retirement stage, because here the differences in handling after decommissioning and though costs may vary severely.

In Annex 4 a contribution can be found about special issue of LCC for second-hand material.

4. COST BREAKDOWN STRUCTURE PROCESS

4.1 General

Costs are a major factor when analysing military systems. Concepts such as LCC, Whole Life Cost (WLC), Cost of Ownership (COO) or Total Ownership Cost (TOC) are used frequently in many NATO documents dealing with military systems and cost analysis. Most NATO Nations have their own methods, tools and terminology but to be able to work together they have to use common language when addressing costing issues. This chapter was written using extensively the RTO Technical Report TR-058 (RTO TR-058 / SAS-028). Some concepts or terms were adapted in order to be consistent with AAP-48.

The list of cost elements to be considered in a project is defined and organised in a Life Cycle Cost Breakdown Structure (LCCBS) also referred to as a CBS.[8] The role of the CBS in the LCC process is twofold: it must support the overall scope of the Cost Estimation Process (CEP), and it must facilitate the calculation and estimation of the relevant costs.

In addition, the CBS will also have a practical administrative function as a checklist of the costs that must be estimated.

The LCC for an SOI, whatever specific definition is used, is not a single number but rather a continuum or distribution of possible values between the bottom value (low estimate) and the upper value (high estimate); the most probable value of the LCC estimated represents the baseline estimate (see also chapter 5).

As such, it is practically useless for analysing, managing or reporting on the cost of the system. To be useful for these purposes, the LCC must be broken down in a structured way into individual cost elements, relevant to the specific scope of the CEP.

Conversely, the LCC cannot be estimated as a whole. LCC estimation therefore inevitably involves breaking down the LCC into cost elements which can be estimated using appropriate methods and models.

The LCC can be broken down in a number of ways, all of which may be relevant in a given way. Such breakdowns may be done:

- chronologically
  - by year, month, etc.
  - by product stage, e.g. development, production, utilisation …
- by type of costs
  - direct, indirect or linked costs
  - variable or fixed costs
- by product
  - by systems, subsystems, components e.g. engine, hull, weapons…
  - hardware, software, data, services etc.
- by processes and activities
  - Quality Management Process
  - Technical Processes e.g.
- administratively/by organisation
  - by unit, service branch, etc.

[8] RTO TR-058 / SAS-028

- by nation (multinational programme)
- by public/private company (cooperative programme)

Most of these breakdowns are not mutually exclusive, and a CBS will typically involve a combination of a number of these types of breakdowns. The example below[9] illustrates a CBS which initially breaks down the LCC chronologically into three stages, and all of these are further broken down by activity. For one of these, maintenance (C_{OM}), the cost is further broken down into costs of various products.

Data/Information (COMD

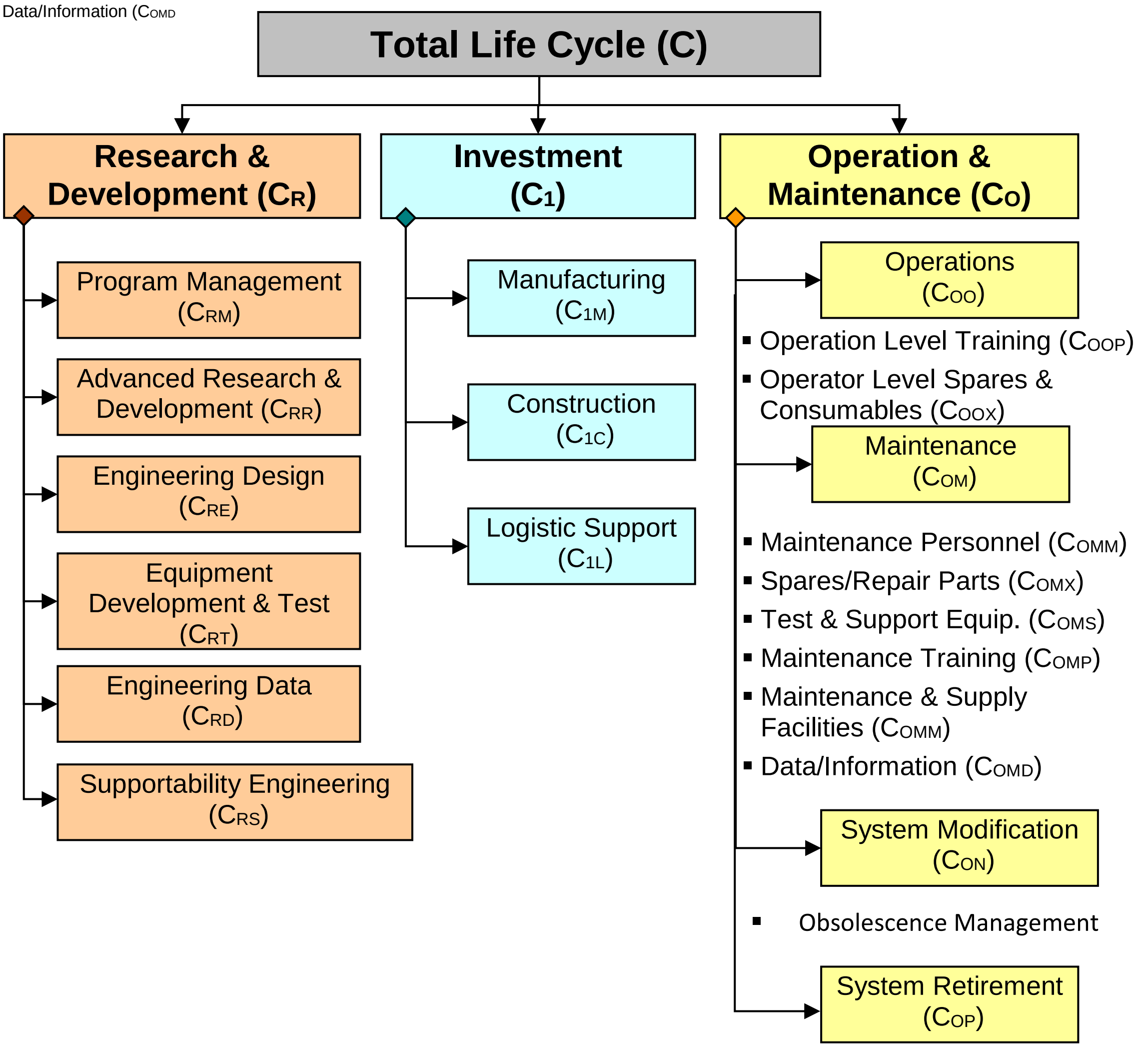

Figure 4.1: Example of Cost Breakdown Structure

It is quite common to develop or illustrate a CBS as a tree structure, as it is in this example. This is intuitive and gives the viewer an instant overview of the CBS. For large, complex and very detailed CBS structures, however, it is useful to assign a code to each cost element in the CBS[10].

[9] From Benjamin S. Blanchard, Logistics Engineering and Management, 6th Ed.

[10] An example of CBS codification is given in RTO TR-058 / SAS-028, Chapter 9

Note that, in most cases, costs can be broken down to different levels of detail (granularity). For example, technical subsystems like engines can be further broken down into pistons, shafts etc. and activities like assembly can be broken down into sub activities (tasks). With increased granularity comes a loss of generality. For example, while an engine is a fairly generic concept and a part of most systems, the technical breakdown of an engine depends on the type of engine. Likewise, a common activity like maintenance will comprise a number of different tasks and activities. This has important implications when it comes to developing a CBS, for example for comparing alternative systems.

For items considered to be of high cost, high risk, or high technical interest an extension of the CBS to lower levels might be necessary to get needed visibility and in order to get an accurate evaluation.

4.2 CBS as part of Cost Estimation Process

CBS is an important part of the Cost Estimation Process being intended to allow cost elements identification, manipulation and updating. Basically, CBS Generation represents the essential part of cost estimation which is performed within Cost Estimation Process. The considerations mentioned above are illustrated in figure 4.2.

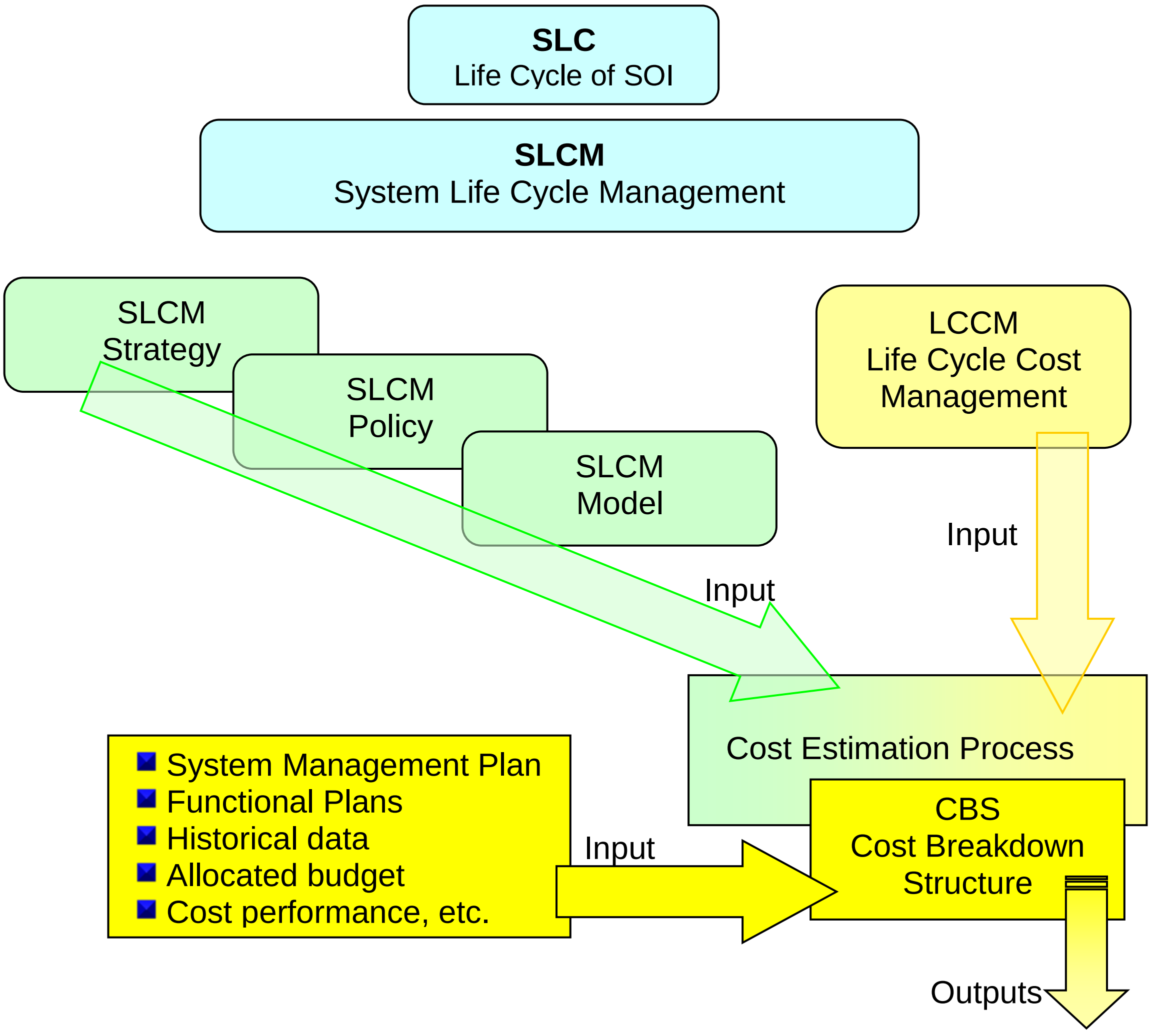

Figure 4.2: Cost Breakdown Structure as part of Life Cycle Cost Estimation Process

Inevitably, the CBS for a SOI will evolve throughout the Life Cycle as the SOI becomes more and more well defined and operating profiles, support plans etc. become available. Furthermore, a CBS generated for a specific study undertaken at a given point in the life cycle will evolve as the study progresses.

4.3 Requirements for a CBS

A Cost Breakdown Structure must have the following characteristics[11] in order to comply with the requirement stated by the scope of Cost Estimation Process:

- Easy to develop. The CBS must be easy to develop, to use and to update
- Comparable. At a certain level, all CBS could be compared, combined, etc. according with the scope of Cost Estimation Process
- Flexible. Each CBS must be able to be 'tailored' to the system or project and may evolve as the programme progresses through its Life Cycle
- Comprehensive. All relevant cost elements are to be identified
- Unambiguous. Definitions must be clear and cover all possible costs
- Without cost duplications / overlapping. Different cost elements may include common cost information, which has to be properly allocated

The last three statements above refer to the Mutually Exclusive Collectively Exhaustive (MECE) principle (also called the 100% rule in Mil Hdbk 881C). This states that the next level of decomposition of a CBS (child elements) must represent 100% of the cost of the next higher level (parent element).
The MECE principle is a grouping principle for separating a set of items into subsets that are:

- **Mutually Exclusive**: information should be grouped into categories so that each category is separate and distinct without any overlap and
- **Collectively Exhaustive**: all categories taken together should deal with all possible options without leaving any gaps.

The MECE principle implies the strong requirement of a clear definition and a common understanding of the content of each cost element. This is followed on the other hand by the need for well-defined and consistent boundaries.

Generally, the CBS must reflect that cost elements which are associated with the element they are supporting must be included in that element. In cases where cost elements support more than one higher element these must be included in the next higher element. These are indirect costs.[12]

[11] From RTO TR-058 / SAS-028

[12] Based on SAS028 "Cost Structure and Life Cycle Costs for Military Systems", September 2003, find also definition in ALCCP-1, annex 3

4.4 CBS Generation Process

The Cost Breakdown Structure represents the final output of a process being under the influence of the same factors as Life Cycle Cost Estimation Process.

Generation of the CBS must fit to purpose and represents an iterative process consisting of several main steps listed below.

An initial CBS will typically be developed after the scope of the Cost Estimation Process has been established, along with the basic content of the programme, the costing boundary and some basic assumptions. At this point, the determining factor of shaping the CBS will be the cost elements required to fulfil the scope of the Cost Estimation Process, and the resulting CBS will most likely be very similar to what will be presented and analysed in a final report of the Cost Estimation Process. First step consists of scope, ground rules, boundaries, history data and System Life Cycle Stages and Processes analysis as they are defined in Scope, Assumptions and Historical Data Document. As part of Cost Estimation Process, CBS Process benefits from the same scope and assumptions the Project Manager has concluded for Cost Estimation Process. A clear definition of what is being considered for costing as well as the out-put parameters must be finalized.[13]

The next step in developing the CBS will then be to break down the initial cost elements into items which can be estimated using relevant methods and models. On the basis of the mapping of SLC using processes / activities / tasks a tree structure of cost elements is developed in the second step. If appropriate, elements of the product tree must be added in order to cover costs related to the use of off the shelf components. Here, determining factors will be:

- **The stage of the system's Life Cycle**. In the early stages, details about the physical composition of the system, its operating profile and environment, support and logistic support system may not be known in details
- **Available data**. The choice of method and model will be influenced by the data available, and this in turn can influence how higher level cost items are broken down into parts which can be estimated

If the study progresses alongside the development of the SOI, the CBS will develop as well. This will typically happen when new information becomes available, either in the form of information about or related to the SOI itself, or in the form of new data which allow the use of more suitable methods and models for estimation.

The CBS changes over time due to the evolution of inputs and use of different methods, tools and techniques. Consequently, the output of the CBS Generation process will vary accordingly. The main input bulk is represented by the SLC mapping accompanied by the clear definition of scope, assumptions, boundaries and system support and operation concept. The output of the CBS Process is a list of cost elements consistent with the assumed scope. It is mandatory to carefully check the complete coverage of processes / activities / tasks and off the shelf components with cost elements. It must be ensured that all project processes / activities / tasks and products are to be estimated by the appropriate approach, and that the estimation is complete. These activities form the objectives of the third step of CBS Process.

[13] Based on RTO-TR-SAS-054 Section 2.3

The CBS Process must be developed for each stage of SLC. The final CBS represents the sum of the CBSs developed for each stage.

4.5 Identification of cost elements

A cost element is always associated with a "resource" used in an "activity" performed on a "product". This principle associates a cost element with a point in 3D space defined by RESOURCE, ACTIVITY, and PRODUCT. By extension, the CBS process becomes one of identification and definition of cost generating activities, resources consumed by these activities, and of relevant products involved in the programme.

In breaking down the programme into a suitable list of cost generating activities and the SOI into a suitable set of products, the conditions stated above (4.3) for a CBS apply as well: It must me comprehensive and unambiguous; flexible enough to be tailored and yet generic enough, at least at some level, to be comparable.

Of the 3 axes, resource, activity, and product, the activities tend to be the hardest to define. According to AAP-48, the Life Cycle (LC) of every SOI consists of a set of stages and activities. The flow in and out of the stages and the control of decision mechanisms is assured by the decision gates based on entry and exit criteria assessment. The stages, processes, and decision gates form the main blocks of the system Life Cycle models. As a result of the creation of a System Life Cycle Model a Life Cycle Model is tailored for each programme providing detailed data regarding the combination of stages, the definition of Decision Gates and Entry/Exit Criteria, as well as the processes performed during each stage.

4.6 Generic Cost Breakdown Structure (GCBS)

The large variety of processes and activities permits a detailed identification of the "activity" generating resource used. Nevertheless, the combination of cost elements calculated on the basis offered by a large list of activities may generate difficulties in data identification and manipulation. Consequently, a large variety of CBS will result according with national procedures and even within the same Nation for different programmes, making comparisons and exchange of cost data difficult. In order to avoid this problem, it is possible to group interrelated activities under the common label of "generic activity". Thus, it becomes possible to identify cost elements as a point in a generic 3D space defined by a GENERIC RESOURCE, GENERIC ACTIVITY and PRODUCT.

4.7 Generic Activity List

According to AAP-48, each stage of the Life Cycle consists of processes tailored by the Programme Manager. Each process consists of one or more activities which are intended to achieve the objectives of the process.

The Generic Activity is a consistent set of tasks (for example; to manufacture an engine, to test a sub-system, to maintain software, etc.) performed in order to obtain an outcome and which uses resources. The list of all possible generic activities that could be applied to a product during its life cycle is given below.

- Management
- Studies and Analysis
- Simulation
- System Engineering
- Design and Development Engineering
- Supportability Engineering
- Design Influence/Changes
- Purchase off the Shelf (Government or Commercial)
- Tooling (Investment)
- Facilities (Investment)
- Reference Sets
- Manufacturing
- Systems Integration
- System Level Test, Evaluation, Trials and Demonstration
- Delivery (PHST)
- Training
- Technical Information and Data
- Installation
- Acceptance Testing
- Operation
- Mission Support
- Maintenance
- Supply Support
- Replenishment
- Continuation Training
- PHST
- Modification Kit Procurement/ Installation
- Sustaining Engineering Support
- Software Maintenance Support
- Restoration
- Disposal
- Other

A description of the generic activities listed above is given in Annex 5.

Most activities apply to a product (hardware or software) with the exception of *management* that applies to all activities and *training* that applies to people. The generic activities listed above apply to the activities within processes tailored according to AAP-48. The same generic activity may be equivalent with different activities which belong to different processes in different stages of the Life Cycle.

4.8 Generic Resources List

The achievement of a task or an activity requires resources that may be provided by the contractor(s) (industry), by the organization, by the Nation or by NATO. Most of the resources needed are similar for all sorts of SOI.

The list of generic resources includes

- Personnel
- Equipment
- Consumables
- Infrastructure/facilities
- Services
- Information

A description of generic resources can be found in Annex 6.

4.9 Product List – Product Tree

The product tree defines and describes the products resulted due to the activities performed within the programme.

These include the products delivered to the user and the specific means required for developing and manufacturing these products.

The products delivered to the user include the main system (aircraft, tank, etc.) and its support elements (spares, support equipment, facilities, documentation, etc.). The various elements mentioned above are shown in figure 4.3.

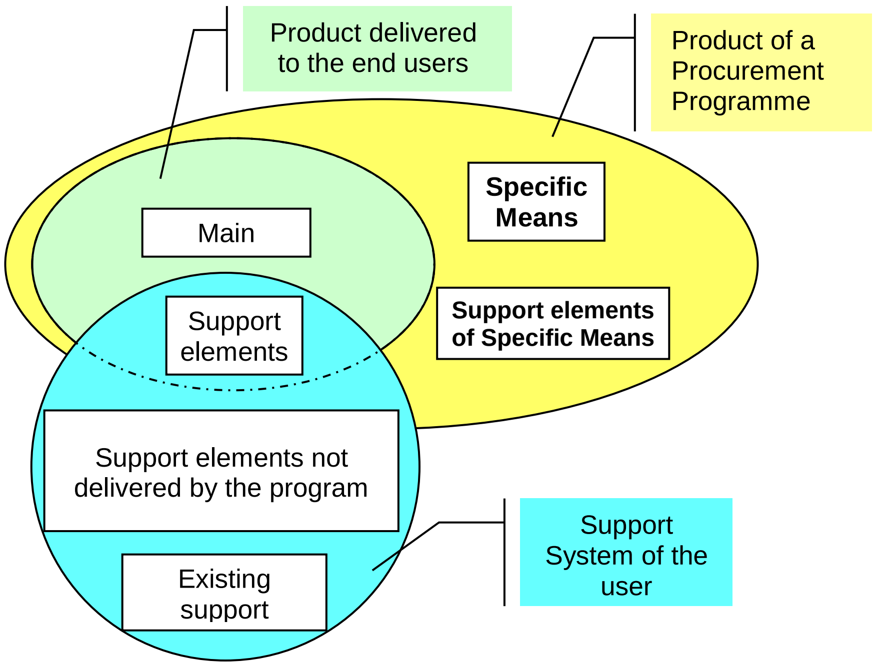

Figure 4.3: Correlation between various types of products

The Main System

The main system consists of both hardware and software, identified as deliverable end item(s), usually represented by standard Equipment Breakdown Structures (EBS), and is very different for air, land and sea equipment. It therefore cannot be described in a generic document.

The Support Element

Whatever the main system, the different categories of support elements are broadly common for all kinds of system. They include:

- **Data**: all deliverable data and publications, e.g., manuals, engineering data, management data, logistic data, Logistic Support Analysis Report (LSAR), and maintenance plan.
- **Spare parts**: components, assemblies, and subassemblies used for replacement purposes during maintenance.
- **Support equipment**: Equipment and computer software required to maintaining, testing or operating a product or facility in its intended environment (Built-in equipment is not included; this is generally considered part of the main system).
- **Training equipment and material**: all training equipment (simulators, etc.) and devices (course materials, etc.), accessories and aides used to facilitate instruction for the operation and the maintenance of the system. This does not include training activities.
- **PHST means**: all means needed for packaging (for example containers), handling, storage and transportation of the main system and other support systems.
- **Facilities and infrastructure**: industrial or government furnished facilities necessary for the operation and maintenance of the main system and its support systems.

The Specific Means

Specific Means (SM) cover all elements designed and developed, manufactured, if necessary modified and used within the programme, which are indispensable for the system procurement process, but which are not delivered to the end user. These may include tools of simulation, assembly facilities, test and trial facilities, etc. It also includes their support elements.

Specific means may be provided by Nation, Organization or Contractor. In the first case, they are usually referred to as Nation or NATO Furnished Facilities (NFF).

4.10 Specific aspects of GCBS Process for each stage

GCBS contents depend on the specific stage of the Life Cycle of the SOI. The level of granularity of the GCBS may be summarized as follows

- PRE-CONCEPT stage: very high level (if design/ characteristic of system are known)
- CONCEPT stage: High level only (at the very beginning of the stage) to major line items (at the end of the stage)
- DEVELOPMENT stage: All line items
- PRODUCTION stage: Fully populated CBS
- UTILIZATION stage: Fully populated CBS

- SUPPORT stage: Fully populated CBS
- RETIREMENT stage: Disposal line items

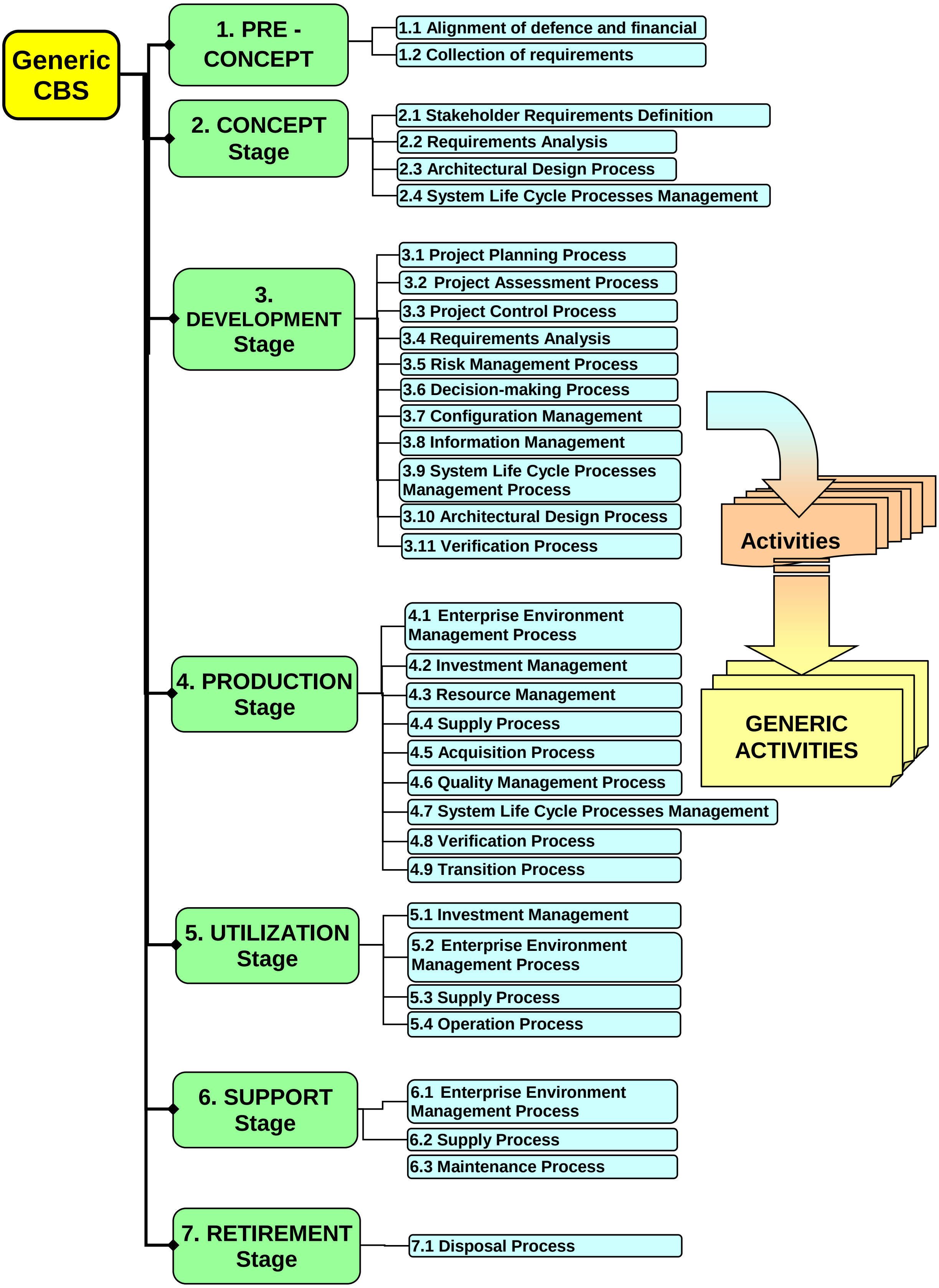

Figure 4.4: Example of GCBS (adapted from RTO-TR-SAS-054)

Figure 4.4 presents an example of a Generic Cost Breakdown Structure. The seven stages of the Life Cycle of SOI consist of processes derived according to the specificity of the programme. The stages and the processes are adopted according to AAP-48 (for further details, please refer to Annex 6). For each process listed in Figure 4.4 one or several activities must be selected.

5. METHODS AND MODELS FOR LIFE CYCLE COST ESTIMATION

5.1 Methods

As mentioned in Chapter 3 and 4, for each individual cost element as part of the CBS the appropriate method or model need to be chosen in order to estimate the costs.

There are many methods and models available to conduct Life Cycle cost analysis and it is important to understand the applicability and boundaries of each method and model in order to use them appropriately.

Most cost estimates require the use of a variety of methods. A different approach may be used for each area of the estimate so that the total system methodology represents a combination of methods. When choosing an estimating method, the cost estimator must always remember that cost estimating is a forecast of future costs based on a logical interpretation of available data. Therefore, availability and the quality of data is a major factor in the estimator's choice of estimating methodology. Also the type of study may influence the selection of the appropriate method.

The best combination of estimating methods is the one which makes the best possible use of the most recent and applicable historical data and systems description information and which follows sound logic to extrapolate from historical cost data to estimated costs for future activities.

For consistency, both the methods and models have been categorised as Optimization, Simulation, Estimation and Decision Support.

Figure 5.1 shows the categorization of methods and the most suitable methods to be used in estimating Life Cycle Costs.

Method Category	Methods
Optimisation	Linear programming Heuristics
Simulation	System Dynamics Discrete Event Monte Carlo
Calculation/Estimation	Analogy Parametric Bayesian Engineering Catalogue
Decision Support	Analytical Hierarchy Process Multi-Criteria Decision Analysis
Empiric	Rule of Thumb Expert Opinion

Figure 5.1: Method Categorisation

RTO-TR-SAS-054 report gives an overview of all the key estimating methods and provides examples to demonstrate their applicability as well as useful references.

5.2 Application of methods

Many cost estimates require the use of a variety of methods. It is often not possible to use a single method to estimate all the cost elements to be considered. Therefore, the total Life Cycle Cost estimate of a system will include the use and outputs from a combination of methods.

	Pre-Concept	Concept	Development	Production	Utilization/ Support	Retirement
Parametric	●	● ●	●	●	●	●
Analogy	●	● ●	●	●	●	●
Expert survey	●	●	●			
Engineering			●	● ●	● ●	
Extrapolation				●	●	
Simulation/ Optimization			●	●	●	
Activity based					● ●	

Figure 5.2: Applicability of cost estimation methods over the stages (amount of points indicates suitability)

The methods defined as calculation or estimation methods are used in all stages. Depending on the scope methods are differently applicable in the stages.

The analogy and parametric method are predominant and are used in almost every particular stage.

The engineering or bottom-up method is most popular in the stages development, production and in-service when major alternatives are compared and more detailed information is available.

In the very early stages decision support methods and system dynamics are becoming more popular. This is not surprising as these techniques can be employed using subjective judgement thus overcoming the lack of quantitative historical data.

In the development, production and the utilization-/ support stage, simulation and optimisation methods are sometimes used to estimate support costs and the effects of alternative support scenarios. During the utilization and support stages activity based costing is widely used to capture actual costs.

5.3 Method Recommendations

It is not possible to recommend a single method to estimate the Life Cycle Costs for a certain stage in the life cycle; several methods may be applied in each stage for various cost elements.

The best cost estimating method is the one that makes the best use of the data available. It is therefore recommended to employ a method that will provide as much detail as the availability of the input data will allow. Therefore, the availability of data is a major factor in the estimator's choice of the estimating method.

It is also recommended that a second method is used in order to improve the confidence and to validate the life cycle cost estimate. In many cases, expert opinion or a simple rule of thumb can provide a good second estimate.

For multi-national programmes, the method chosen depends on the level of detail of the data available to each nation. This will probably result in choosing a method that does not demand detailed design information and supporting data.

It is important to remember that each estimation method of the LCC is primarily and must remain an individual choice linked to the considered project and the decision-making process of the potential buyer (incl. the decision parameters). This choice of method and model is ideally done in the early stages and will also be influenced by the first orientations for the project: own development or through a third party (NATO agency or industrial), national or multinational project, acquisition of existing systems (COTS or second-hand material), rapid acquisitions.

Since there are many cases where a project is conducted in a reduced timeframe, especially in the case of an urgent or immediate operational requirement, some additional considerations on the rapid acquisitions are included in the Annex 8.

5.4 Models

A Cost Model is a set of mathematical and/or statistical relationships arranged in a systematic sequence to formulate a cost methodology in which outputs, namely cost estimates, are derived from inputs. These inputs comprise a series of equations, ground rules, assumptions, relationships, constants, and variables, which describe and define the situation or condition being studied. Cost models can vary from a simple one formula model to an extremely complex model that involves hundreds or even thousands of calculations. A cost model is therefore an abstraction, which can be the whole or part of a life cycle cost estimate.

In developing life cycle cost estimates very often in-house developed models are used that are based on a defined Cost Breakdown Structure. Data for these models are estimated either by empiric methods or parametric formulae (for completeness, sometimes both techniques are employed).

There are more life cycle cost models possible to be used, and the cost analysts must commit enough effort to select the best suitable model according to the existing data and requirements for cost estimation. More details about models are presented in RTO-TR-SAS-054 Report, Ch.5.

5.5 Application of models

During the early life cycle stages most of the cost models are used to support operational analysis studies therefore implying the need for high-level analysis and the use of in-house developed models is common.

In the later life cycle stages most models are used to support investment appraisal, logistic modelling and through life management planning. The quantity and range of applications of the models are greater for the project definition stages than for the earlier stages, this is valid both for in-house developed and commercial models.

Optimisation or simulation models are not quite often used for estimating the costs. These models are mainly used from the project definition stages and onward for optimisation of logistic resources and simulation of the support system. Optimisation and simulation methods are also used to analyse system availability and endurance to support operational and tactical planning of technical system in a cost-effective way.

5.6 Model Recommendations

Models for estimation are the preferred models for life cycle cost analysis. There is also a clear pattern that to supplement models for estimation, more models for decision support, like multi criteria analysis models, are used in the early stages when there is a shortage of cost data, whereas more models for optimization and simulation (like maintenance cost optimization models, supply chains optimization, etc.) are used later on, when cost data becomes available.

To ensure Best Practice, the use of more than one model is recommended. If data is available, the use of models for simulation and/or optimisation to supplement models for estimation is recommended. However, the use of multiple methods and models should always be balanced with the knowledge and understanding of how the estimate will be used. It is important to ensure that the life cycle costing activities are conducted in a cost-effective manner and balanced with what is realistically achievable at a specific stage in the programme.

It is important that the life cycle cost estimate and the models and methods used are fully documented.

When it comes to multi-national programmes, there is a need for all participating nations to understand and trust the models used. The participating nations need to agree on at least one common model or framework. There is also a need to be clear on which data to use and how to collect these data. One way of handling these needs is to use one or more commercial models, maybe supplemented with national models, for multi-national programmes. Furthermore, a uniform communication format should be used for presenting life-cycle cost estimates.

There is no single model, of all the models available, which cover all aspects. However it is possible to describe some of the more prominent attributes a good model should have. These attributes can also be used as a checklist when creating or constructing an in-house model or when evaluating a commercially available model.

5.7 Risk and uncertainty

5.7.1. General

Life cycle cost estimates of defence programmes are inherently uncertain and risky. Estimates are often made when information and data are sparse. Estimates, in turn, are based on historical samples of data that are almost always messy, of limited size, and difficult and costly to obtain and no matter what estimation tool or method is used, historical observations never perfectly fit a smooth line or surface but, instead, fall above and below an estimated value. To complicate matters, the system under study is often of sketchy design.

For all of these reasons, a life cycle cost estimate, when expressed as a single number, is merely one outcome or observation in a probability distribution of costs. That is, the estimate is stochastic rather than deterministic, with uncertainty and risk determining the shape and variance of the distribution. To better support the decision making process, some sense of risk and uncertainty needs to be present along with the point estimate.

A wide variety of methods and models are available for conducting risk and uncertainty analysis of life cycle cost estimates of systems. Each, if used properly, can give scientifically sound results and provide a better yardstick for an accurate life cycle cost estimate.

Uncertainty is the indefiniteness or variance of an event. It captures observations, favourable or unfavourable, falling to the left and right of a mean or median value.
Risk is exposure to loss and opportunity to favourable outcomes. Or, in a system acquisition context, it is a measure of the potential inability to achieve overall programme objectives within defined cost, schedule, and technical constraints, and has two components: (1) the probability/likelihood of failing to achieve a particular outcome, and (2) the consequences/impacts of failing to achieve that outcome.

Risks are translated into costs and added in the initial point estimate. Cost Risk has three (3) components

- **Cost Estimating Risk:** Is the risk arising from cost estimating errors and the statistical uncertainty in the estimate

- **Schedule/Technical Risk:** Is the risk associated with infeasible tight schedule and the difficulty of conquering the problem posed in the System specification phase of the SOI
- **Requirements Risk/Threat Risk:** Is the risk of changing the proposed requirements of the SOI and the risk associated with the change of the threat for which the SOI was designed in the first place

The most important part of the process of estimating risk and uncertainty, and probably the most difficult, is data collection and analysis. All variables in the cost estimating model potentially affected by risk and uncertainty first need to be identified. These variables often include simple ratios and factors as well as more sophisticated CERs based on regression analysis.

Probability distributions need to be estimated or selected for each variable. This entails first choosing the type of distribution to apply and then estimating the distribution's parameters such as high, low, and most-likely values. Popular distributions for this step include the normal, log-normal, triangular, and Weibull. There are a number of techniques used to cull or estimate distribution types and parameters, such as using checklists or sound engineering judgment.

It is also important in the concept stage to identify discrete risk events, or unfavourable outcomes that might occur in developing, manufacturing, and operating systems. An example might be failure of new, state-of-the-art radar to work as intended when integrated on a ship or aircraft. For each of these risk events, probability distributions also need to be estimated or selected as well.

After the data collection and concept stage, the analyst first generates a baseline cost estimate using Monte Carlo simulation followed by a risk-adjusted cost estimate. The output of each estimate is actually a frequency distribution of total costs, or, more technically, a probability density function, rather than a single number.

It is essential to convey to senior leadership the notion that cost estimates are uncertain, that programmes can and do incur difficulties, and that the probability of a cost estimate becoming reality, when expressed as a single number, is actually zero.

In generating the baseline cost estimate, the analyst first regards as fixed the values of the explanatory or independent variables (Xs) in each of the cost model's CERs. Values of the Xs are usually found in the programme's CERD (Cost Estimation Requirements Document), or in the APB (Acquisition Program Baseline).

The baseline estimate does capture uncertainty in the relationship between dependent and independent variables in each CER. This uncertainty, in turn, results from three possible, though not mutually exclusive, sources:

- **Limited data**. In explaining changes in the cost of any CBS element, the list of relevant factors may be extended ad infinitum. However, due to data availability, perhaps only two or three of these factors are included in the analysis. Indeed, sometimes it is lucky to get just one relevant explanatory variable. The CER, then, becomes an over simplification of the complexities of reality. Errors result.
- **Human unpredictability.** Over and above the total effect of all relevant factors, there is a basic and unpredictable element or randomness in human responses that can

be adequately characterised only by the inclusion of uncertainty in the analysis. This will hold as long as people rather than machines acquire and build systems.

- **Errors of observation or measurement**. Cost and technical data are almost always difficult to obtain and are often of less than perfect accuracy. For example, overhead costs from different contractors may not be of the same scope or consistency due to differences in ways of doing business. Further, even data from the same contractor may differ significantly over time due to changes in the company's accounting system. Again, errors result.

In generating a risk-adjusted cost estimate, not only is basic CER uncertainty captured, as above, but technical risk and uncertainty as well. Unlike before, the Xs in each of the model's CERs are now regarded as stochastic. Technical, acquisition, and cost-estimating risks are now considered. Variables affected might include

- Quantity of units to be developed or procured.
- Weight of a platform or system
- External parameters such as the price of oil
- System-to-platform integration challenges
- Number of drawings
- Number of Source Lines of code (SLOC) or percentage of SLOC reuse
- Number of test flights
- Key schedule milestones such as date of critical design review or date of first use.
- Cost parameters such as learning curve rates, T1s (first unit costs), and percent award fee, assuming these variables are not already covered in uncertainty analysis.

Moreover, discrete risk events such as failure to effectively design a new aircraft engine or a new circuit card are captured here as well. As before, for each of these risk variables, probability distributions are estimated or selected, and Monte Carlo simulation is used to generate a probability density function.
The process described above is presented graphically in figure 5.3.
More details on the risks and uncertainties associated with the cost estimation process can be found in RTO-TR-SAS-054 chapter 7.

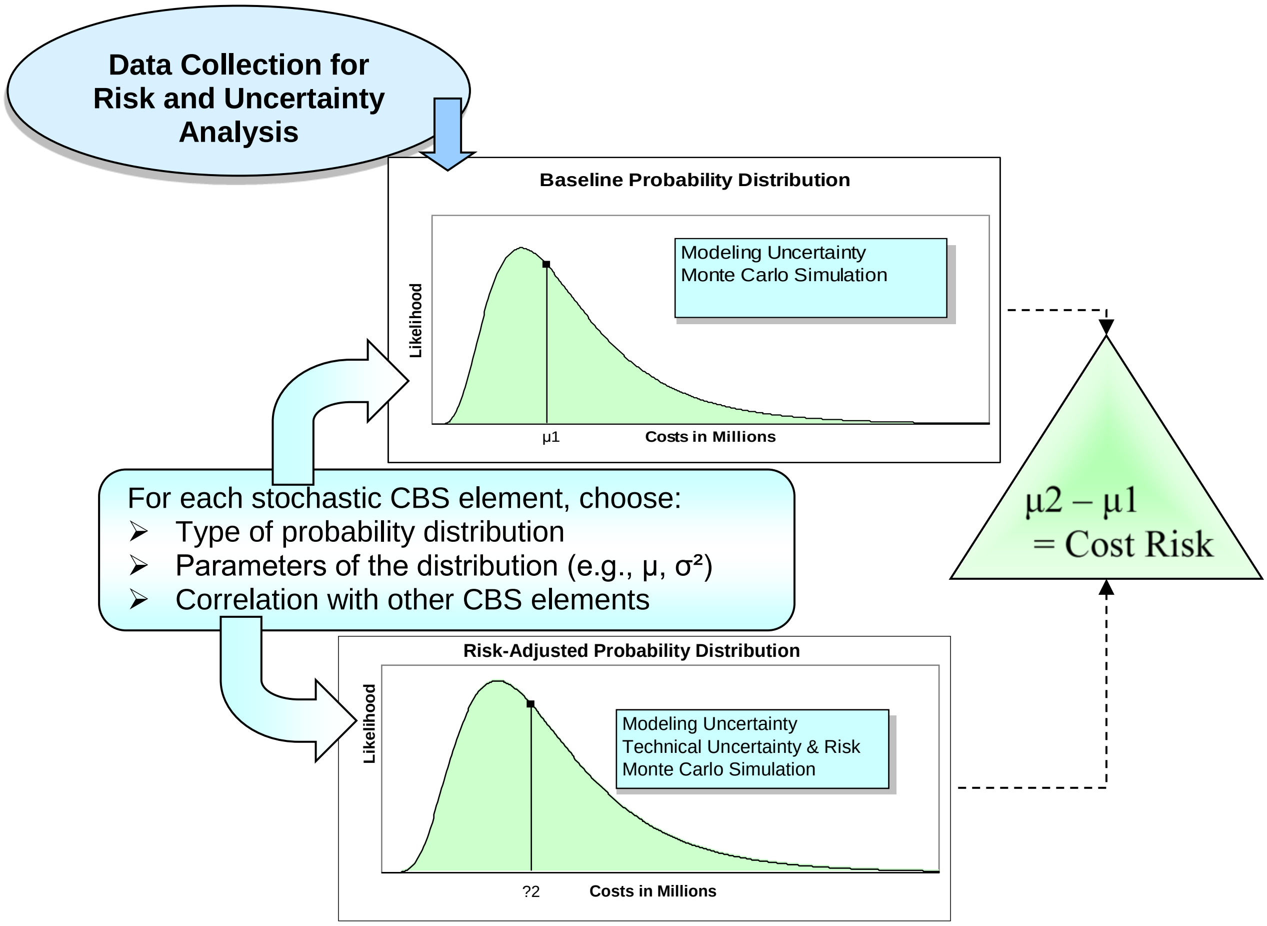

Figure 5.3: The Process of Estimating Risk and Uncertainty

5.7.2 Application of risk and uncertainty

Risk and uncertainty analysis is mandatory in many Nations as part of the acquisition process. The application of risk and uncertainly analysis is important for LCC, but its use in Nations and in projects varies widely and there are no standard approaches.

More specifically, risk and uncertainty analysis seems to be undertaken by the Nations, but it does not indicate that it is used in all projects. Quite often risk and uncertainty analysis is not undertaken at all in generating a life cycle cost estimate. Instead single point estimates are provided to the decision makers.

At other times, when risk and uncertainty analysis is conducted, the two most commonly used techniques seem to be expert opinion and sensitivity analysis. Detailed risk and uncertainty modelling, such as Monte Carlo simulation, may also be undertaken. In these cases, the estimate is usually presented as a three point estimate or a confidence interval, rather than a single point estimate.

5.7.3 Recommendations related to risk and uncertainty

It is recommended to use the detailed risk and uncertainty modelling, such as Monte Carlo simulation in all NATO projects.

Figure 5.4 presents a recommended approach for communicating the results of a life cycle cost estimate to senior decision makers.[14] 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. This is referred as the three-point-estimate.

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 the assumptions or scenarios associated with the low, baseline, and high estimates. This enables decision makers to see clearly the cost implications of events that can influence the outcome of an acquisition programme.

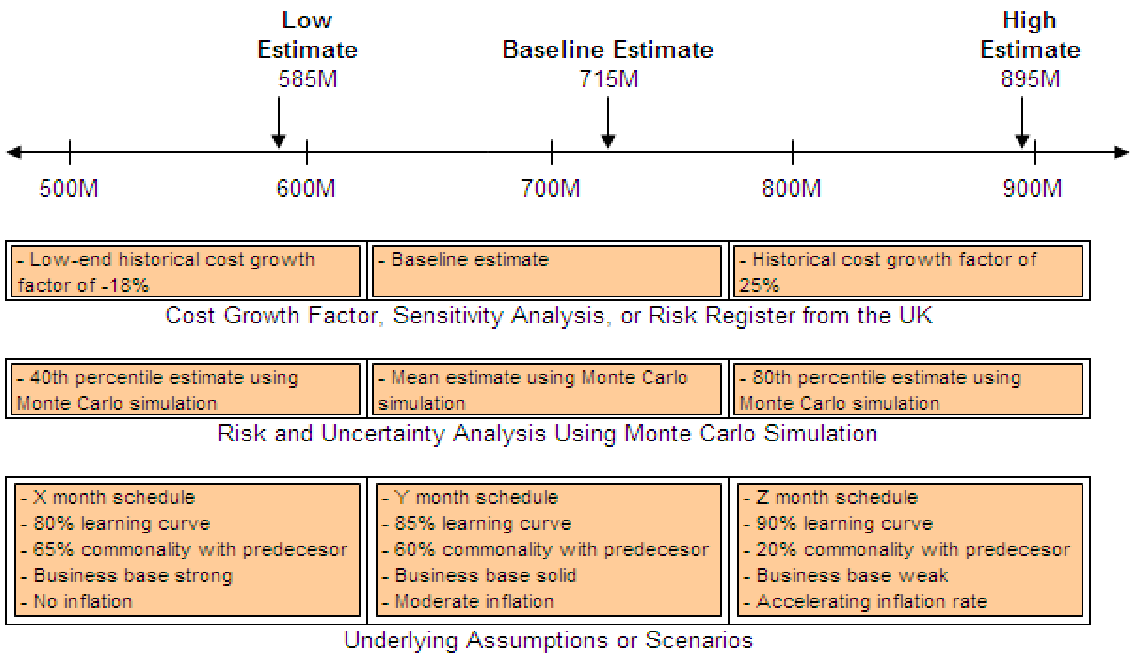

Figure 5.4: Recommended Presentation of Cost Estimating Risk Analysis

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

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6. LIFE CYCLE COST ESTIMATION REPORTING

The output of the Life Cycle Cost Estimation Process represents in fact a complex package of information which must meet the requirements of both Programme Managers and cost analysts. This information is obtained based on assumptions, the LCC model adopted and using adequate methods.

The cost estimate is not complete until the cost documentation is done. The way of documentation of a Life Cycle Cost estimate is defined in regard to scope, period, responsibility in the CERD. Without adequate cost documentation, it is very difficult, if not impossible, to revisit the cost estimate for both the analyst who performed the estimate and for other analysts who wish to review the estimate. The significance of cost estimate documentation, organization and structure are the key elements of a good cost estimate and the **Life Cycle Cost Estimation Report** must emphasise them.

The documentation needs to be organized and structured in a logical, clear and concise manner. It should be easy to follow and not be prepared after the cost estimate is complete. The documentation should be included in the initial plan and developed as the estimate evolves. By documenting an estimate, it is assured of having accurate information.

Cost documentation can be logically segmented into three major sections with supporting appendices. The major sections include an introduction, a main body, and a summary. The appendices provide information relevant to the estimate which may be too detailed to include in the major sections.

- **Introduction**: This section includes a table of contents and a narrative summary which needs to be complete and explain succinctly the basics of the estimate. The narrative should include the name and a short description of the programme, explain the purpose of the estimate, list the names and other details of the estimating team members, describe what is being estimated.
- **Main Body**: This section develops and expands upon the narrative summary in the introduction. The ground rules and assumptions are clearly detailed. The estimating methodologies are presented. Data sources which have been used are provided or referenced. Cost data are appropriately labelled and their uses in preparing the estimate are specified. Calculations are described and supported by statistics. The objective of the main body is to provide that level of detail which will allow another cost analyst unfamiliar with the programme to replicate the estimate.
- **Summary**: This section includes
  - The programme schedule.
  - Cost estimate summary
  - Risk and uncertainty.
  - Any caveats or limitations to the cost estimate
  - Discussion at the summary level of the cost estimate viability
  - Degree of confidence in the estimation

Frequently, the output of the Life Cycle Cost Estimation Process represents an input for other processes like cost analysis which should include an affordability analysis, cost comparisons, budgeting etc., imposing specific requirements for data presentation. Life cycle cost analysis should also include an affordability analysis (see for more details on affordability analysis section 2.9 of the RTO-TR-SAS-054 report).

Updates of the cost estimate due to changes in input data or assumptions and boundaries also impose specific requirements for traceability and visibility of the cost estimation process.

The CIPT must assess whether the estimates satisfy all constraints, especially the level of granulation, cost and schedule.

At the same time, the CIPT must determine whether all estimation approaches, assumptions, and results are fully recorded and documented.

All the aspects mentioned above need to find an appropriate answer in the Life Cycle Cost Estimation reporting. New revisions of estimates must always be compared to the old estimates, and the eventual differences should be evaluated and explained.

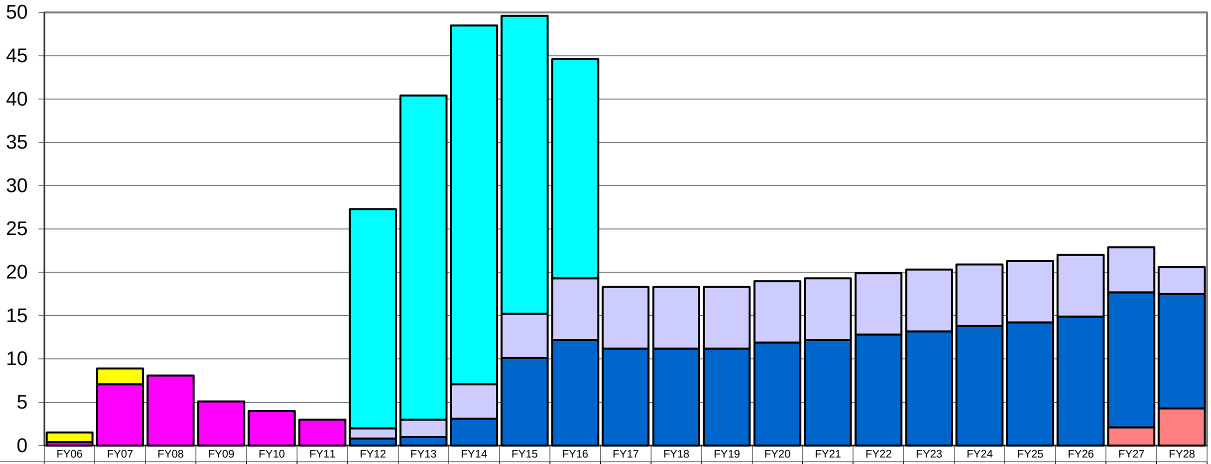
The Programme Manager must ask for a specific format of the cost estimate, but at least the following information must be included in the LCC report:

- Basic definitions, ground rules, boundaries and assumptions used in cost estimation process
- Models and methods adopted for costs estimation
- Cost elements data according to the level of granulation required by the Programme Manager
- Identification of the cost drivers
- Estimated Life Cycle Cost data in a format consistent with the results of the estimation method used and with the uncertainty and risk assessment. The recommended form for presentation of estimate cost includes:
    - Baseline estimate,
    - Low estimate
    - High estimate (see chapter 5.7.3 for details)

The above listed elements of LCC Estimation Report are mandatory in order to elaborate the **Cost Estimation Process Assessment** document. The main goal of this document is to asses in the future the quality of the LCC estimation based on the comparison of cost estimates and actual cost when it becomes available. This operation must be accompanied by the identification of all changes affecting the cost estimation process in order to underlie pertinent conclusions.

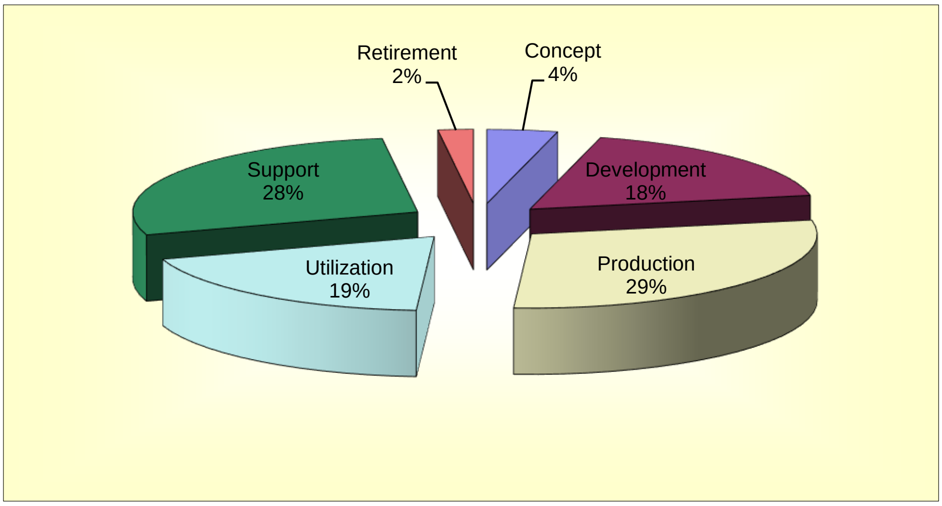
The results of cost studies can be presented in a wide range of tabular and graphical forms. The favour is to include graphical presentations of the results wherever possible. This enables the widest possible audience to have a clear picture of the overall results while retaining the detailed tabular presentations for those that require them.

Two common form of graphical presentation (the spend profile and cost allocation pie chart) are shown as figure 6.1 and figure 6.2. 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.



	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
CONCEPT	1.1	1.8																					
DEVELOPMENT	00	07	08	05	04	03																	
PRODUCTION							25	37	41	34	25												
UTILIZATION							01	02	04	05	07	07	07	07	07	07	07	07	07	07	07	05	03
SUPPORT							01	01	03	10	12	11	11	11	12	12	13	13	14	14	15	16	13
RETIREMENT																						2.1	4.3

Figure 6.1: Example of a Baseline Life Cycle Cost Spend Profile



The cost allocation percentage shown should not be considered as being representative of all life cycle cost estimates.

Figure 6.2: Example of a Life Cycle Cost Allocation

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7. LIFE CYCLE COST DATA COLLECTION AND PROCESSING

7.1 Introduction

Life Cycle Cost data is the raw material for Life Cycle Cost Estimation Process. Data provides credibility, accuracy and defensibility to the Life Cycle Cost Estimate. Data, when properly analysed, provides assessments of the statistical accuracy and reliability of the Life Cycle Estimate.

The Life Cycle Cost Estimation Process is a data driven process, as the amount, quality and other characteristics of the available data, define what methods and models can be applied, what analysis can be performed and the credibility of the results that can be achieved.

Quantity and quality of data directly influence the reliability of the LCC estimation. In the course of a programme both factors increase, while the need and amount of assumptions decreases.

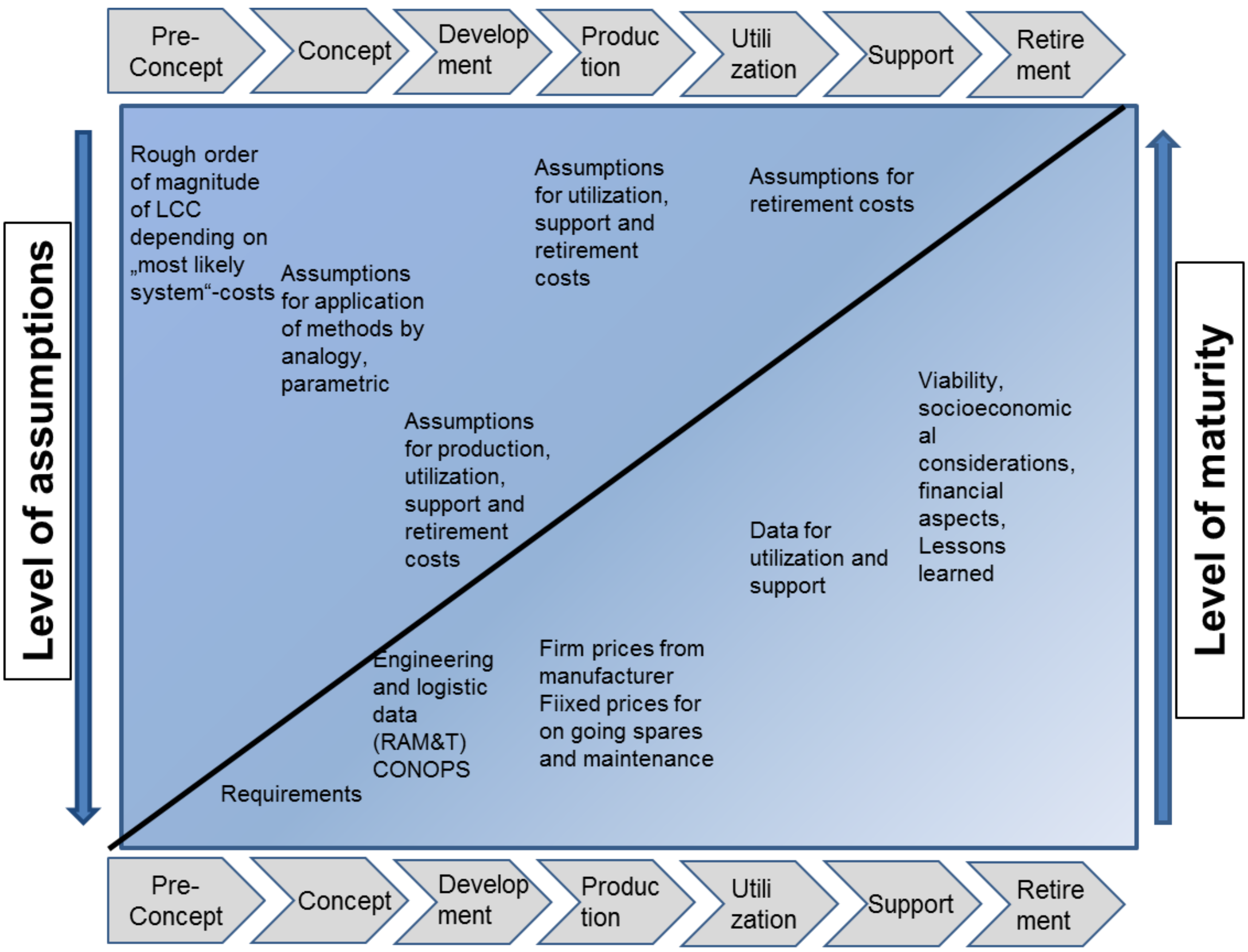

Figure 7.1**:** The development of data and assumptions through the stages

When a project begins, very little is known about the end system. At this stage, the expert's knowledge, expertise and predictions are the main source of data. Estimators may also rely on “outside” data from other comparable systems and programmes, until reliable “internal” data will be generated.

As the project enters the next stages of its Life Cycle, more and more facts, “hard numbers”, accurate and detailed information become available and can be documented as internal data. The more solid the data the better will be the estimate.

This chapter focuses on the various types of data used in the Life Cycle Cost Estimation Process, on the data collection process, including some issues to consider in data collection and normalization, and reviews some typical sources of data.

7.2 Life Cycle Cost Data Collection

7.2.1 Data Collection Objectives

The data collection objective is to obtain the information needed to feed the Life Cycle Cost models, which by using the appropriate methodology, will produce cost forecasts and estimations. Ideally, the data collection process should be based on a fully standardized and automated system, and aims to

- Improve the quality and the accuracy of the Life Cycle Cost estimate
- Reduce the effort needed to conduct the Life Cycle Cost estimate
- Reduce the time schedule to conduct the Life Cycle Cost estimate
- Obtain data for use in the further study of the system itself or of comparable systems

7.2.2 Types of Data

Life Cycle Cost Estimate is based on a large variety of data types. The main data types are listed below.

- **Cost Data**
  Cost data represent costs, in a specified type of currency, associated with activities (labour) or materials. The analyst needs both technical and programmatic data in order to have the adequate information that provides the context to the cost numbers.
- **Technical Data**
  Technical data add requirements definition to the SOI and provide the basis for the cost estimation (size, weight, special security requirements, payload requirements, speed, crew composition, deployment plans etc.). Technical characteristics define the SOI and allow for comparisons.
- **Programmatic Data**
  Programmatic data refer to the programme parameters that explain and drive cost (schedule, multi-year procurement, contract type, etc.).

Each main type of data listed above may belong to the following categories

- **Primary Data** which are obtained from the original source (contractor-facility, government reports, depots, etc.) and in the original form without being changed or altered. Primary data are typically the most defendable, best quality and most useful data that an analyst can capture.

- **Secondary data** which are derived from primary data, and are therefore, not obtained directly from the source. Because secondary data are derived from the original data (actually changed), it may be of lower overall quality and usefulness. For the cost analyst it can be very valuable when used in combination with other data for cross-checking purposes,
- **Objective data** which are quantitative in nature and like primary data, are preferred. This type of data is collected through a formal data collection process.
- **Subjective data** which are based on a personal view or group's feelings or understanding of a characteristics or condition of the SOI (complexity, level of difficulty). It tends to be non-quantitative and typically provides information needed to interpret or validate objective data.

The most valuable data are primary and objective data. Consequently, the efforts of the Programme Manager must focus on the collection of these types of data.

7.2.3 Data Sources

Life cycle costing requires a wide variety of data, which must be collected from an even wider variety of sources.

Primary sources of data should be given the highest priority for use whenever feasible.

Another distinction can be made between internal and outside data. In the early stages of a systems Life Cycle, data will have to come from comparable systems and programmes. Outside data sources can be industry or other branches of the military or the government.

It is immensely helpful if there is an understanding of Life Cycle cost by the providers of data, including how and why it is done and how it is used, otherwise the quality of data will drop, which will turn in poor estimates. Hence, the proper time and effort must be spent informing data providers on how their output is used.

Potential data sources may include

- Basic accounting records
- Cost reports
- Historical cost databases
- Functional specialists
- Technical databases
- Subject Matter Experts (SMEs)
- Contracts
- Cost proposals
- Supplier catalogues – Catalogue prices
- Vendor quotes

7.2.4 Life Cycle Cost Data Collection Process

The Life Cycle Cost Data Collection Process runs more or less in line with the Life Cycle Cost Estimation Process. Five basic steps can be distinguished in this process:

- **Understand Total Picture of the estimating task**

The Cost analyst should understand the intended use of the estimate (Budget, AoA, Risk estimate, see chapter 1.2 and 2.2 of this publication) and the stage of the Life Cycle the SOI is in.

- **Establish Life Cycle Cost Breakdown Structure (CBS)**
  In order to understand, what data needs to be collected, a documented CBS must be established. A detailed CBS will add structure to the data collection effort and will help to keep track of data gaps.
- **Understand Estimating Technique and Data Collection needs**
  The cost analyst must define the data requirements for the estimate. In order to do so, the cost analyst should understand the scope of the estimate; the boundaries set by the CBS, and have an idea of the estimating technique(s) that he may want to use in developing the estimate. The available data drive the estimating technique to be employed in developing the estimate.
  The next step is to identify the potential data sources for each component of the estimate. The potential data sources must support both the CBS and the proposed estimating technique.
- **Develop Data Collection Plan**
  The cost analyst must develop and execute a data collection plan which will capture all data types (primary or secondary, technical etc.) and ensures that every cost element in the CBS is covered. Back up/alternative data sources should be identified. Data sources for cross – checks should also be identified. Finally a timeline/schedule should be established.
- **Collect the data**
  Selecting and collecting the appropriate data for the estimate requires sound analytical judgment, because the estimating process benefits from organized and structured data. The data must be consistent and accurate.

The data collection process may be affected by various issues and problems such as

- **Availability**: Does it exist?
  The type and amount of data needed for a particular estimating approach may simply not exist.
- **Accessibility**: Can it be obtained?
  The data may exist but cannot be accessed due to security classification, its competition sensitive nature, or proprietary use issues.
- **Validity:** Is data reliable?
  - The collected data are relative, current and applicable.
    Investigate the data before accepting them. Does the data pass the sanity check?
  - The collected data may not be accurate. Validate the accuracy of the data through the use of multiple sources.
- **Time Constraints**: Can it be obtained on time?
  Data gathering tends to be very time intensive. There may not be sufficient time available to gather all the primary data required or desired for the estimate, even if they exist.
- **Underlying Requirements** Is it relevant and needed?

Data may only be useful in certain circumstances. You need to understand the use of the specific data source, the purpose or indented use of the data and the estimate itself.

The cost analyst must act in close cooperation with the Programme Manager in order to find the adequate solution for each problem that may occur.

7.3 Processing the Collected Data

7.3.1 Data Analysis

Collected data need a carefully conducted data analysis process in order to avoid errors. The main data analysis operations are the following:

- **Graph the data**. The objective of graphing the data is to identify unusual patterns. Any shift or nonlinearity in the data must be given special attention in developing the estimate.
- **Data Validation**. The objective is to examine the descriptive statistics of the data set, treat potential outliers, and compare the data with historical data (rule of thumb, standard factors, other historical data, etc.)

7.3.2 Data Normalization

In section 7.2.2 the concept of primary and secondary data was introduced, and it was indicated that primary data are preferable. However, since raw data come from a variety of sources, there is generally a lack of uniformity in data and therefore a certain amount of normalization will be unavoidable. Generally speaking, data normalization covers changes and adaptations made to primary data to make it applicable in a given model. It is defined by ICEAA as

- To adjust a measured parameter to a value acceptable to an instrument or technique of measurement
- For a data base: to render constant or to adjust for known differences
- For currencies: Then-Year values and/or actuals are escalated to a common Base Year for comparison

The last definition in particular will be relevant for cost data. However, normalisation can take many different forms and have different specific purposes, such as:

- Adjusting costs to a common year or adjusting to different inflation or discounting mechanisms or other variations in accounting standards
- Adjusting system or parts costs for technical specifications like size, weight, complexity, technological maturity etc.
- Adjusting costs or technical performance data such as failure rates for different operating profiles like operating temperature, mileage etc.
- Adjusting prices for lot size, learning curve considerations, producer capability and maturity, etc.
- Adding cost items not originally included, for example through error or because of a different costing scope, or removing cost items which are not applicable

Regardless of how data are normalised, exact, complete and detailed documentation of the process is very important. This is the case whether normalisation of primary data is performed as part of the LCC estimating process or secondary data has been obtained for use in LCC estimation. Serious errors can occur if data is not properly understood and interpreted. It is therefore vital to fully understand data and to know where data is coming from.

The types of data normalization are the following:

By Cost Units:
Correct the cost units for price level changes associated with inflation. The following terms are used when you make the price level changes for inflation:

Base Year	A point of reference representing a fixed price level and usually defined as the fiscal year in which a programme was initially funded.
Base Year Euro[15]	Reflects the value or purchasing power of a Euro in the specified base year as if all the Euros were to be expended in that year.
Constant Year	Means expressing the Euros in terms of constant euros for the specified year.
Constant Year Euro	Reflects the value or purchasing power of the Euro in any specific year (the specified constant year), which may or may not be the base year
Current Year - Then Year	Means expressing the Euros in terms of then year Euros for the specified year.
Current Year Euros - Then Year Euros	Reflects the euros needed when the money is actually expended. They are derived from Constant Year Euros or Base Year Euros that have been inflated or deflated to indicate the amount of money needed when the goods and services expenditure actually takes place.
Price relative Index:	Expresses the percentage change in the price of a single commodity from one time period to another. It is calculated by dividing the price at time period two (T2) by the price at time period one (T1).
Raw Inflation Indices	Convert from base year (constant year) euros in one fiscal year, to base year (constant year) euros in a different fiscal year. Raw inflation indices are not influenced by outlay profiles.
Weighted Inflation Indices	Combines the raw inflation indices with the outlay profile to illustrate the amount of inflation occurring for the expected period required to expend the total obligation authority for a given year/appropriation.
Inflation	The sustained and persistent rise in the general level of prices for all goods and services in an economy.

Figure 7.2 Price level changes from inflation

Check whether the numbers represent Euros, thousands of Euros, millions of Euros, or billions of Euros. All data should be transformed to the same cost unit and to the same currency using the correct exchange rate.

- **By sizing units**: Check whether the data represent the same units of size, weight, and density. It is very critical for all sizing units to be consistent.
- **By special grouping** such as mission application: All data should be collected according to comparable groupings, such as similar missions or similar characteristics.

[15] Euros are only used for illustration purpose and can be substituted with any other currency.

- **By operating environment**: Data should be grouped by the environment the SOI operates in. For example, the manned space systems will exhibit costs and characteristics quite different from unmanned space systems.
- **By Cost Types**: Data should be grouped according to the different cost types. Recurring/ non-recurring costs, fixed/ variable costs.
- **By system's stage in the Life Cycle**: The analyst accounts for the system's stage in the development cycle and the impact of the learning curves. Cost, labour hours may vary significantly for a system or a product that is a concept or technology demonstrator, a prototype or something still in the development phase versus one that has been in the assembly line and in full rate production for some time.
- **By terms of homogeneity**: When data is collected in order to make comparisons or perform analysis, content differences between the systems should be accounted for. Definitional content consistency is very important when analogies are used. Furthermore the missing or absent elements should be identified and the excess or inapplicable elements from the systems.

7.4 Life Cycle Cost Data Format

Estimating future costs is rather challenging, especially during the early stages of a SOI Life Cycle. Because of limited actual data, analysts base their projections on assumptions and use costing techniques that estimate a range of possible future costs.

For a cost analyst, cost data expressed by a single numeric value is incomplete. To express comprehensive and meaningful information regarding the LCC of a SOI, a set of additional attributes is required. To configure a typical LCC data exchange format, one should consider which supplementary pieces of data are required to provide complete and meaningful LCC information. Therefore, it is suggested that a typical Life Cycle cost data format should be configured by at least the following Basic Life Cycle Cost Data Attributes:

- **Envelope information**: This attribute establishes the communication channel, specifying the sender and the receiver of LCC data. Thus, the message will not be lost; the receiver will be able to confirm and give feedback to the sender or ask for additional data, etc.
- **The SOI that the cost data refers to**: This attribute describes the brand name, model type, stock number, part number, etc. Usually, after its production, the SOI will be coded and expressed by a unique NATO Stock Number (NSN) through the rest of its Life Cycle
- **The number of units or quantity of SOI**: This attribute defines the LCC allocation base (units or quantity), enabling adjustments and comparisons between different groups of a SOI
- **A short description of the cost element**: This attribute is a generic description of the CBS element, as reference to the Life Cycle stage and the activity, product or resource it is associated with
- **The CBS that is being used**: This attribute describes a standard vocabulary of identifying and classifying the costs of the SOI. This information requires a fully coded CBS, as described in Chapter 4.10, Figure 4.1 In this case, each CBS element is expressed by numerical fields that represent Life Cycle information

- **The numerical expression of the cost element in the CBS**: This attribute specifies the exact location of the cost element in the CBS. Each element is coded in numerical fields that express its exact position in a levelled hierarchy
- **The value of the cost element**: This attribute provides the core information, which is the numeric value of the cost
- **Uncertainty**: This attribute describes the type of probability distribution and parameters of distribution (see Figure 5.3), or the three-point estimate (see Figure 5.4)
- **The currency**: This attribute defines the metric of the monetary value of the cost
- **The estimating method**: This attribute indicates whether the LCC estimate derives from analogy, parametric, engineering, or other estimating techniques. It provides useful information to cost analysts about how accurate or how vague the estimate might be (see Figure 7.1)
- **The period of time or date that the cost was captured (recorded)**: This attribute is important for normalization purposes (see Figure 7.2). In case the data is already normalized, the base year should be mentioned
- **The source of cost data (i.e. nation, organization, authority, etc)**: This attribute provides useful information to cost analysts, in case data need to be counter-checked and verified
- **Security classification and information use rights**: This attribute designates the constraints for data handling. It supplements the Envelope Information attribute.

	LCC Data attributes	**Description**
1	Envelope Info	From Hellenic Air Force General Staff to NSPA
2	SOI	F-16C/D Block 30
3	Units	20
4	Cost Element Description	Maintenance Cost
5	CBS	NATO Guidance on LCC, Chapter 4, Figure 4.4
6	Numerical Expression of Element	5.3.
7	Value	20.000.000
8	Uncertainty	-
9	Currency	EURO
10	Estimation Method	Bottom – up
11	Recording Date - Period	20/12/2006 – Refers to 1/1/06 up to 30/6/06 period
12	Source of Data	Greece, Hellenic Air Force General Staff, Branch D
13	Security Classification	Unclassified

Figure 7.3: Example of LCC data attributes

7.5 Life Cycle Cost Data Coding

The concept of coding is to create and/or agree on specific rules, in order to express information in a coherent manner. For example, it should be determined whether a number should be expressed according to the decimal system (i.e. 7) or according to the binary system (i.e. 111).

Web-sharing environment is the essential factor for coding Life Cycle Cost data. Data modelling languages may[16] support web-based entries and databases of life cycle cost data, in a shared data environment. These languages are artificial tools that can express information in a structure that is defined by a consistent set of rules. A modelling language can be.

- **Graphica**l – where modelling languages use diagram techniques with named symbols that represent concepts and lines that connect the symbols and that represent relationships and various other graphical annotation to represent constraints. An example of a graphical modelling language, used in ISO 10303, is EXPRESS-G, or
- **Textua**l – where modelling languages typically use standardized keywords accompanied by parameters to make computer-interpretable expressions. An example of a textual modelling language, used in ISO 10303, is EXPRESS.

[16] ISO 10303 refers to SOI Life Cycle data. ISO 10303 parts specify the representation of various data types associated to a product. The representation of Life Cycle Cost data has not been specified according to any ISO part, so further developments have to be made in order to facilitate the representation of Life Cycle Cost data via ISO 10303

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8. LIFE CYCLE COST DATA EXCHANGE

8.1 Data Management of a System of Interest (SOI)

The data management related to a product (SOI) is a key activity in the Product Life Cycle (pre-concept, concept, development, production, utilization, support and retirement).

New information technology systems provide the means to manage data in efficient, reliable and cost effective ways, to make it available to the product stakeholders throughout the life of the product. Usually, it is a real need to exchange all the product life cycle data necessary to plan, to acquire and to execute support for the SOI.

The information management process, which is extensively described in AAP-48, facilitates the right information at the right time for the right purpose to the right user, with the lowest possible cost, with the highest possible quality, actuality and security, and abiding to current laws and regulations.

The basic tool for the Data Management of a SOI is the ERPs (Enterprise Resource Planning System) that have appeared in the last decade. Some of the benefits that can be derived from the utilization of these are:

- Managing information within rapid changing processes
- Utilizing internet for rapid links to access, transmit or import data (data exchange)
- Setting up a common tool between Stakeholders and Industries which allows a two ways life cycle cost data exchange
- Reducing cost of handling, operating, and maintaining a SOI

8.2 Data Exchange

Data Exchange is the process of the information flow, in a Shared Data Environment (SDE) between different users or systems. Further details on SDE are included in section .8.5.

On the other hand, it is particularly important to anticipate future data requirements and to frame agreements and contracts accordingly. The timing of collection and delivery of the data as well as the contents and formats of the required data should be clearly defined. The quality and reliability of data from suppliers is often inferior. Whether this is caused by a lack of incentive or ability, it is recommended to have previously agreed upon and well documented templates or standards for the data to be exchanged.

To be able to make such an effort achieved related articles which governs life cycle cost analysis producers could be added into the contracts/agreements as advised in Annex – 9.

8.3 Data Exchange Objective

Computer-based technology has led to inherent differences among the hardware, software and human elements, which make up a system. The lack of harmonization and integration of the disciplines involved (science, engineering, management and finance) created a need for a common framework, to improve communication and co-operation among the parties that create, utilize and manage modern systems, so that they should have an integrated and coherent approach.

Therefore, the data exchange objective is to adopt a common process framework, in order to:

- Exchange ideas among different users (NATO (bodies, nations, agencies), international organizations, suppliers, etc.)
- Promote effective use in predicting future costs
- Assure data consistency
- Harmonize the nomenclature and directives of different users
- Improve data management
- Group functionalities
- Enhance import – export file handling
- Promote life cycle management application throughout all stages of life cycle

8.4 Data Management Scheme

An information architecture should be developed that will be in place for its full life cycle. The information architecture captures the data definitions, the relationships between and among them, and the functions that are supported by the information architecture.

8.5 Shared Data Environment (SDE)

Shared Data Environment is the information infrastructure which supports digital communication and allows data to be controlled, accessed, and shared electronically between different users, according to the security rights and the access limits that must be predetermined.

In a wide multinational environment such as NATO, the philosophy of SDE must be adopted in order to achieve the communication and the digital exchange of information between different users.

Furthermore, the ability to share and access the data throughout the entire supply chain over the life cycle is a prerequisite for flexible cooperative management among all the users involved.

8.6 Standards for Data Exchange

A number of standards exist for exchanging of data. ISO 10303 (STEP) is frame standard with its Application Protocols (APs) for data exchange. ISO 10303-239 (PLCS) is an AP of STEP while DEX is a way of dividing up the ISO 10303-239 information into sections suited for a particular process.

Interrelationship among standards is shown below:

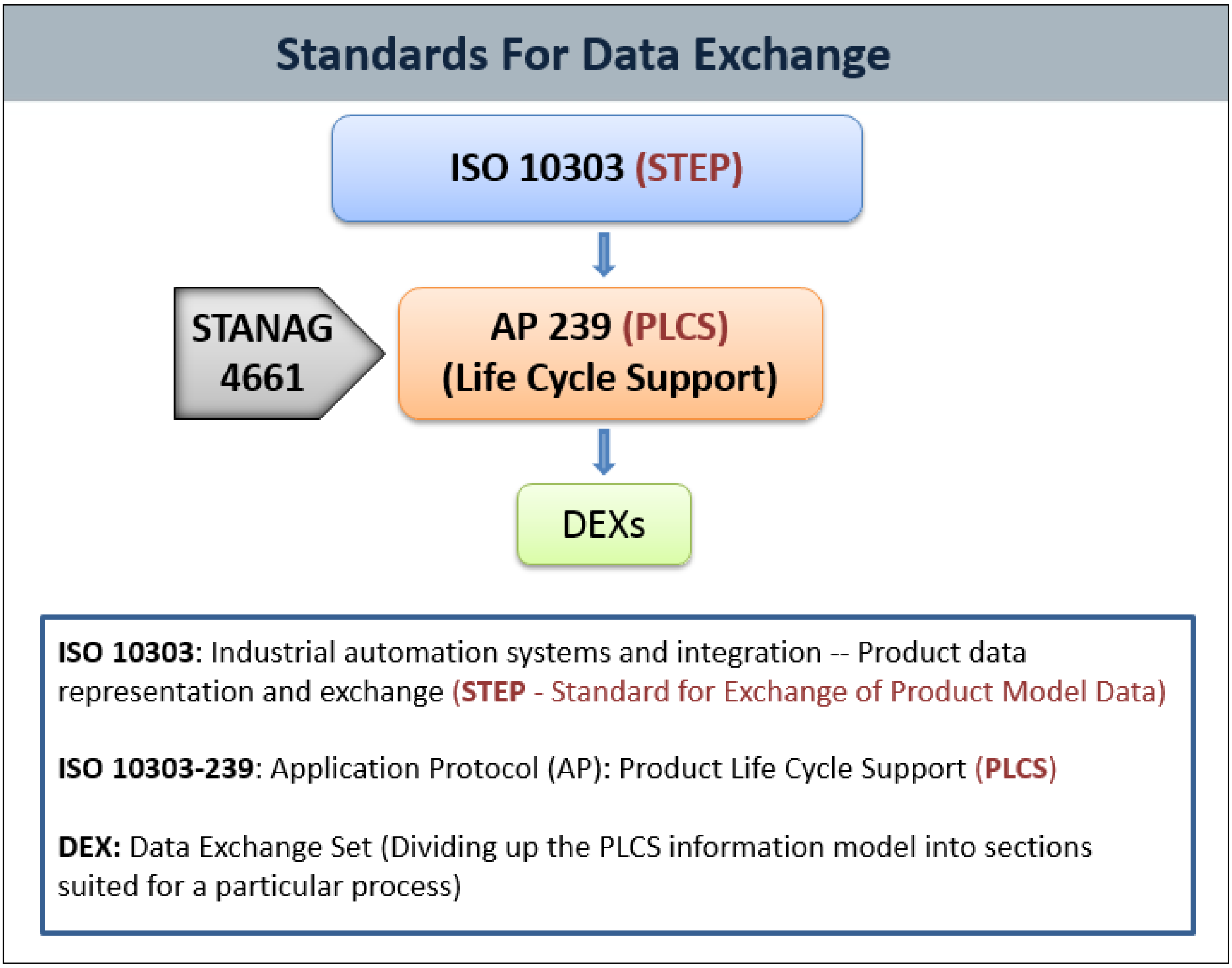

Figure 8.1: Standards for Data Exchange

8.6.1 ISO 10303 - Standard for the Exchange of Product Model Data (STEP)

ISO 10303 is known as STEP (Standard for the Exchange of Product model data). It is an International Standard for the computer-interpretable representation and exchange of product data. The objective is to provide a mechanism that is capable of describing product data throughout the life cycle of a SOI, independent of any particular system. STEP is addressing product data from mechanical and electrical design, analysis and manufacturing, with additional information.

8.6.2 ISO 10303-239 Product Life Cycle Support (PLCS) – STANAG 4661

NATO promulgated STANAG 4661 for life cycle data exchange which is based on ISO 10303-239 PLCS. This agreement is to register acceptance amongst NATO Nations of ISO 10303-239 Application Protocol - PLCS for Product Data Management. Ratifying nations agree to apply ISO 10303-239 for product data management in cooperative NATO acquisition programmes with STANAG 4661.

Data exchange could be applied among parties based on STANAG 4661 which references ISO 10303-239.

ISO 10303-239 PLCS is an international standard (application protocol) that specifies the information model that can be used for data exchange.

ISO 10303-239 provides a neutral mechanism, capable of describing products throughout their life cycle. This mechanism is suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases and as a basis for archiving.

PLCS for product data management concerns the ability to handle, classify and control the product data and the ability to manage the changes of this data over its life cycle.

8.6.3 Data Exchange Set (DEX)

DEX is a way of dividing up the ISO 10303-239 information into sections suited for a particular process, providing a way of extracting the PLCS information model into sections suited for a specific business process.

However, DEXs do not support LCC entities (elements), and in order to reach this target, the appropriate actions must be taken in connection with the appropriate body for improvement of the current packages of DEX's, according to the existing specific life cycle cost data exchange needs. Figure 8.2 shows a possible way of integrating ISO 10303 modules into a single root suitable for LCC data exchange, according to chapter 7.4.

Basic Life Cycle Cost Attribute	ISO 10303 part	
Envelope information	1265 1270	Envelope Message
Security classification and information rights	1015 1241	Security classification Information rights
System of interest (SOI)	1164 1021 1340 1018 1022 1056	Product as individual Identification assignment Name assignment Product version Version identification Configuration item
Number of units or quantity of SOI	1054	Value with unit
Cost breakdown structure (CBS)	1214 1216 1217 1248	System breakdown Functional breakdown Zonal breakdown Product breakdown
CBS element short description	41	Resource document schema
CBS element hierarchy / position	1118	Measure representation
CBS element cost	1118	Measure representation
Currency	1118	Measure representation
Uncertainty	1106	Extended measure representation
Costing Technique	1049 1261	Activity method Activity method implementation
Period of time or date	1010 1014	Date time Date time assignment
Source of data	1276 1013	Location Person organization assignment

Figure 8.2: Integration of ISO 10303 parts into an Application Protocol for LCC data exchange

ANNEX 1 - List of Acronyms and Abbreviations

ACRONYM	DESCRIPTION
AAP	Allied Administrative Publication
AC/327	NATO Life Cycle Management Group (LCMG)
ADMP	Allied Dependability and Maintainability Publications
ALCCP	Allied Life Cycle Cost Publication
AoA	Analysis of Alternatives
ANEP	Allied Naval Engineer Publication
AP	Application Protocol
APB	Acquisition Program Baseline
CARD	Cost Analysis Requirements Description
CBS	Cost Breakdown Structure
CEP	Cost Estimation Process
CER	Cost Estimating Relationship
CERD	Cost Estimation Requirements Document
CES	Cost Element Structure
CFR	Constant Failure Rate
CI	Configuration Item
CIPT	Cost Integrated Project Team
CLS	Contractor Logistic Support
CNAD	Conference of National Armaments Directors
CONOPS	Concept of Operations
COO	Cost of Ownership
COSMIC	Common SW Measurement International Consortium
COTS	Commercial Off The Shelf
CP	Capability Package
CUR	Crisis Response Operation Urgent Requirement Process
DEX	Data Exchange Set
DFR	Decreasing Failure Rate
DMS	Diminishing Manufacturing Sources
DoD	United States Department of Defense
EBS	Equipment Breakdown Structures
ERPs	Enterprise Resource Planning Systems
EVM	Earned Value Management
EXPRESS	Computer Language [ISO94b]
FY	Financial Year
GCBS	Generic Cost Breakdown Structure
GFI	Government Furnished Item
ICEAA	International Cost Estimating and Analysis Association
IFR	Increasing Failure Rate
ILS	Integrated Logistic Support
IPT	Integrated Project Team
ISO/IEC	International Organization for Standardization / International Electrotechnical Commission
LC	Life Cycle

ACRONYM	DESCRIPTION
LCC	Life Cycle Cost
LCCBS	Life Cycle Cost Breakdown Structure
LCCM	Life Cycle Cost Management
LCM	Life Cycle Management
LTB	Life Time Buy
LSA	Logistic Support Analysis
LSAR	Logistic Support Analysis Record
MECE	Mutually Exclusive Collectively Exhaustive
MoU	Memorandum of Understanding
MTBF	Mean-Time Between Failures
NATO	North Atlantic Treaty Organisation
NFF	NATO Furnished Facilities
NSN	NATO Stock Number
NSO	NATO Standardisation Office
OEM	Original Equipment Manufacturer
PfP	Partnership for Peace
PHST	Packaging , Handling, Storage and Transportation
PLCS	Product Life Cycle Support
POL	Petroleum, Oil and Lubricants
POW	Programme of Work
QA	Quality Assurance
R&M	Reliability and Maintainability
RAM	Reliability Availability Maintainability
RFI	Request for Information
RTO	Research and Technology Organisation (today: STO)
SAS	System Analysis and Studies
SDE	Shared Data Environment
SIP	Software Intensive Projects
SLC	System Life Cycle
SLCM	System Life Cycle Management
SLOC	Source Lines Of Code
SM	Specific means
SME	Subject Matter Expert
SOI	System-of-Interest
STANAG	NATO Standardization Agreement
STEP	Standard for the Exchange of Product model data [ISO94a]
STO	Science and Technology Organization
SW	Software
T1	First Unit Costs
T&Cs	Terms and Conditions
TOC	Total Ownership Cost
TR	Technical Report
WBS	Work Breakdown Structure
WLC	Whole Life Cost

ANNEX 2 - List of the referred documents

REFERENCE	TITLE
AAP – 6	NATO glossary of terms and definitions
AAP – 20	NATO Programme Management Framework
ALP – 10	NATO Guidance on Integrated Logistics Support for Multinational Armament Programmes
AAP - 31	NATO Glossary of Communication and Information Systems Terms and Definitions
AAP - 48	Life Cycle Stages and Processes
ANEP - 41	NATO standard for shipbuilding Work Breakdown Structures
NATO CALS Handbook June 2000 Version 2	NATO Continuous Acquisition & Life Cycle Support
CM(2005)0108	NATO Policy for Systems Life Cycle Management
ISO 9000	Quality Management systems-Fundamentals and vocabulary
ISO 10303-239	Industrial automation systems and integration – Product data representation and exchange – Part 239: Application protocol: Product life cycle support
ISO 15288	Systems Engineering – System Life Cycle Processes
Mil Hdbk 881C	Work Breakdown Structures for Defense Materiel Items
RTO TR-058 / SAS-028	Cost Structure and Life Cycle Costs for Military Systems
RTO-TR-SAS-054	Methods and Models for Life Cycle Costing
RTO-TR-SAS-069	Code of Practice for Life Cycle Costing
RTO-TR-SAS-076	NATO Independent Cost Estimating and the Role of Life Cycle Cost Analysis in Managing the Defence Enterprise

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ANNEX 3 - List of Terms and Definitions

Capability: the ability to perform actions to achieve desired objectives/effects

Cost: All costs to be incurred and paid by the government including both Industry and Government effort associated with all stages of the life cycle of a military project.

Cost Breakdown Structure (CBS) List of all the cost elements to be considered in the LCC calculation of a System of Interest
(RTO TR-058 / SAS-028)

Cost Data: Cost data represent costs, in a specified type of currency, associated with materials, activities (labour), intellectual propriety right, etc. The analyst needs both technical and programmatic data in order to have the adequate information that provides the context to the cost numbers.

Cost Element Structure (CES): A unit of costs to perform a task or to acquire an item. The cost estimated may be a single value or a range of values.
(RTO-TR-SAS-054)

Cost Estimating: The art of approximating the probable cost or value of something based on information available at the time.
(Glossary of The International Cost Estimating and Analysis Association (ICEAA), CEBok Glossary of Terms,v1.2, pg 44, copyright 2002-2013

Cost model: A Cost Model is a set of mathematical and/or statistical relationships arranged in a systematic sequence to formulate a cost methodology in which outputs, namely cost estimates, are derived from inputs. These inputs comprise a series of equations, ground rules, assumptions, relationships, constants, and variables, which describe and define the situation or condition being studied. Cost models can vary from a simple one- formula model to an extremely complex model that involves hundreds or even thousands of calculations. A cost model is therefore an abstraction of reality, which can be the whole or part of a life cycle cost."
(from RTO-SAS-054 POW)

Earned Value Management (EVM): A project management technique that objectively tracks physical accomplishment of work.
EVM has the unique ability to combine measurements of technical performance (i.e., accomplishment of planned work), schedule performance (i.e., behind/ahead of schedule), and cost performance (i.e., under/over budget) within a single integrated methodology.

Estimation Methods: Popular methods of estimating life cycle costs include analogy, engineering (bottoms-up), parametric etc.

Direct costs: Cost referring to an activity or a resource that can be easily allocated (without ambiguity and intermediate analysis) to a system or product
(RTO TR-058 / SAS-028)

Facility: the physical means or equipment for facilitating the performance of an action, e.g. buildings, instruments, tools

Indirect costs: Cost referring to an activity or a resource associated to several systems or products. It must be shared (apportioned) between those products before being attributed to each one (RTO TR-058 / SAS-028)
Indirect costs may include linked costs such as additional common support equipment, additional administrative personnel and non-linked costs such as new recruiters to recruit additional personnel. All indirect costs related to activities or resources that are not affected by the introduction of the system are not part of LCC.

Life Cycle Cost (LCC) LCC consists of all direct costs plus indirect variable costs associated with the Life Cycle stages of the System of Interest. (adapted from RTO TR-058 / SAS-028)

Life Cycle Costing: a process meant to determine the Life Cycle Cost.

Process: set of interrelated or interacting activities which transforms inputs into outputs

Product: The results of activities or processes. It includes the products delivered to the user and the specific means required for developing and manufacturing these products.
(RTO-TR-058 report)
The products delivered to the user include the main system (aircraft, tank, etc.) and its support elements (spares, support equipment, facilities, documentation, etc.).
"Product" may be –depending on the individual case - equivalently used as "SOI"
See also AAP_20 1.1 and 2.2

Resource: an asset that is utilized or consumed during the execution of a process
(ISO 15288)

<u>NOTE 1</u> Resources may include diverse entities such as personnel, facilities, capital equipment, tools, and utilities such as power, water, fuel and communications infrastructures.
<u>NOTE 2</u> Resources may be reusable, renewable or consumable.

Shared Data Environment (SDE): Is the information infrastructure which supports digital communication and allows data to be controlled, accessed, and shared electronically between different users, according to the security rights and the access limits that must be predetermined
(NATO CALS Handbook, Edition 2, June 2000 Para. 1.2.7.1.3)

Stage: a period within the life cycle of a system that relates to the state of the system description or the system itself.
(See also AAP-20 and ISO 15288)

<u>NOTE 1</u> Stages relate to major progress and achievement milestones of the system through its life cycle.
<u>NOTE 2</u> Stages may be overlapping.

Supplier: an organization or an individual that enters into an agreement with the acquirer for the supply of a product or service

System: consists a SOI (subsystems, main components, components) and all Enabling Systems (Logistics, Personnel, Infrastructure, etc.) related to the SOI. Through the Life Cycle Stages it must reach a certain status of maturity in order to operate and perform a needed capability.
(NATO AAP-20, NATO PROGRAMME MANAGEMENT FRAMEWORK)
System life cycle: the evolution with time of a system-of-interest from pre-conception to retirement

System-of-interest (SOI): the subject whose life cycle is under consideration in the context of a project or programme

Task: Is the most elementary process or piece of work to be done, especially done regularly to obtain an expected result and specified in terms of performance, cost and time. The performance of a task is entrusted to an identified actor and usually requires human, material and financial resources allocation.
(RTO TR-058 / SAS-028)

Total Ownership Cost (TOC): Total ownership cost consists of the elements of a programme's life cycle cost, as well as other infrastructure or business processes costs not necessarily attributable to the programme.
This may include items such as common support equipment, common facilities, personnel required for unit command, administration, supervision, operations planning and control, fuel and munitions handling.
TOC represents all costs associated with the ownership of a system except non-linked fixed costs that are related to the running of the organisation. TOC is used for budgeting purposes, determining the use of services between systems, for optimization purposes and for financial analysis.

User: 1. The command, unit, or Element which will be the recipient of a production item[17], for use in accomplishing a designated mission; 2. The operator and/or maintainer of a system; and 3. The customer.
(The International Cost Estimating and Analysis Association (ICEAA), CEBok Glossary of Terms,v1.2, pg 198, copyright 2002-2013)

Validation: confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled.
[ISO 9000: 2015]
<u>NOTE</u> Validation in a system life cycle context is the set of activities ensuring and gaining confidence that a system is able to accomplish its intended use, goals and objectives.
Within the context of LCC estimation process, **validation of the estimate** consists of checking if the estimate meets its intended use, goal and objectives.

Verification: confirmation, through the provision of objective evidence, that specified requirements have been fulfilled
[ISO 9000: 2015]

[17] System of interest

NOTE Verification in a system life cycle context is a set of activities that compare a product of the system life cycle against the required characteristics of that product. This may include, but is not limited to, specified requirements, design description and the system itself.
Within the context of LCC estimation process, **verification** consists of checking if the cost estimate is verified against its estimating requirements.

Work Breakdown Structure (WBS): A technique for representing all the components, software, services and data contained in the project scope statement. It establishes a hierarchical structure or product oriented "family tree" of elements. It is used to organize, define and graphically display all the work items or work packages to be done to accomplish the project's objectives.
(RTO-TR-058 report)

ANNEX 4 - Considerations about used material in regard to LCC

1. Introduction:

This Annex focusses the LCC special aspects of buying used material.

The reasons for acquiring a used system may be various. In regard of LCC the reduced price may be the deciding factor. Additionally, potential buyers may be targeting the expected shorter lead-time when developing and implementing a new capability supported on used material.

Notwithstanding these two key advantages, a careful balance and full understanding of the costs behaviour through the entire life cycle is decisive for efficient decision-making. The expected lower initial investment will have to balance against potential higher operating and maintenance costs. Moreover, depreciation will depend on the remaining expected lifetime of the system. Therefore a business case and risk analysis (economical and technical) is highly recommendable.

These aspects will be discussed through the stages of the lifecycle. They should be regarded as complementary to general guidance in ALCCP-1, with a special emphasis to the used material paradigm. Very precise guidance was avoided taking into consideration that the magnitude of types/situations that may occur would not fit in the generic guidance intended for this Annex.

2. Pre-concept and concept stage

During pre-concept and concept stage there will be hardly any modifications in relation to an ordinary system technical specifications, considering that the system is already produced and these stages are (from the original user perspective) done. Nevertheless, with regards to the potential buyer this is the specific key-moment to decide if buying used material. This has to be supported in a careful study that weights all costs through all LCC of buying used material against the option of buying new.

During the acquisition process the acquiring nation will consult the pre-using nation and request information about the LCC of the used system. Original data can be transferred or bought and included in the deal package. Furthermore, Original Equipment Manufacturer (OEM), contactors or associations of end-users could be available and should be considered valuable sources for obtaining data.

Due to possible different standards in data extraction/ handling/ perspective and calculation there may be differences between states and commercial organizations (CBS, structure of forces, purpose/ use of equipment, national budget rules, cost-schemes…). If the differences between both standards are too big, assistance from an independent consultant may be helpful. Transferring original, preprocessed LCC data into the structure of the second-hand using nation with an off-the-shelf LCC tool should not be neglected as a major activity.

The hand-over and training costs should be previously estimated and forecasted to happen in this stage.

3. Development

After having decided to make a second hand buy of a system that has been produced and used, there will be a need for some development activities in order to integrate it in an existing environment. The scope of integration also has costs that will grow with the complexity of the future environment and the amount of interfaces needed to connect to existing capabilities. If the used system is operated on its own (stand-alone), this point may be reduced. Again, looking for hidden costs on conversion or re-certification is mandatory.

Before entering the utilization stage the acquirer will have to think about his own logistical support concept. Depending on the concept of operations there will be parallels to the pre-using nation. This will not substitute the acquirer's need to make their own calculations, as analogy may not apply entirely, but benchmarking may give a rough hint and it´s highly recommended.

4. Production

Except for minor degrees of conversion/customization/adaptation/re-militarization from previous owner this stage is considered not applicable in the case of used material.

5. Utilization and Support

Another motivation to buy a used system may be in order to use it as spare part carrier or as spare part itself. This is commonly referred as “cannibalization policies”: concentration of parts shortage into the least number of next-higher assemblies. Cannibalization can be a powerful management adaptation that, in certain contexts, helps the logistics system cope with uncertainties in parts demands (adapted, RAND Corporation). Here the different characteristics have to be considered. There may be a clearance time for a system. That when it is exceeded the material has to be refitted or entirely disposed. Before storing used material into the depot, it has to be checked, probably refitted for the next use and properly packed. Depending on the input-status this increases LCC in various ways. Regarding some electronic spare parts the aging, if properly packed and store, may be ignored. Bottom line is the need to take into consideration the source and nature of the material (e.g. in aeronautics the material is tagged and can be controlled up to serial number. Tags identify certification for type of use, e.g., flying, Labs, Simulators). Depending on the source/nature of the material, used items may need

- Re-inspection
- Re-calibration at OEM
- Maintenance actions due to need to extend life-time can be considered
- Double maintenance actions/costs when cannibalizing, since a “hole” will have to be fitted in the origin
- Additional configuration management activities, airworthiness and property/stock

In general, used material has another Mean-Time Between Failures (MTBF) than new, due to the fact that calculations should take into account different life expectancies. This might indicate failure, damage and an earlier crash of the entire system. Furthermore, warranty coverage will not probably be in place in the case of used material.

The technical and financial risk grows. This increases LCC and has to be evaluated in a risk analysis and can be expressed with a risk surcharge. An economic study of LCC for new parts and used parts (incl. risk surcharge) reveals then the most efficient way.

When considering the used material, it is important to take into account Obsolescence and, especially, Diminishing Manufacturing Sources (DMS). DMS is defined has "The loss or impending loss of manufacturers of items or suppliers of items or raw materials”. These will happen, potentially, sooner than new material, since material lifetime will be shorter. That is due to the fact that there is a correlation between the time and DMS.

In order to manage DMS, several topics can be considered good practices

- Obtaining from the contractor or supplier within the supply/sustainment chain information of potential/eminent DMS issues
- Maintain line production working if there is a business-case. Costumer may buy the right to maintain the production line pending on a balance against a Life Time Buy (LTB). Consider
    - Volume of demand expected
    - Buffer/security margin
    - Cost
- MTBF or failure rate together with the utilization rate data are the main data to consider when deciding on LTB. When considering MTBF, take into account the data forecasted in the drawings, real data and the life-time expectancy
- If LTB is not an option e.g. for economic reasons, consider:
    - Requesting a Modification Change, re-drawing the asset
    - Integrated upgrade (AAP-20 Annex 3)
    - Or retirement

6. Retirement

As general guidance, Retirement of used material when comparing with new acquired material does not present significant differences.

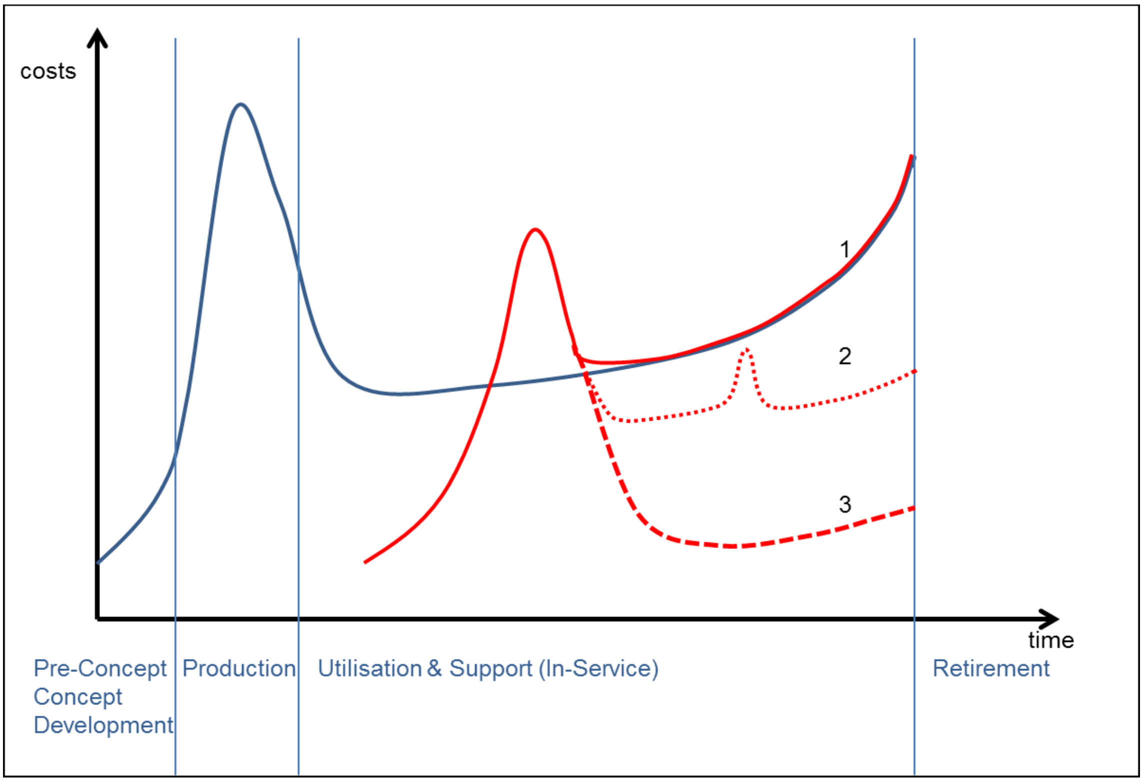

Figure **1** Used material Costs across Life Cycle Stages

The blue graph shows a typical distribution of LCC over the stages of a programme.

The red graph displays the costs of second-hand material. The curve is similar but compressed

Depending on the utilization after acquisition several kinds of the curve are imaginable. Here are three possible examples

- The first example displays utilization similar to the pre-hand user
- In the second graph the second-hand user has to make a greater investment due to obsolescence or DMS
- The third curve may give an impression of costs, if the material is used to replenish the spare parts stock

ANNEX 5 - Generic activities list

Pos.	*Activities*	*Description*
1.	***Management***	This element includes business management of the system/programme. It encompasses the overall planning, direction, and control of all stages of the programme. It comprises the management of the project including cost, schedule and performance measurements, risk management, configuration control, contract management, Reliability Availability Maintainability (RAM), Integrated Logistic Support (ILS), Quality Assurance (QA) including reviews and quality audits and documentation tasks. This element includes government and contractor activities. It excludes those management activities covered by system engineering.
2.	***Studies and Analysis***	All efforts culminating in documents that establish potential solutions to outstanding areas of risk or problem definition. This can include technology review, R&M, ILS and LSA studies, trade-off/risk reduction, basic researches, preparatory studies, the analysis of the initial need, the external functional analysis and a market survey and may also include user and system requirements.
3.	***Simulation***	Non deliverable representations to prove concepts and allow testing. This can include digital and physical models aiming to demonstrate the feasibility of all or any part of a system.
4.	***System Engineering***	This consists of the technical and management efforts of directing and controlling the totally integrated engineering effort of the architecture, system or programme.
5.	***Design and Development Engineering***	It includes all the activities to design and develop: technical, test and quality assurance specifications, engineering drawings, parts lists and wiring diagrams. It also includes the costs of raw and semi-fabricated material plus purchased parts consumed in the performance of component engineering efforts.
6.	***Supportability Engineering***	It includes all the activities to design supportability of the system in order to have the greatest impact on system performance and life cycle cost when taken early in the period of the life cycle.
7.	***Design Influence /Changes***	It includes the systems engineering process to impact the design from the early stages throughout the life cycle and concerns, the possible evolutions of the system design appearing both before and after the initial deployment.
8.	***Purchase off the Shelf (Government or Commercial)***	This may include the purchase or provisioning of the main system but also the purchase of major subsystems to be integrated by the manufacturer. This element excludes subcontractor’s efforts and purchased parts/equipment for systems that have significant additional development efforts, which should be captured in the manufacturing activity.
9.	***Tooling (Investment)***	This includes planning, designing, fabricating, purchasing, assembling, installing, modifying, inspecting, testing, maintaining and reworking all tools (including dies, jigs, and fixtures), inspection equipment, and test equipment supporting the development and production of a specified system component.
10.	***Facilities (Investment)***	This includes any infrastructure such as new building, conversion or expansion of facilities or sites, and the procurement of real estate for developing, producing and testing (-operating and supporting-) the system. This includes facilities to handle or store hazardous materials or waste including underground storage tanks.
11.	***Reference Sets***	This includes developing, manufacturing and purchasing interface equipment that allows compatibility checks and try out modifications.

Pos.	Activities	Description
12.	***Manufacturing***	This element includes the fabrication, test and checkout, processing, subassembly, final assembly, reworking modification, and installation of parts and equipment, power plants, boosters, electronic equipment, explosives, and the proving of such equipment and instruments for the specified system. This element also includes subcontractor's efforts and direct material used in making the product. This does not include the purchase of major subsystems to be integrated by the manufacturer (purchase off the shelf). The element further includes the efforts to integrate and assemble the various subassemblies into a working system, efforts to install special and general equipment, to paint and package the system for shipment to its acceptance destination, and efforts associated with pre-planned product improvements. It also includes moves in order to assemble into a final system. This element includes official alterations made to the system while it is still in the manufacturing process (before acceptance into service) This element includes implementing quality control processes necessary to ensure that a manufacturing process produces a system that meets the prescribed standards. The above definition applies for both prototype equipment and delivered equipment (user end items).
13.	***Systems Integration***	This includes the final integration of systems into a capability and ensures interoperability. Ensuring that all equipment, whether purchased off the shelf or bespoke manufactured, operates satisfactory to meet the mission objectives.
14.	***System Level Test, Evaluation, Trials and Demonstration***	This element includes detailed planning, conduct, support, data reduction and reporting from system-level test activities, to include both supplier and user testing. It also includes efforts associated with pre-planned product improvements. This element also includes test items that are used or consumed in the conduct of such tests and specially fabricated hardware to obtain or validate engineering data on the performance of the system. Also included are all efforts associated with the design, production, and disposal of models, specimens, fixtures, instrumentation and hazardous materials in support of the test programme.
15.	***Delivery (PHST)***	This element includes moving materiel from the manufacturer to the first point of acceptance, receipt or storage by the Contractor or Government. It includes conditioning, packaging, handling, storage and transportation activities to government operational sites.
16.	***Training***	This includes training the trainers and other initial training courses through which personnel will learn to operate and maintain the system.
17.	***Technical Information and Data***	Technical information and data is the information necessary to operate, maintain, repair, support and dispose of a system throughout its life.
18.	***Installation***	This includes installing all equipment at a location or at contractor's premises.
19.	***Acceptance Testing***	This includes demonstrating that the system configuration works in an operational environment.
20.	***Operation***	This includes the operation of the system in peacetime circumstances, including deployment and exercises, to sustain operational proficiency and skill levels.
21.	***Mission Support***	This includes commanding, administrating, supervision, operations control, planning, scheduling, safety, quality control, security, logistics, ground safety, fuel and ammunition handling, and simulator operations as well as special mission support functions, such as intelligence, photo interpretation, etc. This may also include functions such as communications, personnel services, base transportation, property maintenance etc. These activities exist only to support the system whose costs are being estimated.

Pos.	*Activities*	*Description*
22.	***Maintenance***	This includes maintaining a primary system, associated support equipment, and unit-level training devices. This includes maintenance at all lines/levels such as on the equipment by crew, on the equipment by specialist repair personnel, by a depot or agency and industry (interim or continuous; this might be part of a logistic support package). This includes detection, inspection, troubleshooting, prevention, testing and calibration, overhaul, and replacement of parts, components or assemblies
23.	***Supply Support***	It comprises all management actions, procedures, and techniques necessary to determine requirements to acquire, catalogue, receive, implement, store, transfer, issue and dispose of spares, repair parts, updates and supplies. This includes initial provisioning for stock of spare parts and support, as well as acquiring, distributing, updating and replenishing inventories in support of supply chain management.
24.	***Replenishment***	This includes re-provisioning for the routine replenishment of stocks as well as the enhancement of existing stock levels to support the introduction of new equipment after the agreed initial provisioning support period.
25.	***Continuation Training***	This includes system-specific training (non-procurement funded) and speciality training for military personnel who are replacing individuals lost through attrition or rotation. It also includes non-combat operations (such as firepower demonstrations) and training exercises.
26.	***PHST***	This includes packaging, handling, storing, and transporting (PHST) of primary mission and support equipment, repair parts, secondary items, POL, and ammunition to and from operational training areas. It may also include transportation of items procured or shipped by the unit. Excluded are PHST costs for repairable items acquired through stock fund reimbursements.
27.	***Modification Kit Procurement/ Installation***	This includes procuring and installing modification kits and modification kit initial spares (after production and deployment) required for a defence system and related support and training equipment. This includes only those modification kits needed to achieve acceptable safety levels, overcome mission capability deficiencies, improve reliability, or reduce maintenance costs. It excludes modifications undertaken to provide additional operational capability not called for in the original design or performance specifications.
28.	***Sustaining Engineering Support***	This includes providing continued systems engineering and programme management oversight to determine the integrity of a system, to maintain operational reliability, to approve design changes, and to ensure conformance with established specifications and standards. This may include (but are not limited to) government and/or contract engineering services, technical advice, and training for component or system installation, operation, maintenance, and support.
29.	***Software Maintenance Support***	This includes the update, maintenance and modification, integration, and configuration management of software. It includes operational, maintenance, and diagnostic software programmes for the primary system, support equipment, and training equipment. Excluded are major redesigns, new development of large interfacing software, or modifications that change functionality.
30.	***Restoration***	This includes all activities associated to restoration (or renovation) of a system carried out for example at mid-life. As this activity may include modifications undertaken to provide additional operational capability not called for in the original design or performance specifications, it could be considered as a new procurement occurring during the in-service stage of the system.
31.	***Disposal***	This includes demilitarisation, detoxification, or long-term waste storage when disposing of operational or associated support equipment.

Pos.	*Activities*	*Description*
32.	***Other***	This includes any significant sustaining support not otherwise accounted for. Examples might include follow-on operational tests and evaluation, such as test range use, test support, data reduction, and test reporting. This includes any activities not otherwise accounted for.

ANNEX 6 - Generic resources list

Pos.	*Resources*	*Description*
1.	**PERSONNEL**	Most activities, either on Nation or Organization side or contractor side involve personnel. On the Nation or Organization side (internal staff), military and civilian personnel required to operate, maintain, and support a discrete operational system are to be considered. This includes the personnel necessary to meet combat readiness, unit training, and administrative requirements. Personnel costs may be direct or indirect. Direct costs are usually associated to operators and maintainers of the system. For personnel that operate or maintain more than one type of system, costs are allocated on a relative (pro rata) workload basis. Indirect costs are usually associated with personnel required for unit command, administration, supervision, operation control, planning, scheduling, safety, fuel and munitions handling, etc. and are not so easily allocated to a specific system. Personnel cost may include basic pay, social security contributions, retired pay accrual, all allowances (housing, clothing, overseas station, etc.) and bonuses.
2.	**EQUIPMENT**	This resource includes all means (usually support equipment) that are used to operate or maintain the system but are not considered as a product of the programme because they are shared between several systems. For example, a piece of test equipment developed in the framework of a programme and used only for the acquired system is considered as a product of this programme. But a piece of test equipment already in use for other existing systems and used by the new one is considered as a resource for the new system. Of course in both cases, the test equipment will be considered as a resource by the maintainer
3.	**CONSUMABLES**	Consumables are all resources that are not considered as a product of the programme and that are consumed in order to operate or to support the main system. They include: • petroleum, oil and lubricants (POL) / energy • ammunitions • non repairable parts (non repairable parts that are not included in initial spare parts are usually included in replenishment, that is why this entry is usually empty) • raw materials • water, food and clothing
4.	**INFRASTRUCTURE/ FACILITIES**	This resource refers to installations and facilities that are not considered as a product of the programme, and that are used to support military forces. They include permanent, quasi-permanent, temporary, or mobile assets (such as buildings, roads, naval bases) required to support the system throughout its life cycle.
5.	**SERVICES**	Services consist of assistance by contractors or sub-contractors. Services may also include transportation, if it is not included in PHST.
6.	**INFORMATION**	Can include copyright information for which a fee is required or GFI.

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ANNEX 7 - Processes and activities in the Life Cycle of SOI

Process	*Description*	*Activities*
Agreement Processes		
Acquisition	The purpose of the Acquisition Process is to obtain a product or service in accordance with the acquirer's requirements.	Establish a plan for how the acquisition will be conducted. Prepare a request for the supply of a product or service. Communicate the request for the supply of a product or service to identified suppliers. Select a supplier. Negotiate an agreement with the supplier. Assess the execution of the agreement. Confirm that the delivered product or service complies with the agreement. Make payment or provide other agreed consideration to the supplier for the product or service rendered.
Supply	The purpose of the Supply Process is to provide an acquirer with a product or service that meets agreed requirements.	Determine the existence and identity of an acquirer who has, or who represents a party or parties having a need for a product or service. Evaluate a request for the supply of a product or service to determine feasibility and how to respond. Prepare a response that satisfies the solicitation. Negotiate an agreement with the acquirer. Execute the agreement in accordance with agreed project plans considering e.g. accelerated fielding of equipment. Assess the execution of the agreement. Deliver the product or service in accordance with the agreement criteria. Accept and acknowledge payment or other agreed consideration. Transfer the responsibility for the product or service to the acquirer, or other party, as directed by the agreement.
Enterprise Processes		
Enterprise Environment Management	The Enterprise Environment Management Process is the process that assures the definition and updates of the policies and procedures necessary to implement this publication to support NATO bodies and NATO Nations efforts to meet defined, operational goals.	Enterprise Management reviews the processes of each business area in order to determine: Applicability, Effectiveness, Processes interrelationship
Investment Management	The Investment Management Process assures the definition and updates of the procedures necessary to support the control of funding and resources.	Enterprise Management identifies the capability gap based on operational needs. Enterprise Management identifies the programme to fulfil the capability gap. Enterprise Management allocates the necessary resources for Programme Management Teams.

System Life Cycle Processes Management	The System Life Cycle Management Process assures that the implemented Life Cycle Management Processes are operational, effective and in accordance with policies and procedures defined by NATO bodies and NATO Nations..	Enterprise Management should: - identify the necessary System Life Cycle processes; - identify tailoring methods and their acceptance criteria; - establish assessment methods/measurements; - execute process surveillance and register the measured result; - execute trend analysis and propose necessary improvement of the processes. - measure process effectiveness.
Resource Management	The Resource Management Process assures the right infrastructure is established and made available to the NATO bodies and NATO Nations in support of their efforts to meet defined operational goals.	Enterprise Management should: - determine the necessary infrastructure and make it available to the Programme Management Team. - establish means to ensure the necessary knowledge is available (e.g. through a knowledge based management). - assure that personnel is motivated and not over loaded. - assure that resources are distributed to the programmes and cross training is executed. - assess the Life Cycle Management system effectiveness, applicability and identify improvement opportunities (see also System Life Cycle Processes Management Process).- identify tailoring methods and their acceptance criteria;
Quality Management	The Quality Management Process assures that the organisation has an effectively implemented, maintained and improved quality management system. This quality management system is used to plan the quality activities at the organisational level and through auditing identifies effectiveness, corrective, preventive and improvement actions.	Implementation of a quality management system. Description of the tailored quality activities defined during the concept stage; e.g: Transformation of operational needs quality activities into measurable technical specifications. Performance of the quality activities in the programme. Performance of the quality assurance activities during the evaluation of potential suppliers. Performance of the quality assurance activities that assure that the appropriate quality assurance requirements are documented in the contract.
Project Processes		
Project Planning	The purpose of the Project Planning Process is to produce and communicate effective and workable project plans.	Detailed planning for the current life cycle stage and overall planning for all life cycle stages. This planning should include: - scope definition - activity definition - activity sequencing - activity duration estimating - cost estimating - schedule estimating - cost budgeting - project plan documentation
Project Assessment	The purpose of the Project Assessment Process is to determine the status of the project. This process evaluates, periodically and at major events, the progress and achievements against requirements, plans and overall business objectives.	Activity completion assessment Schedule assessment Cost assessment
Project Co	The purpose of the Project	Maintain momentum in the project in accordance with the project plan through

	Control Process is to direct project plan execution and ensure that the project performs according to plans and schedules, within projected budgets and satisfies technical objectives for technical requirements. This process includes redirecting the project activities, as appropriate, to correct identified deviations and variations from other project management or technical processes. Redirection may include re-planning as appropriate.	proactive management
Decision-making	The purpose of the Decision-making Process is to select the most beneficial course of project action where alternatives exist. This process responds to a request for a decision encountered during the life cycle of a system, whatever its nature or source, in order to reach specified, desirable or optimized outcomes. Alternative actions are analysed and a course of action selected and directed.	Define decision strategy Using the defined decision strategy, evaluate the balance of consequences of alternative actions to arrive at an optimization of, or an improvement in an identified decision situation. Record, track, evaluate and report decision outcomes to confirm that problems have been effectively resolved, adverse trends have been reversed and advantage taken of opportunities. Maintain records of problems and opportunities and their disposition, as stipulated in agreements or organizational procedures and in a manner that permits auditing and learning from experience
Risk Management	The purpose of the Risk Management Process is to minimize the effects of uncertain events that may occur and would result in adverse consequences to system cost, schedule and technical characteristics.	Risk management planning Risk identification Qualitative risk analysis Quantitative risk analysis Risk response planning Risk monitoring and control
Configuration Management	Configuration Management Process provides the means to apply technical and administrative direction over the life cycle of a product, its configuration items, and related product configuration information. Configuration management documents the product's configuration for both the supplier and the acquirer.	Configuration identification and documentation: The process of identifying and documenting the functional and physical characteristics of configuration items (CI). Configuration Control: The systematic evaluation, coordination, approval or disapproval and dissemination of all proposed changes to a CI and/or its configuration documentation after formal establishment of its configuration baseline and verifying the implementation of all approved changes. Configuration Status Accounting: The recording and reporting of the information that is needed to manage the configuration effectively, including a list of approved configuration documentation, the status of proposed changes to the configuration and the implementation status of approved changes. Configuration audits: Checking an item for its compliance with the configuration documentation
Information Management	The Information Management process will facilitate the right information, at the right time, for the right purpose, to the right user, with the lowest possible cost, with the highest possible quality, actuality and security, and abiding to current laws and	Implement information resource management Information creation Information identification Creation and authoring of information – for capability and system in focus Information exchange

	regulations.	Exchanging information between parties, systems, people and organisations. This includes catering for Information Interoperability, or Semantic Interoperability. Exchange provides Semantic Interoperability, ensuring that the meaning of the information exchange is contained and understood by the stakeholders Information sharing Sharing information between stakeholders, information systems or organisations Information hosting Hosting data and information in data repositories – managing and presenting data and information for stakeholders and information systems Implement information quality management Verification of data and information accuracy Information assurance Control, maintain and improve information quality Information security assurance Manage information resources in accordance with laws and regulations for security. Safeguard information repositories, transmissions and distribution. Information legal assurance Managing information within laws and regulations – governing the content of information. Information governance Management methods and procedures for Information resources. Information governance includes – information owners, information management routines, information accessibility.
Technical Processes		
Stakeholder Requirements Definition	The purpose of the Stakeholder Requirements Definition Process is to define the requirements for a system that can provide the services needed by users and the stakeholders in a defined environment.	Identify stakeholders Elicit stakeholder requirements Document requirements Identify constraints Structure and prioritise requirements Ensure stakeholders accept the documented requirements Identify external interfaces Identify interoperability requirements.
Requirements Analysis	The Requirements analysis process is to set up the representation of future system products that meets the stakeholders' requirements and enables implementation in the frame of existing constraints. System requirements represent the basis for the tests to validate stakeholders' requirements.	Perform an analysis of the stakeholder requirements and transform the stakeholder requirements into a set of measurable technical and performance requirements. Create upward and downward traceability to ensure that no stakeholder requirement has been omitted and all defined technical requirements have a parent stakeholder requirement. Maintain throughout the system life cycle the set of system requirements together with the associated rationale, decisions and assumptions. Manage system requirements in accordance with the Configuration Management Process
Architectural Design	Architectural design synthesises a solution that satisfies system requirements, expressed as a set of separate problems of manageable, conceptual and, ultimately, realisable proportions	Identify and explore one or more implementation strategies at a level of detail consistent with the system's technical requirements and risks. Define a design solution in terms of the requirements for a complete set of technically viable components from which the system is configured.

	and ensure that a defined design standard of materiel meets the requirements of the contract specification.	Plan and devise an assembly and test strategy that will detect and diagnose faults during the integration steps. Define areas of solution and establish a basis for detection/correction of errors throughout the system life cycle. Establish traceability of architectural design to system requirements
Implementation	The purpose of the Implementation Process is to produce a specified system element.	Define implementation strategy. Identify implementation strategy/technology constraints on the design. Realize system element. Record objective evidence that system element meets supplier agreements, legislation, and organizational policy. Package and store system element appropriately.
Integration	The Integration Process is to assemble a system that is consistent with the architectural design. This process combines system elements to form complete or partial system configurations in order to create a product specified in the system requirements.	Define an assembly sequence and strategy that minimizes system integration risk Identify the constraints on the design arising from the integration strategy. Obtain integration enabling systems and specified materials according to the defined integration procedures. Obtain system elements in accordance with agreed schedules. Assure that the system elements have been verified against acceptance criteria specified in an agreement. Integrate system elements in accordance with applicable interface control descriptions and defined assembly Create procedures, using the specified integration facilities. Record integration information.
Verification	The purpose of the Verification process is to confirm that the specified design requirements are fulfilled.	Define the strategy for verifying the systems throughout the life cycle. Define a verification plan based on system requirements. Identify and communicate potential constraints on design decisions. Ensure that the enabling system for verification is available and associated facilities, equipment and operators are prepared to conduct the verification. Conduct verification to demonstrate compliance to the specified design requirements. Make available verification data on the system. Analyse, record and report verification, discrepancy and corrective action information.
Transition	The Transition Process establishes an integrated and verified system to provide services specified by stakeholder requirements in the operational environment.	Prepare the site of operation in accordance with installation requirements Deliver the system for installation at the correct location and time. Install the system in its operational location and interfaced to its environment according to its system specification. Demonstrate proper installation of the system. Ensure user training Activate the system. Demonstrate the installed system is capable of delivering its required services. Record the installation data, including the operational configuration, anomalies detected, actions taken and lessons learned.
Validation	The Validation Process provides objective evidence that the services provided by a system when in use comply with stakeholders' requirements.	Prepare a validation plan. Ensure that any operators, enabling system for validation and associated facilities are ready in order to conduct validation. Conduct validation to demonstrate conformance of services to stakeholder

		requirements. Make available validation data on the system according to legal, regulatory or product sector requirements. As appropriate to agreement terms or organizational objectives, conduct validation to isolate that part of the system giving rise to a non-conformance. Analyse, record and report validation data according to criteria defined in the validation strategy.
Operation	The purpose of the Operation Process is to use the system in order to deliver its services.	Obtain other services related to operation of the system. Assign trained, qualified personnel to be operators. Activate the system in its intended operational situation to deliver instances of service or continuous service according to its intended purpose. Consume materials, as required, to sustain the services. Monitor operation to ensure that the system is operated in accordance with the operations plans, in a safe manner and compliant with legislated guidelines concerning occupational safety and environmental protection. Monitor the system operation to confirm that service performance is within acceptable parameters. Perform failure identification actions when a non-compliance has occurred in the delivered services. Determine the appropriate course of action when corrective action is required to remedy failings due to changed need. Introduce remedial changes to operating procedures, the operator environment, human-machine interfaces and operator training as appropriate when human error contributed to failure. Continuously or routinely communicate with users to determine the degree to which delivered services satisfy their needs. Request for corrective design change
Maintenance	The purpose of the Maintenance Process is to sustain the capability of the system to provide a service.	Prepare and implement a maintenance strategy. Obtain the enabling systems, system elements and services to be used during maintenance of the system. Monitor the system's capability to deliver services, record problems for analysis, take corrective, adaptive, perfective and preventive actions and confirm restored capability. Maintain a history of problem reports, corrective actions and trends to inform operations and maintenance personnel, and other projects, that are creating or utilizing similar system elements.
Disposal Process	The purpose of the Disposal Process is to end the existence of a system entity.	Define a disposal strategy for the system, to include each system element and any resulting waste products. Communicate unavoidable constraints on the system design arising from the disposal strategy. Acquire the enabling systems or services to be used during disposal of a system. Deactivate the system to prepare it for removal from operation. Withdraw operating staff from the system and record relevant operating knowledge. Disassemble the system into manageable elements to facilitate its removal for reuse, recycling, reconditioning, overhaul, archiving or destruction. Remove the system from the operational environment for reuse, recycling, reconditioning, overhaul or destruction. Specify containment facilities, storage locations, inspection criteria and storage periods if the system is to be stored. Conduct destruction of the system, as necessary, to reduce the amount of waste treatment or to make the waste easier to handle.

		Confirm that no detrimental health, safety, security and environmental factors exist following disposal. Archive information gathered through the lifetime of the system to permit audits and reviews in the event of long-term hazards to health, safety, security and the environment, and to permit future system creators and users to build a knowledge base from past experiences.

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ANNEX 8 – Consideration about Rapid Acquisition in regard to LCC

1. Introduction

The focus of this Annex are the special considerations on Life Cycle Cost (LCC) of **Rapid Acquisition.**

In the case of rapid acquisition, LCC is typically used in different stages of the decision-making process, whether to evaluate the opportunity to join a programme or to estimate the financial consequences of the considered acquisition. Therefore, it is important to collect enough reliable data and to implement a minimal LCC structure to ensure the quality of the cost analysis that will be used to support the decision-making.

In consideration of LCC for NATO, the majority of the Rapid Acquisition programme funding happens within Crisis Response Operation (CRO) Urgent Requirement Process (CUR) projects. These are a special case developed in recognition that NATO's established procedures for Capability Packages (CP), designed for peacetime implementation, are time intensive and therefore unsuitable for the tempo encountered on Alliance Operations and Missions (AOM) projects. Requirements are submitted under this procedure for reasons of urgency and must be justified on the basis of the Operation Plan (OPLAN), mission assessments and reviews, identified lessons or technical reports. Resulting projects need to be implemented promptly in order to enable the execution of key military tasks; to mitigate operational risk or to improve operational effectiveness or efficiency.

2. Time Constraints

Considering rapid acquisition also implies that it is not always possible to thoroughly go through each stage of the Life Cycle Management (LCM), and there is generally less time to put in place a complete solution for the collection and analysis of the information related to the considered System of Interest (SOI) and the resulting calculation of the LCC. Therefore, it is recommended to start with an LCM or LCC methodology that allows for ease of usable decision outputs or start with a cost estimating method which will enable the ease of cost estimation in a rapid acquisition environment.

The more the acquisition becomes urgent, the greater the risks and uncertainties related to the estimation of the costs become. In the case of CUR procedures of a CP, tactical planning may happen within 6–24 months vs. strategic planning, which may happen within 5-10 years.

3. Risks and Uncertainties

In some cases, the gathered data may not be sufficiently complete or ready for use in the chosen costs estimating approach. The result of this is an uncertainty on the estimated costs, which is higher than when the LCC calculation is performed through the whole LCM-process and within a normal timeframe. In addition, if it is not possible to pursue the full acquisition process, the client will have to realize the lack of information or understanding on some stages which also implies a higher risk on the costs estimation. However, the risk can remain limited if the calculation is performed from the concept stage.

Projects designed as "mission critical" are assigned to a specific categorisation which offers a more flexible risk management approach, remaining subject to only a periodic review.

Manufacturers have also to deal with additional uncertainty as they are asked to perform the LCC process faster. As a result of related risk, additional contingencies must be taken into account.

4. Additional costs

When considering rapid acquisition, it is sometimes more difficult to find or develop a system that meets all requirements. If a client joins late in a programme, and especially if the programme is beyond the concept and development stages, the final product will certainly not match 100% of the initial requirements. It is possible that some non-covered requirements can be let aside or solved by alternatives external to the product. Nevertheless if some non-present requirements need to be integrated into the acquired system, the additional cost to cover this customisation should be taken into account, knowing that the cost of a late insertion is generally higher than if the option had already been planned from the beginning (concept stage). It is therefore important not to underestimate the costs related to customisation.

Generally, it is important to know as soon as possible the value of all components of the LCC. In the case of rapid acquisition, by joining an existing programme or buying commercial-off-the-shelf (COTS), it is essential to ask for complete data on the existing project in order to make requests for quotation around the necessary options that have to be added to the system.

On the other hand, if certain characteristics already inserted in the acquired system are not required, the cost of these options remains part of the overall cost even if they are not or rarely used.

Technology insertion helps to keep material up to date, while not knowing what technology will exactly be within several years. In this case, it is very difficult to estimate related future costs. Generally, benchmarking of similar systems can give a percentage of the initial acquisition price that is needed per year to provide the upgrade. In particular, benchmarking of insertions made by other countries or users can help to estimate both direct and indirect costs related to those insertions.

5. Cost Estimation and Data Collection Methods

Although the ideal way is to make a complete calculation of the LCC as for an acquisition according to a standard scheme, an accelerated acquisition can cause a lack of time or means to obtain the data. In this case the methods used to gather these data will be adapted.

If the most appropriate method is not workable, simpler methods can be used, such as methods based on assumptions or the opinion of experts. In these cases, global cost estimations are used and the Cost Breakdown Structure (CBS) can be less lower-level detailed. If the project allows it or if the desired equipment is already used by other clients, the approach by benchmarking or consultation of other clients should be used as well.

In particular for COTS purchases, it should be possible to find useful data from other users. In some cases, actual users agree to share their calculation methods, data and parameters. This is an excellent opportunity to increase additional elements of decision-making, but we must be careful and make sure to understand how the method was used and how the data was taken into account. Even if the data does not directly concern the system costs, some data may be used as lessons learned and therefore lead to better understanding of the composition of the costs and risks that may lead to additional costs. An important advantage of COTS purchases is that more cost data is generally available, especially regarding the utilization stage which is the stage that generates most of the time the biggest part of the overall LCC.

In any case, it is essential to evaluate the influence of the necessary modifications and the available options. Therefore the calculation methods as well as the used calculation tools have to take into account the variations related to the choice of options.

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ANNEX 9 - Contract/ Agreement Clauses Template for Data Exchange

Following Terms and Conditions (T&Cs) could be added/adapted to the contracts signed by parties in acquisition/modernization projects to be able to establish a legal enforcement between parties regarding data exchange. In order to add below T&Cs into a contract, related articles, which provide legal basement for not only launching a contract but also obtaining declaration of intention of the participant states or NATO bodies whom might require such T&Cs in a contract, should be covered in an agreement or Memorandum of Understanding (MoU) signed by participant states or NATO bodies for launching a project or a programme. Once the related articles regarding permission granted for data exchange were covered by the MoU which allows a NATO Contracting Authority (agency/programme office) to launch a contract, those articles should also be flow downed to the contract in addition of following T&Cs.

- **Data Exchange for Life Cycle Cost Analysis and Data Security**
    - Data exchange under the conditions of this contract shall be accepted by parties as rudiment of contract
    - Contractor shall provide cost data in accordance with the format, shape and in detail given in annex … of the contract*(a CBS template should be given or referred in accordance with "MIL-STD-881C Work Breakdown Structures (WBS) for Defence Materiel Items (03-OCT-2011)", "RTO Technical Report TR-058 SAS-028 Cost Structure and Life Cycle Costs for Military Systems," etc.)* of this contract along the …*(time period should be defined)* time table of the contract dictated by *….(Contracting Agency)…*
    - User(s) will provide required data for cost analysis along the …*(time period should be* defined *by Contracting Agency)*of this contract in accordance with the format, shape and in detail given in annex… of the contract *(a special format should be defined in context and in accordance with permission of participant state(s)(User(s))/NATO bodies granted and flow downed from governing MoU)*
    - *(Contracting Agency)…,* Contractor and the User(s) shall be responsible for security of the cost data provided by all parties along the *…. (should be defined by Contracting Agency)* time period. *(Contracting Agency)…* will provide/construct/permit to access cost database for storing and analysing cost data and shall maintain aforementioned database. To be able to construct and maintain such cost database an Agreement governs privacy and security of cost Data will be signed by parties and procedures and conditions relating data exchange among parties will be defined in this agreement comprehensively and explicitly.
    - Contractor shall provide a Cost Analysis Report to *…. (Contracting Agency)…*, relates to cost estimation/calculation procedures of each cost elements stated in CBS.
    - Cost Analysis Report will be compromised in three main sections as follows:
- • Section-1: **Initial Estimation/Calculation of Costs**
- • Section-2: **Actual Costs**
- • Section-3: **Cost Analysis including Gap Analysis between initial Estimation and Actual Costs**

Section-1 will be submitted in To + 1 month in accordance with CBS of contract defining how each cost element have been calculated/estimated.

Section-2 will be submitted and updated constantly in accordance with the payment schedule of the contract based on the realization of the costs. Section will cover but not limited to below listed information:

- Realization of each cost item in CBS
- Differences between estimation and realization of each cost element
- Realization percentage of each cost element

Section-3 will be submitted and updated constantly by comparing the data provided in Section-1 and Section-2 and will cover but not limited to below information regarding

- Gap Analysis
- Reasons underneath the differences between estimation and realization
- Precautions which will be taken for eliminating/minimizing differences

ANNEX 10 Software Intensive Projects

1. Introduction

This chapter discusses the best practices for the development of independent, data-driven, lifecycle cost estimates for software intensive projects from the intended audience's standpoint. As software (SW) is always running on hardware, the heading used here is software intensive projects or systems.
SW is not tangible like hardware, so is more ambiguous and difficult to comprehend. In addition, SW is built only once, whereas hardware is often mass produced, once design and testing are complete. Size and complexity are cost drivers for both. How quickly SW can be developed depends on the developer's capability, available resources, and familiarity with the environment. SW is mainly labor intensive, and all the tasks associated with developing it are nonrecurring—there is no production stage. That is, once the SW is developed, it is simple to produce a copy of it.
This chapter covers topics that pertain specifically to the SW cost estimating process:

2. SW cost drivers

There are many items that drive the cost for SW. Some of the main drivers for SW costs are:

- Size of the SW - more lines of code require more effort and more schedule time to develop
- Operating platform – the host environment
- Acquisition method – where will the SW come form; rework?
- Complexity of the SW – depending on the application of the SW
- Development method (agile, incremental, waterfall etc.)
- Development standard (security requirements)
- Development environment (location)
- Intellectual Property Rights

These are only high level cost drivers, there are many more.

3. Data

For data please refer to Chapter 7 in main body of text, added by the following which applies specifically to software intensive projects:
SW cost estimates can still be made even when in-house data is not available. Good COTS tools for SW cost estimating come up with access to databases. Based on the inputs provided by the estimator, the tool picks a number of reference projects from a database – either internal or external. The projects in the database are from projects executed by others. The estimate is made by parametric analysis of the reference data. Effort should be made to calibrate tools with own data where possible, and compare those to 'industry average' figures.

4. SW size estimating

SW sizing is the process of determining how big the application being developed will be. The size depends on many factors. Estimating SW size is not easy and depends on having a detailed knowledge about the programme’s functions in terms of scope, complexity, and interactions. Not only is it hard to generate a size estimate for an application that has not yet been developed, but SW also often experiences requirements growth and scope creep that can significantly affect size and the resulting cost and schedule estimates. Programmes that do not track and control these trends typically overrun their costs and experience schedule delays.

Methods for measuring size include COSMIC (Common SW Measurement International Consortium), Functional Sizing Method, Function Point Analysis (FPA), object point analysis, Source Lines Of Code (SLOC), and use case. While SW sizing can be approached in many ways, none are accurate because the “size” of SW is an abstract concept. Moreover, with the exception of COSMIC and FPA, none of the methods has a controlling body for internationally standardizing the counting rules. It is critical that the sizing method is used consistently. The test of a good sizing method is that two separate individuals can apply the same rules to the same problem and yield almost the same resulting size.

Function points tend to be the most predominant method for sizing software. For programmes for which detailed requirements and specifications have been developed, function point counting is appropriate, as long as the SW does not contain many algorithms; if it does, then COSMIC points should be used.

SLOC is used to measure the size of a computer program by counting the number of logical lines in the text of the program's source code once the SW is produced. SLOC is not used to predict the amount of effort that will be required to develop new code, because the number of SLOC is not known in that phase. SLOC is used to estimate programming productivity or maintainability.

There are several categories of SW size that need to be taken into account:

- Reused software: pre-existing SW that is reused as is (unmodified)
- Adapted software: pre-existing SW that is modified prior to reuse
- Auto-generated software: SW not written by developers (not counted for effort)

When adding new functionality to an existing program, the existing code has to be modelled as reused software. The effort associated with reused code depends on whether significant integration, reverse engineering, and additional design, validation, and testing are required. If the effort to incorporate reused SW is too great, it may be cheaper to write the code from scratch. For the cost estimate the size of the SW should reflect the amount of effort expected with incorporating code from another source. This can be accomplished by calculating the equivalent SLOC (ESLOC), which adjusts the SW size count to reflect the fact that some effort is required for integration, engineering, design validation and testing. Assumptions regarding savings (for example, assume less effort is required and no testing is necessary) from reused, adapted, and auto-generated SW code should be looked at sceptically because of the additional work to research the code and provide necessary quality checks. As a minimum, regression testing will be required before integrating the SW with the hardware for this type of code.

SW porting is a special case of SW reuse that is getting increasing visibility in cost estimation. Porting comes into play when SW is to be transferred from old hardware to new hardware. Also, the quality of SW commenting and documentation and the modularity of the initial code’s design and implementation greatly affect the porting of standard code in general purpose processors. For porting as a minimum, regression testing will be required.

It is extremely important to include the expected growth in SW size from requirements growth or underestimation (that is, optimism). Adjusting the SW size to reflect expected growth from requirements being refined, changed, or added or initial size estimates being too optimistic and less reuse than expected is a best practice. This growth adjustment should be made before performing an uncertainty analysis. Understanding that SW will usually grow, and accounting for it by using historical data, will result in more accurate SW sizing estimates. It is a best practice to continually update the size estimate as data become available so that growth can be monitored and accounted for.

5. SW Effort Estimating

Once the initial SW sizing is complete, it can be converted into SW development effort—that is, an estimate of the Level of Effort needed for the software's development. The sizing value usually represents only the actual SW development effort, so the cost estimator needs to use other methods to estimate all the other activities related to developing the software. Sometimes factors (such as percentages of development effort) are available for estimating these additional costs. SW cost estimating models often provide estimates for these activities. If a model is not used or not available, then the cost estimator must account for the cost of the other labour as well as non-labour costs, such as hardware and licenses. Accurately estimating all these tasks is challenging, because they are affected by a number of risks.
SW development cost estimating tools—or parametric tools—can be used to estimate the cost to develop and maintain software. Parametric tools are based on historical data collected from hundreds of executed projects that can generate cost, schedule, effort, and risk estimates based on inputs provided by the tool user. Among other things, these inputs generally include the size of the software, personnel capabilities, experience, development environment, amount of code reuse, programming language, and labor rates. Once the data have been input, the tool relies on cost estimating relationships and analogies to past projects to calculate the SW cost and schedule estimates. When these data are not available to the cost estimator, most tools have default values that can be used instead.
As the project matures and actual data becomes available, the precision of the cost estimate produced by a parametric tool is likely to improve. For this to happen, the tool must be calibrated with actual data from completed programmes so it can be adjusted to reflect the actual development environment. This applies particularly to additions and changes to existing programmes. Cost models for competitions will have to be built on industry averages, simply using default values in the tool

6. SW Maintenance

Once the SW has been developed, tested, and installed in its intended location, it must be maintained, similarly to hardware. Often called the utilization and support stages for software, its costs must be accounted for in the LCCE. During this support phase, SW is maintained by fixing any defects not discovered in testing (known as corrective maintenance), modifying the SW to work with any changes to its physical environment (adaptive maintenance), and adding new functionality (perfective maintenance). When adding capability, the effort is similar to a mini-development effort and the cost drivers are the same as in development. SW maintenance may also be driven by technology upgrades (adaptive maintenance) and users requesting enhancements (perfective maintenance). In

addition to providing help desk support to users of the software, perfective maintenance often makes up the bulk of the SW maintenance effort.
In addition to the need to maintain the SW code, costs are associated with help desk support that need to be included in the software's operation and support phase. Effort will be spent on trouble calls and generating defect tickets for SW maintenance and should be included as part of the SW cost estimate.

7. Commercial-Off-The-Shelf (COTS) SW and licenses fees

Using COTS SW has advantages and disadvantages, and estimators need to understand the risks that come with relying on it. One advantage is that development time can be faster. The SW can provide more user functionality than custom SW and may be flexible enough to accommodate multiple hardware and operating environments. Also, help desk support can be purchased with the commercial license, which can help reduce SW maintenance costs.
Among the drawbacks to COTS SW is the learning curve associated with its use, as well as integrating it into the new program's environment. In addition, most COTS SW is developed for a broad spectrum of users, so it tends to address only general functions. More specific functions must be customized and added, and 'glue-code' (also known as 'spaghetti code') may be required to enable the SW to interact with other applications. And, because the source code is usually not provided to customers of COTS software, it can be hard to support the SW in-house. When upgrades occur, the SW may have to be reintegrated with existing custom code. Thus, it can be wrong to think that COTS SW will necessarily be an inexpensive solution.
Estimators tend to underestimate the effort that comes before and after implementing COTS software. For example, requirements definition, design, and testing of the overall system must still be conducted. Poorly defined requirements can result in less than optimal SW selection, necessitating the development of new code to satisfy all requirements. This unexpected effort will raise costs and cause program delays. In addition, adequate training and access to detailed documentation are important for effectively using the software.
License fees need to be paid for COTS SW, to obtain the right to use the software. Income from license fees allow the provider of the COTS SW to make upgrades to the SW.

8. Enterprise Resource Planning (ERP) Software

ERP SW refers to the implementation of an administrative SW system based on COTS SW throughout an organization. The ERP's objective is to integrate information and business processes—including human resources, finance, manufacturing, and sales—to allow information entered once into the system to be shared throughout an organization. ERP systems force business process reengineering, allowing for improved operations that can lead to savings down the road. To achieve savings requires an extensive knowledge of business processes so that users will optimize automation, programming skills, and change management in the new work processes. Although an ERP system is configured COTS SW and should be treated as such, it is highlighted here because of the unique difficulty of estimating its implementation costs and duration.
At the heart of an ERP system are thousands of packages—built from database tables—that need to be configured to match end business processes. Each table has a decision switch that opens a specific decision path. By confining themselves to only one way to do

a task, stove-piped units become integrated under one system. Deciding which switches in the tables to choose requires a deep understanding of the existing business operating processes. Thus, as table switches are picked, these business processes become reengineered to conform to the ERP's way of doing business. As a result, change management and buy-in from the end users are crucial to the ERP system's ultimate success.

Cost estimators and auditors need to be aware of the additional risks associated with ERP implementation stated below. These risks are specific ERP system risks and are additional to the risks stated in Chapter 5 of the main body text:

- Training
- Integrating and testing SW links
- Interfacing with legacy systems
- Customizing
- Converting and analyzing data
- Following up installation

Other costs associated with ERP system implementations include costs for adding "bolt-ons," which are separate supplemental SW packages that deliver capability not offered by the ERP system. Bolt-ons connect to the ERP system using standard application programming interfaces or extensible markup language schema, which allow for data to pass between both systems. Costs for interfacing the bolt-on with the ERP system need to be identified and estimated. In addition, the number of bolt-ons that need to be integrated, as well as the type, complexity and size of the bolt-on functionality, will drive the cost of the interface.

9. <u>Information Technology Infrastructure and Services</u>

Information Technology (IT) services outside SW development and maintenance (for example, hardware cost, help desk, upgrade installation, training) can make up a majority of lifecycle costs.

Even systems such as ships, aircraft, and mission control centers have major IT infrastructure and services components to them. In fact, some IT systems encounter over 90 percent of their costs in the infrastructure and services required to support and run them. Yet when we read of costs, successes, failures, and challenges in IT systems, the vast majority of the systems typically refer to the SW portions only, ignoring the IT services and infrastructure components. Making matters more difficult for those estimating IT systems or networks are the numerous definitions of IT infrastructure. One useful definition is that it consists of the equipment, systems, software, and services used in common across an organization, regardless of mission, program, or project. IT infrastructure also serves as the foundation on which mission, programme, or project-specific systems and capabilities are built. We discuss in this section estimating the information technology services, hardware systems, and facilities required to support SW and systems.

IT estimation is in some ways simpler than SW development estimation, since IT infrastructure and services are more tangible. However, IT estimation is fraught with issues such as

- What is the cost of the system engineering to define the IT system?
- How much computing power is needed to support a system?
- How many help desk personnel are needed to support X users?

- How can costs be contained while still achieving innovation?
- How can the value of the IT investment be quantified against its costs?
- How do buy and lease decisions affect expenses and profitability?
- How can we make tradeoffs between technology and costs?
- What kind of application initiatives are needed to support the business?
- How many vendors and how much vendor interface is required to run the IT operation?
- How many sites does the IT infrastructure support? How many and how clearly defined or stable are the requirements for the IT to align itself with the business goals? Consider help desk support services for applications and equipment; facilities costs; costs of on-going installation, maintenance, repair, and troubleshooting; employee training, both formal training and self-training.

Many vendors offer IT infrastructure either as a “SW as a service” platform or as just “cloud computing.” Vendor-operated IT infrastructure hardware can be viable if issues such as loss of control, security, and potential resource sharing are acceptable. However, such vendor-operated infrastructure does not usually eliminate the costs of ongoing IT services to provide users help desk support, local computing, setup training, and other infrastructure services. The cost estimator must be aware that these costs should be considered, whether the infrastructure is to be owned by the government, leased, or owned and operated by vendors under contract with the government.

Common elements for IT Infrastructure that should be considered are:

- Financial
- Logistics and equipment
- Schedule
- Personnel (labour categories)
- Project management and system engineering
- Technical (reserve capacity but also refreshment)
- Power, security and general facilities
- Licenses
- Training
- Service Level Agreements
- User expectations

10. Intellectual Property Rights

Intellectual Property (IP) refers to creations of the intellect for which a monopoly is assigned to designated owners by law. Intellectual Property Rights (IPRs) are the protections granted to the creators of IP, and include trademarks, copyright, patents, industrial design rights, and in some jurisdictions trade secrets. Artistic works including music and literature, as well as discoveries, inventions, words, phrases, symbols, and designs can all be protected as intellectual property.
In case an operator pays a contractor to develop some specific SW, the operator can ask for the IPR if he delivers the basic algorithms (intellectual property) for the code to the contractor. In that case the IPR will be provided at no cost to the operator. The other way around the contractor can reduce his price in return for IPRs. Now he can sell the SW to

other parties as well to make a profit. License fees or royalties charged for the use COTS software fulfil the same purpose. These fees allow the producer of the software to maintain and update the software. See also chapter 7 in this annex above.
In case an operator wants to maintain SW himself, he needs to have IPRs to do so. The party that owns the IPR charges an IPR fee for this.
IPRs come at different levels that determine different rights of access to the SW.

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ANNEX 11 Recommended reference documents related to Life Cycle Costs (LCC)

Categories	Title	Language	Source	Remarks
National	GAO - Cost Estimating and Assessment Guide	english	US GAO	March 2009, 440p.
National	GAO-10-717 "Defense Management: DoD Needs Better Information and Guidance to More Effectively Manage and Reduce Operating and Support Costs of Major Weapon	english	US GAO	2010
National	DGMR-APG-LICYC-PPGX-001 Life Cycle Cost (LCC)	french/dutch	national	
National	DGBF-GID-PSSTCOS-BXXX-001, « Coûts standards »	french/dutch	national	2010
National	NASA Cost Estimating Handbook	english	NASA	Revision in 2013
National	FAA Life Cycle Cost Estimating Handbook, Investment Cost Analysis Branch	english	FAA	June 3, 2002
National	FAA Standard Cost Estimation Methodology, ASD-410	english	FAA	Version 1.0, April 2003
National	DGM 98-4	dutch*	national	
National	Aanwijzing DGM inzake levensduurkosten bij materieelprojecten, DGM 98-4	dutch	national	December 1998
National	Mearig T., Coffee N. & Morgan N., Life Cycle Cost Analysis Handbook	english	State of Alaska	Department of Education & Early Development Education Support Services / Facilities,1st Edition, 1999
National	« Guide du coût global pour la conduite des opérations d'armement »	french	DGA	
National	KPMG "Next Generation Fighter Capability: Life Cycle Cost Framework"	english	DND Canada	November 27, 2012
National	The Forecasting Guidebook	english	UK MoD, DE&S	2009, 1st Edition, revision in 2014
National	Guideline "LCCM in Bundeswehr for all Phases"	german, engl.	GE MoD	October 2, 2013
National	OSD CAIG "Operating and Support Cost-Estimating Guide"	english	US DoD	Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG), October 2007
NATO	ALCCP-1 NATO guidance on life Cycle Costs	english/french	NATO	July 2008
NATO	RTO Publication SAS-069, « Code of Practice for Life Cycle Costing »	english	NATO	2009
NATO	RTO Technical Report 13, « Life-Cycle Cost of All-Electric Combat Vehicles »	english	NATO	1999
NATO	RTO Technical Report SAS-028, «Cost Structure and Life Cycle Costs for Military Systems»	english	NATO	2003
NATO	RTO Technical Report TR-SAS-054, « Methods and Models for Life Cycle Costing »	english	NATO	2007
NATO	RTO-TR-SAS-076 "NATO Independent Cost Estimating and the Role of Life Cycle Cost Analysis in Managing the Defence Enterprise"	english	NATO	2012
OCCAR	OCCAR-EA, Internal guideline IG 32-3, Life Cycle Costing	english	OCCAR	issue 2, 10 May 2006
OCCAR	OCCAR-EA, Internal procedure IP 26-12-1, Life Cycle Costing	english	OCCAR	issue 1, April 2009
OCCAR	OCCAR-EA, ISS Guide	english	OCCAR	issue 2, May 2013
OCCAR	OCCAR-EA, « A400M LCC Management Plan », A400M/04/350	english/french	OCCAR	Version 4, October 2004
OCCAR	OCCAR-EA, « A400M LCC Tools Evaluation Methodology »	english/french	OCCAR	Version 4, October 2002
Publication	HEUNINCKX B., Systématisation de l'analyse du coût global de possession des systèmes d'arme dans le processus décisionnel du gestionnaire de matériel	french	Publication	Research paper Royal Military Academy, 2011, 78p.
Publication	Ryan E., Jacques D., et al "A Proposed Methodology to Characterize the Accuracy of Life Cycle Cost Estimates for DoD Programs"	english	Publication	Elsevier, Procedia Computer Science 8pp. 361-369, 2012

Categories	Title	Language	Source	Remarks
Publication	Meersman A., «The use of life-cycle cost-techniques as a decision supporting criterion for the material acquisition and management of the material resources in the (Belgian)	dutch*	Publication	ERM/KMS, 2007
Publication	Ceuterick L., « A life-cycle cost model for the Army»	dutch*	Publication	IRSD/KHID, 1997
Publication	D'Haene B., « What opportunities and limitations can be derived from the legislation on government procurement concerning the use of life cycle cost as an attribution criterion?	dutch*	Publication	IRSD/KHID-DAM, 2004
Publication	Suffys G., «Life Cycle Cost Analysis within the General Directorate Material Resources»	dutch*	Publication	Research paper (BE) Royal Military Academy, 2014, 120p.
Publication	Decuyper N., « Life-Cycle Cost and Cost-Effectiveness »	dutch*	Publication	IRSD/KHID, 1991
Publication	Demaseure G., « "Life Cycle Cost Analysis" (LCCA) within Defence: potential and obstacles: application on the Light Multirole Vehicle (LMV)»	dutch*	Publication	ERM/KMS, 2011
Publication	Husniaux A., « Analysis of the use of cost models in support of management decisions during the exploitation phase of weapon systems (AIRFORCE) »	dutch*	Publication	IRSD/KHID, 1997
Publication	Barringer P., « A Life Cycle Cost Summary », Conference Paper / International Conference of Maintenance Societies, Perth	english		May 2003
Publication	Whole Life Costing (WLC) – The CIPS position, and what the buyer needs to know	english	CIPS Knowledge	2009
Publication	Dixon M., « The Maintenance Costs of Aging Aircraft : Insights from Commercial Aviation », RAND MG-486	english		2006
Publication	Fabrycky W. & Blanchard B., Life-cycle cost and Economic Analysis, Englewood Cliffs	english		1991
Publication	Farr J., Systems Life Cycle Costing: Economic Analysis, Estimation, and Management	english		Edition 1.0, January 2010
Publication	Gebman J., « Challenges and Issues with the Further Aging of U.S. Air Force Aircraft : Policy Options for Effective Life-Cycle Management of Resources »	english		RAND TR-560, 2009
Publication	Greenfield V. and Persselin D., An Economic Framework for Evaluating Military Aircraft Replacement	english		RAND MR-1489-AF, 2002
Publication	Griffith P. & Heuninckx B., « Partnering for A400M Whole Life Cost Calculation »	english	IQPC Defence Partnering	January 2006, presentation
Publication	Griffiths A., « An update of the research study examining Methods and Models for Life Cycle Costs in the NATO environment »	english	IQPC Whole Life Costing for Defence 2006	July 2006, presentation
Publication	Griffiths K. & Walker P., « MAAP – A high stakes decision support system »	english	TFD conference	July 2002
Publication	Heuninckx B., « Whole Life Cost as the Basis for Successful Support of Military Aircraft»	english	IQPC Military Aviation Repair and Maintenance 2006	April 2006
Publication	Kaye M., Sobota M., Graham D. & Gotwald A., « Cost as an Independent Variable (CAIV) : Principles and Implementation »	english	USAF	1999
Publication	Keating E. & Dixon M., Investigating Optimal Replacement of Aging Air Force Systems	english		RAND MR-1763, 2003
Publication	Keating E., Snyder D., Dixon M. and Loredo E., Aging Aircraft Repair-Replacement Decisions with Depot-Level Capacity as a Policy Choice Variable	english		RAND MG-241, 2005

Categories	Title	Language	Source	Remarks
Publication	Kirat T. et Bayon D., Contrats d'acquisition, maintenance et coût global de possession: comparaisons dans le domaine aéronautique entre la France	french		Le Royaume-Uni, les Etats-Unis et l'OTAN, Institut des Sciences de l'Homme, 2004
Publication	Kirkpatrick D., « The Purpose and Practice of Whole Life Costing (WLC) »	english	IQPC Whole Life Costing for Defence 2006	July 2006, presentation
Publication	Larraz J., « L'appréciation du coût global : Rapprochement des points de vue des utilisateurs et des concepteurs »	french		Conference Paper pour la conférence SOLE Les Facteurs de l'Aptitude Logistique, Paris, septembre 2002
Publication	Lindholm A. & Suomala P., « Learning by costing – Sharpening cost image through life cycle costing? »	english	Publication	International Journal of Productivity and Performance Management Vol.56 No. 8, 2007, pp. 651-672
Publication	Smit M., « NATO Initiatives to Improve Life Cycle Costing »	english	Conference Paper	RTO-MP-SAS-080
Publication	Smit M., A NATO framework for Life Cycle Costing	english	Publication	International Journal of Computer Integrated Manufacturing, 2011, 29p.
Publication	Unger E., An Examination of the Relationship Between Usage and Operating-and-Support Costs of U.S. Air Force Aircraft	english		RAND TR-594, 2009
Publication	Andrés Navarro-Galera, Rodrigo I. Ortúzar-Maturana & Francisco Muñoz-Leiva (2011): The Application of Life Cycle Costing in Evaluating Military Investments: An Empirical Study at an International Scale, Defence and Peace Economics, 22:5, 509-543	english	http://dx.doi.org/10. 1080/10242694.2	In "Defence and Peace Economics", 22:5, 509-543
Standards	IEC 60300-3-3:2004, Dependability Management Application Guide – Life Cycle Costing	english	ISO	November 2002
Standards	Guideline : VDI 2884:2005 "Purchase, operating and maintenance of production equipment using Life Cycle Costing (LCC)"	german*	GE-VDI	2005
Standards	Guideline : VDI 2067:2012 "Economic efficiency of building installations - Fundamentals and economic calculation"	german*	GE-VDI	2012
Standards	Richtlinie: VDMA 34160:2006 "Forecasting model for life cycle costs of machines and plants"	german*	GE - VDMA	2006
Standards	SAE AIR 1812 Environmental Control Systems Life Cycle Cost	english	US SAE	1997
Standards	SAE AIR 1939 Aircraft Engine Life Cycle Cost Guide	english	US SAE	1986
Standards	SAE AIR 5416 Maintenance Life Cycle Cost Model	english	US SAE	2010
Standards	SAE ARP 4293 Life Cycle Cost - Techniques and Applications	english	US SAE	1992
Standards	SAE ARP 4294 Data Formats and Practices for Life Cycle Cost Information	english	US SAE	1992
Standards	ASTM E 917 Practice for Measuring Life-Cycle Cost of Buildings and Building Systems	english	ASTM	2013
Standards	ASTM E 2150 Classification for Life-Cycle Environmental Work Elements - Environmental Cost Element Structure	english	ASTM	2013
Standards	AS/NZS 4536 Life Cycle Costing - an Application Guide	english	AS - Standards	1999
Standards	BIS IS 13174-1 Life Cycle Costing - Part 1: Terminology	english	India - BIS	
Standards	BIS IS 13174-2 Life Cycle Costing - Part 2: Methodology	english	India - BIS	

Categories	Title	Language	Source	Remarks
Standards	BS 5760-23(1997) Reliability of Systems, Equipment and Components - Guide to Life Cycle	english	GB - British	1997, document superseded 2004
Standards	BS KIT 200 Standardized Method of Life Cycle Costing for Construction	english	GB - British	2008
Standards	EN 1325-1 Value Management, Value Analysis, Functional Analysis Vocabulary - Part 1: Value Analysis and Functional Analysis	german, english, french	CEN	2002
Standards	NFX 50 155 Value Management - Life Cycle Cost	french	AFNOR	2007

Categories:	
National	National documents, e.g. governmental, military
NATO	NATO documents
OCCAR	OCCAR documents
Publication	e.g. publications, presentations, conference papers
Standards	National or international standards

ANNEX 12 OTHER RELATED DOCUMENTS ON LIFE CYCLE COSTS (LCC)

Categories	Title	Language	Source	Remarks
National	Planning & Scheduling Excellence Guide (PASEG)	english	US NDIA	June 2011, 194p.
National	Defense Acquisition Guidebook	english	US DAU	January 2012
National	Policy, information and guidance on the Through Life Management aspects of UK MoD Defence Acquisition	english	UK MoD	version 1.01 – May 2008
National	Toetsingkader - Verwerving van de Plank	dutch	NL MoD	2013
NATO	AAP-48 NATO System Life Cycle Processes	english/french	NATO	2013, Edition B
NATO	ALP-10, Guidance on Integrated Logistics Support for multi-national equipment projects (ILS)	english/french	NATO	2011, Edition 2
NATO	AAP-20 Phased Armaments Programming System	english/french	NATO	2010, Edition 2., currently under revision
OCCAR	OCCAR-EA, « A400M Common Support Strategy », A400M/06/068	english/french	OCCAR	Version 9.1, February 2006
Publication	Ramaroson F., « OCCAR, a new approach to European collaborative defence procurement Programmes »	english	IQPC Whole Life Costing for Defence 2006	July 2006, presentation
Publication	K. Vitasek, M. Ledyard, K. Manrodt "Vested Outsourcing - Five Rules That Will Transform Outsourcing"	english	Publication	2009
Standards	ISO/IEC 15288 "Systems engineering – System Life Cycle Processes"	english	ISO	November 2002
Standards	AS/NZS 14102 Information Technology - Guideline for Evaluation and Selection of Case Tools	english	AS - Standards	1998
Standards	BS 7000-5(2001) Design Management Systems - Part 5: Guide to Managing Obsolescence	english	GB - British	2001, document superseded 2007
Standards	EN 62402 Obsolescence Management - Application Guide	german, english, french	CENELEC	2007
Standards	EN ISO 16091 Space Systems - Integrated Logistic Support	german, english, french	CEN	2002
Standards	BS 8887-1(2006) Design for Manufacture, Assembly, Disassembly and End-Of-Life Processing (Made) - Part 1: General Concepts, Process and Requirements	english	GB - British Standards	2006
Standards	BS ISO/IEC 14764 Software Engineering – Software Life Cycle Processes - Maintenance	english	GB - British Standards	2006
Standards	ISO/IEC 25040 Systems and Software Engineering - Systems and Software Quality Requirements and Evaluation (Square) - Evaluation Process	english	ISO	2011
Standards	ISO 26382 Cogeneration Systems - Technical Declarations for Planning, Evaluation and Procurement	french/english	ISO	2010

Categories:	
National	National documents, e.g. governmental, military
NATO	NATO documents
OCCAR	OCCAR documents
Publication	e.g. publications, presentations, conference papers
Standards	National or international standards

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