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LIFE CYCLE COST ESTIMATION PROCEDURE FOR A WEAPON SYSTEM IN SPAIN

Abstract

Instruction 67/2011 SEDEF/MINISDEF/ESPAÑA regulates the procurement process of material resources accounting for their life cycle. In order to undertake an initial evaluation of the programmes that meet the conditions of the solution required, life cycle cost estimation is used as decision-making tool. The purpose of this paper is to present the procedure in place for estimating the life cycle costs (LCC) of programmes in Spain by comparing it to those of the major organisations to which we belong (NATO/OCCAR), and verifying the use of historical and technical information, parameters and breakdown structures from September 2011 onwards in the LCC estimates performed.

KeyWords

Project, Life Cycle Cost, estimation, techniques, parameters, breakdown structure.

LIFE CYCLE COST ESTIMATION PROCEDURE FOR A WEAPON SYSTEM IN SPAIN

1. INTRODUCTION

The defence economic sector comprises a group of companies that facilitate the provision of goods and services. This group of suppliers can be divided into two types: on the one hand, the providers of goods and services for general use within the armed forces and for society itself, as well as, on the other hand, the suppliers of more specific products required by the armed forces which is now generally called Armaments and Material. [1]

The most important aspect within armaments and material is weapon systems. These are designed on an ad hoc basis, produced in short series, with a high level of technological content and are extremely complex, subject to constant modernisation and with high durability (with a life cycle of 20-50 years). These conditioning factors mean that the defence industry must make major investments to develop and produce such systems. A major part of this investment targets R&D&I, investment that is not able to benefit the private sector. All of the above, combined with the protectionist nature afforded by the state to the industry thanks to subsidies (a subsidised market since part of this industry passes on higher prices than those it passes on to other markets), and the awarding of contracts etc. represent major barriers to entry for other companies, thereby fostering the formation of oligopolies and monopolies.

The life cycle of these weapons systems is defined as the time interval between the product conception stage and its withdrawal from service. The LCC technique is a discipline or process of gathering, interpreting and analysing data and utilising tools and quantitative techniques to forecast the resources necessary at any stage of the life cycle of the system in question [2] Life cycle costs are the result of this process.

The more technologically advanced a weapon system, the more the likelihood of success will be when measured against other systems. This complexity intrinsic to weapon systems is reflected in an exponential rise in life cycle costs and more

1 www.potalcultura.mde.es/galerias/ùblicaciones/fichero7cuaderno_isdefe02.pdf. Defence Industrial Policy Journal. MINISDEF (Defence Ministry), Technical General Secretariat. 2010. p. 8. IPO: 076-10-056-2.

2 NATO, RTO. Code of Practice for Life Cycle Costing. RTO-SAS-069. RTO Publication. Neuilly-sur-Seine, (Paris). 2009. Chapter 1. Page 1.

specifically in those relating to logistical support. The LCC of a product, from the client's perspective, refers to the combined cost of all costs connected to a product or service throughout its life span, including research, development, acquisition, operation, logistical support, maintenance, modernisation and withdrawal of the good.

From this viewpoint, in order to quantify LCC, in addition to external costs (contracts), it is necessary to estimate internal costs (e.g. operation), which are usually based on historical trends within an organisation.

For the time being, internal system costs are not estimated in Spain as we lack the means to do so (cost accounting recently deployed, difficulty in accessing historical costs, a patchwork of databases etc.).

With regard to the estimation of external costs (contracts) of the systems developed, we frequently see market research employed as an estimation technique. When these contracts for procurement (research, development and acquisition), modernisation or maintenance of weapon systems or other items only leave one company in a position to provide the good or service, we cannot carry out this type of research.

This circumstance of one single tenderer and the absence of other providers means that contracts are not put out to open tender. In the Public Sector Contracts Act (LCSP),[3] this case, among others, is known as a negotiated contracting procedure and occurs extremely frequently for weapon system procurement.

In the scenario described above, an oligopoly, and in some subsectors a monopoly, on the supply side coexists with a monopsony, a situation where market failure appears when only one consumer exists instead of many, on the demand side, and generally affects all ministries of defence.[4] [5] In such cases, the monopsonist may obtain a price[6] lower than the marginal value of the good depending on the market's elasticity of supply. This power is however counterbalanced by the strength possessed by the monopoly or oligopoly as it manages information and the high cost of any type entailed by a replacement of the supplier. This type of market structure gives rise to

3 SPAIN. Royal Legislative Decree 3/2011 of 14 November, consolidated text of the Public Sector Contracts Act. BOE, 15 Nov 2011, no. 276, Article 170.

4 ÁLVAREZ, I. and FONFRÍA, A. Estructura e innovación en la industria de defensa española [Structure and Innovation in the Spanish Defence Industry], Madrid, Economistas , no. 85, 2000. pp. 102-121.

5 GIL, J. A. Reestructuración de la industria de defensa en España [Restructing of the Defence Industry in Spain]. Minerva Ediciones, Madrid, 2002. pp. 53-76.

6 In the context of cost and price analysis within the defence sector, we shall refer to price as the sum of the admissible costs for a contract, with the addition of the profits agreed upon with the contractor.

behaviours that are far-removed from conditions of perfect competition and this has an adverse impact on companies and defence ministries.

When this situation arises whereby there is almost no or no competition for external contracts for the systems to be purchased, there is a lack of references allowing the *price* of a contract entered into, or which is in the process of being entered into, to be deemed the *right* price.[7] This is thus when we most need help to reproduce the price that would be set in a market without these imperfections. In such atypical cases, the measurement of performance in order to reach a price is no mean feat. Consequently, advanced analysis techniques are required in order to reproduce the procurement price that would arise in a perfect market.

Price formation in these imperfect markets and those with partial balance is studied as part of Industrial Economics. This field analyses the interdependencies of companies within these markets and studies the conditions of these markets, the behaviour of companies and economic results. In order to correct these imbalances, Industrial Economics recommends that the state develop economic regulation, promote protection of competition policy and exercise industrial policy to boost the competitiveness of the sector.

The implementation of industrial policy and the promotion of antitrust policy fall beyond the scope of this article. Meanwhile, concerning the economic regulation it pursues with a view to preventing such inefficiencies, the state's role is to establish a fair pricing policy for both parties that balances out these inequalities. Our regulator addresses this policy in two standards:

1. In order to regulate costs, among other measures, the Spanish Ministry of Defence (MINISDEF) introduced standards regarding the criteria applicable to costing for certain supply, consultant and service contracts for the Ministry of Defence (NODECOS).[8] With regard to the profit involved, a formula is being developed to determine the percentages to be applied depending on a range of factors such as the type of contract, the industrial sector, the level of risk etc.

2. Another standard has been issued in order to implement NODECOS: "Procedure for the Provision of *Cost and Price Analysis Services* within the Ministry of Defence",[9] which provides the Cost Evaluation Group (Grupo de

7 ARIAS F, PASTOR J. La determinación del precio en ausencia de mercado [Price Determination with an Absence of Market], Madrid, La Ley. Revista Practica. Year 9 No. 89. 2009. p. 7.

8 SPAIN. MINISDEF. Ministerial Decree 283/1998, of 15 October. NODECOS "*Normas sobre los criterios a emplear en el cálculo de costes en determinados contratos de suministros, consultoría y servicios del Ministerio de Defensa*" (Standards for the criteria applicable to costing for certain supply, consultant and service contracts for the Ministry of Defence). BOD of 21 October 1998, no. 212/98 p. 35408.

9 SPAIN. MINISDEF. SEDEF Instruction 128/2007, of 16 October, "Procedimiento para la

Evaluación de Costes, GEC) within the Ministry of Defence with the remit of undertaking the activities necessary to ensure compliance with these standards. This instruction describes the cost and price analysis services provided by the GEC in order to supply precise and objective information concerning programme costs. Some of the more significant analysis services for the purposes of this research paper include support services for resource planning, budgeting, economic programming and programme management for the Ministry of Defence and, more specifically, the 'Price and Cost Estimation for Investment Projects and Programmes'.

Optimal regulation should reward companies that invest with a view to reducing costs.[10] thereby generating greater profits, instead of providing them with a benefit when these costs fall as a result of reasons outside their control (e.g. drop in oil prices).

LIFE CYCLE COSTING TECHNIQUE

The LCC technique first began to be applied in the USA during the Second World War. Yet it was in the 1970s when it really developed and the LCC technique began to be applied to investment decisions, in particular in the construction sector. From this decade onwards and in the following decades, the contributions made by Blanchard and Fabricky have been of relevance to the defence sector.[11] In 1987, as part of a first attempt to standardise the processes that needed to be undertaken as part of its execution, the US National Institute of Standards and Technology (NIST) published a document entitled Life-Cycle Costing for the Federal Management Program. In 2002, the original ISO/IEC 15288 standard was published, the first international standard to facilitate a whole set of processes and phases of system life cycles (revised in February 2008).

The LCC technique is the one most used when evaluating investment projects and is considered to be one of the most effective decision-making tools. [12]

prestación de los servicios de análisis de costes y precios en el ámbito del Ministerio de Defensa" [Procedure for the Provision of Cost and Price Analysis Services within the Ministry of Defence]. BOD of 16 October 2007, no. 212/07 Pg 12,733.

10 LAFFONT, J. J. and TIROLE, J. Using Cost Observation to Regulate Firms, Chicago, Journal of Political Economy, Press, Vol. 94, no. 3, 1986, p. 614.

11 Blanchard, Benjamin S. Design and manage to life cycle cost. Oregon: M/A Press, 1978. Fabrycky, Wolter J., and Benjamin S. Blanchard. Life-cycle cost and economic analysis. Englewood Cliffs, NJ: Prentice Hall, 1991.

12 This is stated by a range of publications such as the US Military Handbook 881, the NASA Cost Estimating Handbook, the Society of Cost Estimating and Analysis (SCEA) and authors such as

In order to address the complexity of the life cycle, it has been divided into phases and stages, and each phase or stage has a different approach to be taken when estimating the costs that will arise in the future. The LCC technique is used with a view to anticipating and establishing a timetable for the allocation of defence resources over time. One must not only estimate the R&D&I, development and procurement required for the system in question, but it also proves necessary to estimate upkeep and logistical support costs. These are incurred in a backdrop where technology is sometimes is not yet placed on the market, where its operation occurs in diverse scenarios, requiring a large team of staff to operate the systems who can assiduously rotate and also due to its modernisation and non-conventional withdrawal. To make estimates for each of these life cycle phases it is possible to access market data, but if so, in oligopolistic or monopolistic conditions, these data must be analysed in accordance with NODECOS.

In terms of the time, effort and resources invested, *data collection forms the bulk of any LCC study*. LCC is a process of extracting data pertaining to the quantity, quality and other characteristics from the data available. These frequently define the methods and models to be applied, the analysis to be made and the results that may be attained.[13] [14]

The United States, the country that dedicates most resources to the study of LCC, recognises that military standards, specifications and most approved cost models only target part of the cost process for this cycle. These specifications, standards and the majority of life cycle cost models generate huge amounts of incompatible data, which are then channelled by programme directors in the hope that they can be used to bolster major cost decisions. [15]

Although the need to estimate LCC is shared with some other private investment goods, as a whole their life cycles are not as complex as those of a weapon system. As a result, the state of the art for the matter is principally contemplated and headed up by defence publications and a few authors who are cited throughout this text.

In terms of the implementation of the LCC technique, we have proven that this is scarce in the private sector and that its application within the public policies of state or local institutions is patchy, with national defence spearheading its application.

Blanchard B.S, Fabrycky, W.J, Waak, O. etc.

13 NATO. Continuous Acquisition and Life-cycle Support. NATO CALS HANDBOOK. Brussels. 2002 Pp. 103, 116, 242.

14 John C. Sterling . Analysis of Life Cycle Cost Models for DoD and Industry Use in "Design-to-LCC". Monterey. 2002. Pp. 103, 116, 242.

15 NATO. Continuous Acquisition and Life-cycle Support. Op cit. 2002. Pp. 103, 116, 242.

Analysis of LCC in decision making

Cost-effectiveness analysis is recommended and utilised as a tool supporting decision-making for evaluating the purchase or modernisation of a weapon system. This is the case, amongst others, for our defence department and for the experts Blanchard[16] and Fabrycky.[17]

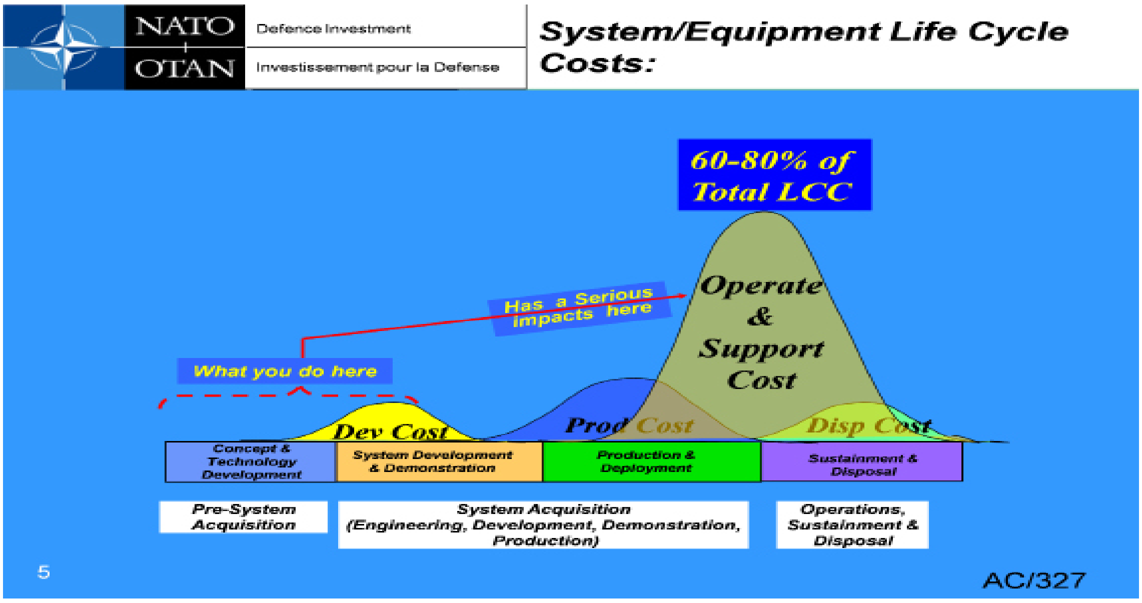


Figure 1: LCC percentage by stage.[18] [19]

The life cycle of economic decisions should be considered from a holistic prospective and not just from the viewpoint of the procurement process currently underway, since, in the aforementioned decisions, costs may rise or fall in other phases and not on a straight-line basis but sometimes exponentially. Reducing the number of times that a programme's design is revised may reduce production costs. Nevertheless, it may increase running and upkeep costs by an amount far greater than the intended savings. The decisions taken in the early stages of the acquisition process are decisive and affect the entire life cycle of a system.

Consequently, the design of a weapon system must focus on its life cycle to a large degree and must incorporate its impact on the organisation, costs, staff, training, infrastructure, etc.

16 BLANCHARD. Systems Engineering. ISDEFE. Madrid. 1995, pp. 44-45.

17 FABRYCKY. W. Analysis of Systems' Life Cycle Cost. ISDEFE. Madrid.1997. pp 4-5.

18 NATO Guidance on Life Cycle Costs. AC/327. ALCCP1. Brussels. 2008. Pg 7.

19 PAUL BARRINGER H.DAVID P WEBER. Life Cycle Cost Tutorial. Gulf Publishing Company. Houston, Texas. 1996. p. 17.

Up until 2011, only the acquisition costs of systems was accounted for in Spain, without taking into consideration the fact that this cost varied between 20% and 30% of the total LCC.

COST ESTIMATE

Cost estimates are predictive processes that aim to lessen the uncertainties involved in the development of a project by means of techniques and tools that should be utilised in the planning phase. The term 'cost estimates' is often used to describe the process by which the present and future impact of engineering design is forecast.[20] Project cost estimating procedures are regulated by international standards such as those of PMI, which are produced by experts in the field.

The current state of LCC estimation for a weapon system is mainly determined by the defence economy, in particular, by international organisations within the sector such as NATO. The latter, for instance, undertook a revision of the cost estimating methods and models for NATO countries and allies in 2007 as part of the RTO-TR-SAS-054 group, facilitating a general overview of the application and use of LCC right from the early conceptual phase through to removal from service. In addition, this addresses how to deal with uncertainty and risk when developing LCC estimates. Report SAS-054 concludes with a series of recommendations to improve the use and understanding of LCC within the formation of the decision-making process. It concludes by formulating best procurement practice for the different phases of a weapons programme and ends with conclusions and recommendations.

Furthermore, various NATO publications, clearly originating in the US, a country with the most influence over the definition of the theoretical and conceptual framework, form the theoretical framework for LCC estimation in Europe. More specifically, the most relevant include the publication ALCCP-1, which provides a common understanding of LCC as well as a common method for conducting LCC analysis for NATO countries, agencies and other entities. This publication is a continuation of the efforts taken by NATO panels such as RTO TR-058,SAS-028, structures for cost and life cycle costs for military systems, and develops a general structure for life cycle costs. Moreover, NATO recently edited the results of the group SAS-076 in 2012. This group publishes estimates for independent costs within NATO and the role of LCC as part of defence activity management.

20 DEGARMO. *DeGarmo Engineering Economy.* Pearson Prentice Hall. Mexico. 2004. Pg 24. ISBN 970-26-0529-6.

Life cycle cost estimates for defence purchasing programmes are by their very nature, as we have already alluded, uncertain.[21] Years of development and production of a system and decades of running costs and support need to be estimated on the basis of historical information that is scarce, disordered and stored in a motley assortment of systems that do not communicate with one another. Additionally, the information available for the system is often very limited such as the timetable, quantity of units to acquire, requirements, purchasing strategy, a rough design, etc. To complicate matters even further, the main characteristics of the system may change over the course of development and production such as variations to the weight of the system or its complexity etc. For all these reasons, a LCC estimate, when it just expresses a number, is merely an output or observation in a probabilistic cost distribution. The estimate is stochastic rather than deterministic.

Cost estimation techniques

Estimation techniques are used to break down a complex problem into a set of small problems that are easier to address. A combination of algorithms, judgement-based mathematical calculations and historical and current information deliver a cost estimate.

Each technique offers advantages and disadvantages. Consequently, it does not seem advisable to use one method exclusively. We can order the estimation techniques according to their reliability: [22]

1. Estimation using actual costs: This is used when we have developed a prototype. Its use is the most advisable and reliable since it permits us to extrapolate the cost according to the ongoing contract (prototype) in order to estimate the final cost of the system.

2. Estimation using engineering procedures (bottom-up): this considers price to be an output variable and cost calculations to be an input variable. This method identifies the cost components and these are valued and added together to obtain the direct cost. The indirect costs and the margin are then aggregated to obtain the sales price. This is the most detailed of all the techniques and the

21 A project in its initial phase, for example, may have a Rough Order of Magnitude Estimate (ROM) ranging from −25% to +75%. At a later project stage, as more information is gathered, the range of accuracy of estimates would fall to -5% to +10%. Source: Project Management Institute. A Guide to the Project Management Body of Knowledge (PMBOK® Guide). Fifth Edition. Pennsylvania. Project Management Institute Inc., ISBN978-1-62825-009-1, 2013, p. 200.

22 Source: Estimator's experience.

most costly to implement. You begin at the lowest definable level of the WBS and cost estimates are made for each task. The most appropriate estimation technique is used for each one.

3. Parametric estimates. In this type of estimates, cost parameters are used that are calculated using linear regressions or other statistical or mathematical methods obtained from historical data stored in databases linking costs with the characteristic physical units of a product (weight, volume, speed, etc.). Parametric estimates are used in studies for which the level of system definition is not very high. Commercial data is not available to carry out market valuations or there is little time to do so.

4. Estimation by analogy (top-down): This method makes a direct comparison of the product with other similar products for which the technical specifications, costs and prices are known. After making adjustments, and depending on the similarity of the product, the cost is calibrated in line with these adjustments and inflation, variation of indices, the number of units to be produced, geographical area etc. are introduced.

5. Prospective methods: strategic foresight studies the forces bringing about change, endeavouring to identify variables and predict their evolution. When there is a great deal of uncertainty surrounding a project, or when it is complex or has an implementation period spanning a large amount of time, prospective analysis should be used. The main difficulty that arises with this method is that the majority of these projects are unique and similar past designs that could serve as a reference point do not exist. The way in which one undertakes a prospective method is merely indicated in the elements presented below and we shall not describe it since this oversteps the purpose of this paper:

   A) Expert opinion.

   B) Creativity group techniques: Delphi method.

   C) Scenarios method.

   D) Relevance trees.

   E) Structural analysis.

   F) Cross-impact matrix.

   G) Morphological analysis.

Technique	Strengths	Weaknesses
Real cost	Most reliable estimate since it allows cost to be extrapolated from the Can dispose of WBS and PBS with a maximal level of detail.	It is very costly as a prototype must be developed.
	Short implementation time if the prototype is developed.	
Bottom up.	Intuitive and justifiable.	Requires considerable knowledge of the entire system. Does not facilitate the comprehension of the cost drivers.
	Usually based on quite a detailed Work Breakdown Structure, enabling the intuitive identification of the greatest cost generators	It is necessary to undertake a new estimate for each alternative scenario.
	Estimation does not become distorted as a result of calculation errors in the cost element. Obtention of very precise estimates.	The estimator works on the basis of plans, sketches and details of elements that have not yet been designed, meaning costs may only be assigned to known activities. Slow and costly. Is not usually useful when estimating complex systems with few units.
		Minor errors in estimates may lead to major errors in the total.
Parametric	There is no need to have a great deal of knowledge of the system to be studied, we can obtain results on the basis of general knowledge, by introducing a series of parameters.	It may initially be costly and require a lot of time to establish the means to do so.
	Possibility of approximating the value of the estimate with new iterations as better knowledge of the system is acquired	Necessitates extensive and well-maintained historical databases.
	Based on more than one reference and therefore less risk of error. Once undertaken, the CERs obtained are a major tool for responding to variations that may be introduced. Able to be adapted to the environment, accounts for such circumstances, country-by-country scenarios, regions, etc.	Difficulties for staff without prior training (Staff specialising in costs with knowledge of costs or in engineering with economic training in costs) may use the estimation software and understand the CERs established by others. Appropriate data collection and the statistical generation of correct CERs is complicated.
	It is compatible with the use of historical databases, although as we mentioned previously, it would be appropriate to use a Cost Breakdown structure (CBS) or at least one compatible with the one used in the Databases. Removes dependency on opinion If an IT tool is available , the resource investment made by the estimator will be extremely low.	Loss of predictive capacity outside the range of applicable data.
Analogy	Easy to handle and understand, provided that we are able to do this in comparable terms, hence the importance of having a database broken down as per WBS. The cost of using this method is low.	Requires data from comparable systems, although in general, it is always possible to find comparable sub-elements, e.g. engine, hull. Complicated to calibrate or adjust an estimate, with the need to use other additional methods.
	It is a quick method, easy to modify and can be used to verify other methods.	This method requires that cost estimators have a wealth of experience and expertise

Table I: Strengths and weaknesses of the main methods presented. Source: prepared by the author.

Estimation techniques applicable to the stages of the life cycle of a system

Depending on the type of programme, the purpose of the cost estimate, the time taken to conduct it and the information available, one technique may be more suitable than another for a certain stage of the programme.[23] It is common to find not just one single method of estimation in each stage, but instead a combination of methods supplemented with expert opinion.

It is possible that in preliminary or even advanced stages, it is not possible to use estimation techniques. In these cases, the following may be used to validate costs quantitatively:

1. Indexed prices.
2. Volume-cost-benefit analysis.
3. Statistical analysis.
4. Development and use of cost estimation ratios (parameters).
5. Regression analysis and moving averages.
6. Learning curves and task measurement.
7. NPV, net present value, for which a discounting technique is used.

The US Army,[24] NATO[25] and NASA[26] list the applications and techniques used to carry out estimations and the stage at which they are applied.

23 NATO, RTO. *Code of Practice for Life Cycle Costing*. RTO-SAS-069. Op. Cit. 2009. Pg. 2.

24 US. US Department of the Army. *Cost Analysis Manual*. 2002. Pp. 171,178.

25 NATO, RTO. *All Methods and Models for Life Cycle Costing*. RTO-SAS-054. RTO Publication. Neuilly-sur-Seine, (Paris). 2007. Pages 4-1 and 5-1.

26 NASA. NASA *Cost Estimating Hand Book*. CAD Publication. Washington, DC. 2015. Page 20-Appendices C,E & F.

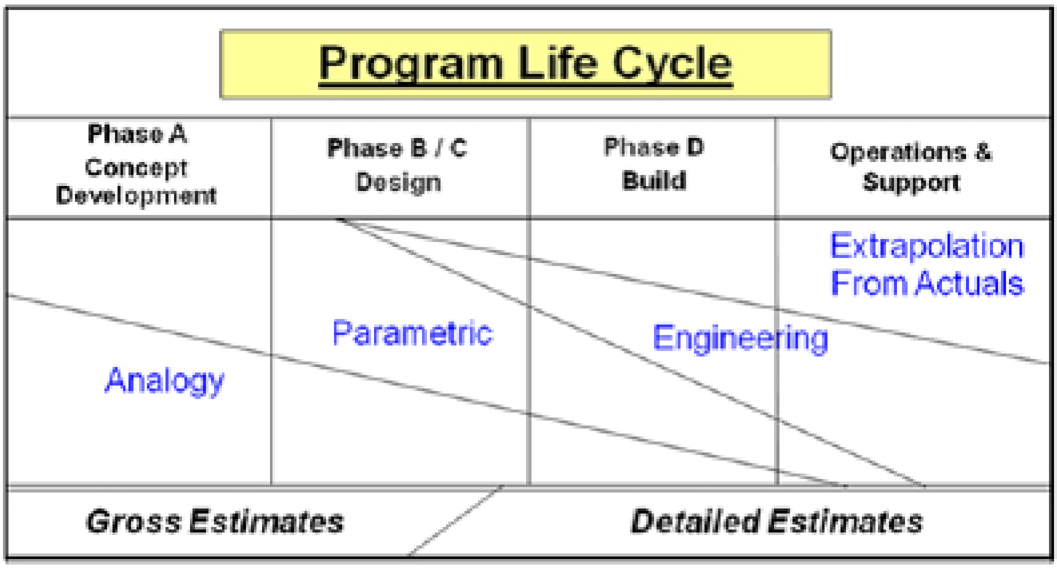


Figure 2: Estimation methods used by NASA, p. 14.

In the earliest stages, the decision support method and the simulation method are most used. This comes as no surprise since these techniques can be employed using subjective judgements that make up for the lack of historical data. Simulation and optimisation methods are used in the development, production and use or support stage to estimate the cost of upkeep and the impact of alternative upkeep scenarios. During the use/system support phases, an activity-based costing system is used. The ABC method is the most widely used to obtain current costs.

Method / Stage		Evaluation of operational need	Pre-feasibility	Viability	Project definition	Design and development	Production	Operational service	Withdrawal from service
Calculation/ Estimate	Analogy	THREE	THREE	THREE	THREE	THREE	TWO / THREE	TWO / THREE	TWO / THREE
	Parametric	THREE	THREE	THREE	THREE	THREE	THREE		
	Bayesian		ONE						
	Engineering	ONE	ONE	TWO / THREE	THREE	THREE	THREE	TWO / THREE	TWO / THREE
	By catalogue Order of magnitude	ONE	ONE	ONE	ONE	TWO / THREE	ONE		ONE
	Expert opinion	THREE	TWO / THREE	TWO / THREE	TWO / THREE	TWO / THREE	TWO / THREE	ONE	ONE

Table II: Summary of the Estimating Methods used by NATO (No. of countries in colour).[27]

27 NATO. RTO-TR-SAS-054.Op. Cit, 2007, Pp. 4-12.

Cost estimation tools

An automatic cost -and price- estimating tool is an IT application that uses estimating techniques to estimate costs, effort, sequencing and duration by means of data input. In addition, it allows for time planning and the identification of associated risks, which is of great help to the planner.

From mid-2010 onwards, the Spanish Ministry of Defence, through the Directorate-General for Economic Affairs (Procurement Sub-directorate; GEC), has taken steps to build parametric estimation capacity, since a stable method was required that would allow for independent cost estimates and that would facilitate decision making. In order to afford itself this capacity, three basic elements were identified:

- A cost database within which tenders are presented and the companies with which this department has contractual relations declare incurred costs. These historical costs will be used to validate estimates, identify cost-drivers, implement control of management and as a source for estimates for new systems.[28] (The Ministry of Defence has begun to develop these).
- A Cost Breakdown Structure (CBS) that links up the structures of the families of systems and of work, which are already defined, and which allows us to register the costs of systems.
- A parametric costs estimating tool that permits us to obtain a better cost approximation for systems by using physical parameters. For most tools, the principal variable or 'cost-driver' is weight.

The tool *True Planning* from the American company PRICE SYSTEMS was selected from among other instruments on the market.[29] In order to manage this, GEC has established a specialised team that has undertaken and carries out estimates in the initial stages of the process. In order to carry out these parametric estimates, the GEC uses some of the product parameters such as weighting quantity, weighting of electronics, the electronics description, the COTS price, manufacturing complexity structure, manufacturing complexity electronics etc.

The tool is used at three levels: for budgeting, procurement and price variation (design to cost or how varying requirements influences the price).

28 NATO, RTO. *Cost Structure and Life Cycle Cost (LCC) for Military Systems*. RTO-SAS-036. RTO Publication. Neuilly-sur-Seine, (Paris). 2009. Pp. 3-6.

29 US, NAVY. NAVSEA *Cost Estimating Handbook*. Op cit. Appendix G (Cost tools) NASA. Cost Estimating Handbook. Op cit. 2005. Vol. 1. Section 4.4 (Other list).

Parameters and references able to be used in LCC estimates obtained from historical data

We have drawn up a table in which the main parameters used by the US and NATO for calculating LCC for a weapon system are summarised.

PHASE	STAGE		PARAMETER/OBSERVATIONS
Implementation	Production stage	R&D&I	Fixed-wing aircraft: Average of 7% /LCC. Rotary wing aircraft Average of 3% /LCC. Ground systems: Average of 4% /LCC. Surface ships: Average of 5% /LCC. Submarines: Average of 7%/LCC. UAVs: Average of 10%/LCC. Space systems: Average of 40%/LCC
		Manufacture	Fixed-wing aircraft: Average of 30% /LCC. Rotary wing aircraft Average of 29% /LCC. Ground systems: Average of 33% /LCC. Surface ships: Average of 26% /LCC. Submarines: Average of 33%/LCC. UAVs: Average of 34%/LCC. Space systems: Average of 45%/LCC
Service	Operational life	OPERATION+ AND UPKEEP O&U	In general between 60% and 75% of the LCC. The highest percentage of LCC, between 60% and 80%, is concentrated in this phase. Surface ships: Staff costs represent 40% on average of operation and upkeep costs. Aircraft: O&U costs represent half of LCC. Vessels: O&U costs represent two thirds of LCC of the vessel. Warships: (Royal Netherlands Navy, Landing Platform Dock Rotterdam class amphibious warfare vessel) Cost estimation: 2012. O&U cost over 30 years of life would represent 84% of the LCC Fixed-wing aircraft: Average of 63% /LCC. Rotary wing aircraft Average of 68% /LCC. Ground systems: Average of 63% /LCC. Surface ships: Average of 69% /LCC. Submarines: Average of 60%/LCC. UAVs: Average of 55%/LCC. Space systems: Average of 15%/LCC
		UPKEEP	**General:** Cost ranging from 2 to 20 times the purch cost.

Table III: Parameters and references collated and utilised in LCC calculations.[30] [31] [32] [33]

30 US, DoD (CAPE). Operating and support cost-estimating guide. Office of the Secretary of Defense. Washington, DC. 2014. Page 2-3.

31 NATO Guidance on Life Cycle Costs. ALCCP1. Op cit.,2008. Page 40.

32 NATO. Independent Cost Estimating and the Role of Life Cycle Cost Analysis in Managing The Defence Enterprise. RTO-SAS-076. RTO Publication. Neuilly-sur-Seine, (Paris). 2012. P. 12. ISBN 978-92-837-0162-0.

33 BARRINGER H. PAUL, DAVID P WEBER. Life Cycle Cost Tutorial. Houston. Op. Cit. 1996.

THE PLANNING OF SCOPE, COST AND EFFORT

A) In a project by means of breakdown structures

Project management is a recent discipline that consists of the *use of knowledge, skills and the application of techniques and tools to the project activities* in order to meet the objectives of *scope, quality, time and cost.* It could be used to enhance the usefulness of any phase or stage of the procurement process.[34] It is applied by means of the following processes: initiation, planning, implementation, control and conclusion.

We shall focus on the planning of a project since it encompasses an ordered and systematic succession of processes to establish and define the WBS, with the greatest precision possible. This is a hierarchical breakdown of an activity by means of a breakdown of tasks. It is expressed in a structure in which the work is split up into separate parts in an exhaustive, hierarchical and descending fashion, comprising the deliverables or work packages (relating to the physical part or to the product) and the activities necessary to carry it out. A careful definition of WBS increases the likelihood of success of a project and the chances of achieving the objectives and results set, as well as optimising the consumption of resources and the costs incurred (control accounts), detailing the timing of each activity and the responsibility for implementation for each project stage.

Product Breakdown Structure (PBS) in a project

PBS uses a tree-like hierarchical structure to describe the *physical elements* that make up a system. By means of the questions 'what exactly do we want to produce?', 'what is the project outcome?', 'what parts does it comprise?' we can start to understand the Product Breakdown Structure of a product. To define this structure we need the same experts who established the requirements, specifications and functional descriptions that the product or service must respect.

p. 17.

34 NATO. The Handbook of Phased Armaments Programming System (PAPS). AAP-20. 2nd ed. Brussels. 2010, page 5. * Emphasis added by author.

Work Breakdown Structure (WBS)

The WBS is a hierarchical breakdown of the full extent of work to be done by the project team in order to meet the project objectives and create the deliverables required. The WBS organises and defines the full project scope and represents the work specified in the approved outline for the project scope in force. Within the context of WBS for a project, the word work refers to the products or deliverables (physical part) of the work that result from the activity carried out and not the activity in itself.[35]

In fact, the WBS is not a document but instead a source of multiple potential documents, an empirical basis for:

- Definition of activities.
- Resource planning.
- Resource estimation.
- Cost estimation.
- Cost budgeting.
- Identification of risks.
- Planning for HR, quality, communications and purchasing.
- Facilitation of effective planning and allocation of management and technical responsibilities.
- The application of the Added Value Management System.

CBS (Cost Breakdown Structure)

A CBS is a tree structure that usually focuses on the product, work, project phase, life cycle or a combination of these aspects. A CBS defines the product/activities that we are going to undertake and links work elements. The standardisation of a CBS is extremely common.

PMI has defined that the WBS terminates once each of the work packages has been assigned to a control account and a unique identifier is established as an account code for this work package. These identifiers provide a structure for the hierarchical consolidation of costs, the timetable and information about resources. A control

35 PMI. *A Guide to the Project Management Body of Knowledge.* Op cit., 2013, p. 126.

account is a management point of contact integrating the scope, budget, actual cost and the timetable and compares these with the value generated in order to measure performance.[36]

B) In a military programme in Spain by means of breakdown structures

Instruction 67/2011 stipulates that: "In order to designate a procurement option, the Directorates-General of the State Secretariat shall follow a standardised procedure that guides and systematises the analysis of the operational or functional solution defined in the REM (General Staff Requirements) or DDR (Definition of Requirements Document). This procedure will be built around the following structures according to its purpose:

1. Product Breakdown Structure (PBS), which breaks down the operational or functional solution proposed into the elements or subsystems that constitute it.
2. Work Breakdown Structure (WBS), which identifies the activities necessary to proceed to procurement and upkeep of the elements identified in the previous structure.
3. Cost Breakdown Structure (CBS), which breaks down the cost of the solution into cost elements by accounting for their nature and typology on the basis of the two previous structures."

For this purpose, the GEC undertook a study whose objective was *to define structures enabling the standardisation of the costs of defence systems* so as to:

1. Register the bids and declarations of incurred costs in a homogeneous and ordered way.
2. Ensure that these can readily be compared with one another.
3. Permit the creation of a database for the costs of systems forming a solid foundation for the production of new cost estimates for future defence systems.

With a view to standardising cost information, military systems were grouped into 14 families (physical PBS) according to the nature of these systems.

1. Aircraft Systems;
2. Naval Systems (vessels);
3. Land Vehicle Systems;

36 PMI. *A Guide to the Project Management Body of Knowledge.* Op cit., 2013, P. 132

4. Electronics and/or Software Systems (CIS);
5. Firearms Systems. (Armament, artillery, ammunition and grenades);
6. Missiles Systems (missiles and torpedoes);
7. Space Systems;
8. to 14) Other goods able to be inventoried (infrastructure), consumer goods, services etc.

For each family (unlike for the planning of scope, cost and effort), three breakdown structures are developed whose intersection marks a cost element:

1. Activity-based breakdown structure (ABS): *Set of activities, tasks and sub-tasks carried out at each phase of the life cycle of a military system. (Equivalent to the WBS organised by phases and stages).*
2. System-based breakdown structure (SBS): *Breakdown tree for physical system elements (Equivalent to PBS).*
3. Cost-based breakdown structure (CBS): *Breakdown based on the nature of the cost, just as is stipulated in the Annex to Instruction 128/2007 of the State Defence Secretariat (SEDEF).*

PHASE	STAGE	PARAMETER/OBSERVATIONS

MINISTRY OF DEFENCE	PRODUCT BREAKDOWN STRUCTURE *(Version v.01 - 2008, September)*	STATE DEFENCE SECRETARIAT DIRECTORATE GENERAL FOR ECONOMIC AFFAIRS SUBDIRECTORATE GENERAL FOR PROCUREMENT COST EVALUATION GROUP

Aircraft System Family

Subfamily *Pruduct Breakdown Structure (PBS)*

Code	Level	Product Breakdown Structure
01	Nivel 1	*Aircraft system*
01.01	Nivel 2	Base platform
01.02	Nivel 2	Principal systems
01.02.01	Nivel 3	*Standard procedures – Aircraft fuselage systems*
01.02.02	Nivel 3	*Environmental Control*
01.02.02.01	Nivel 4	Compression
01.02.02.02	Nivel 4	Distribution
01.02.02.03	Nivel 4	Pressurisation Control
01.02.02.04	Nivel 4	Heating
01.02.02.05	Nivel 4	Refrigeration
01.02.02.06	Nivel 4	Temperature Control
01.02.02.07	Nivel 4	Humidity/Air contamination control
01.02.02.08	Nivel 4	Liquid/gas refrigerant
01.02.02.09	Nivel 4	Integrated environmental control system
01.02.03	Nivel 3	*Auto pilot - General*
01.02.03.01	Nivel 4	Autopilot
01.02.03.02	Nivel 4	Velocity - Flight approach correction
01.02.03.03	Nivel 4	Automatic Regulation of Impulsion
01.02.03.04	Nivel 4	System monitor
01.02.03.05	Nivel 4	Aerodynamic load mitigation
01.02.03.06	Nivel 4	Flight envelope
01.02.03.07	Nivel 4	Flight management
01.02.03.08	Nivel 4	Management, guide and flight envelope system
01.02.03.09	Nivel 4	Integrated device for maintenance of autopilot system
01.02.04	Nivel 3	*Comunications*
01.02.04.01	Nivel 4	Voice communication
01.02.04.02	Nivel 4	Data Transmission and Automatic Calling
01.02.04.03	Nivel 4	Megaphone and inflight entertainment system
01.02.04.04	Nivel 4	Intercom
01.02.04.05	Nivel 4	Audio Integration
01.02.04.06	Nivel 4	Static discharge
01.02.04.07	Nivel 4	Audio and video and monitoring
01.02.04.08	Nivel 4	Automatic Integrated Frequency Tuning
01.02.04.09	Nivel 4	Comunications via data-bus
01.02.05	Nivel 3	*Electric Generation/Power*
01.02.05.01	Nivel 4	Management of Generator
01.02.05.02	Nivel 4	AC Generation
01.02.05.03	Nivel 4	DC Generation
01.02.05.04	Nivel 4	External Power
01.02.05.05	Nivel 4	AC Distribution
01.02.05.06	Nivel 4	DC Distribution
01.02.05.07	Nivel 4	Monitoring and electrical protection
01.02.05.08	Nivel 4	Distribution of electric current
01.02.05.09	Nivel 4	Multi-use equipment
01.02.06	Nivel 3	*Equipment and furniture*

Table IV: Part of a product structure for a family of aircraft regulated by the Spanish Ministry of Defence (Fourteen families for the time being).

WORK BREAKDOWN STRUCTURE

WBS

MINISTRY OF DEFENCE
STATE DEFENCE SECRETARIAT

DIRECTORATE GENERAL FOR ECONOMIC AFFAIRS

SUBDIRECTORATE GENERAL FOR PROCUREMENT

COST EVALUATION GROUP

Code	Work Breakdown Structure	
00	LIFE CYCLE	
01	1	*Conceptual Phase*
01.01	2	Definition of Operational Need Stage
01.01.01	3	*Planing Work*
01.01.02	3	*Management Tasks*
01.01.03	3	*Administrative Tasks*
01.02	2	Operational Pre-Feasibility Stage
01.02.01	3	*Planing Work*
01.02.02	3	*Management Tasks*
01.02.03	3	*Administrative Tasks*
02	1	*Definition and Decision Phase*
02.01	2	Definition of Requirements Stage
02.01.01	3	*Management Tasks*
02.01.02	3	*Tecnical Tasks*
02.01.03	3	*Administrative Tasks*
02.02	2	Selection of Procurement Alternative Stage
02.02.01	3	*Management Tasks*
02.02.02	3	*Administrative Tasks*
02.03	2	Programme Establishment Stage
02.03.01	3	*Management Tasks*
02.03.02	3	*Administrative Tasks*
02.04	2	Preparation for Implementation Stage
02.04.01	3	*Management Tasks*
02.04.02	3	*Administrative Tasks*
02.04.03	3	*Logistical Tasks*
3	1	*Implementation Phase*
03.01	2	Desing Stage
03.01.01	3	*Activities of the Ministry of Defence in the Design Stage*
03.01.01.01	4	*Management Tasks*
03.01.01.02	4	*Tecnical Tasks*
03.01.01.03	4	*Administrative Tasks*
03.01.02	3	*Activities of the Contractor in the Design Stage (Armaments and Material)*
03.01.02.01	4	*Management Activities*
03.01.02.02	4	Engineering Work
03.01.02.03	4	Generation of Product Documents
03.01.02.04	4	Prototype Manufacture
03.01.02.05	4	Prototype Testing
03.01.02.06	4	Prototype Guarantee Work
03.01.03	3	*Activities of the Contractor in the Design Stage (Infrastructure)*
03.01.03.01	4	Development of Projects and Infrastructure
03.01.03.02	4	Development of Infrastructure Demonstrators
03.01.04	3	*Activities of the Contractor in the Design Stage (CIS Programmes)*
03.01.04.01	4	CIS Tecnical Work
03.01.04.02	4	Development of CIS prototypes
03.02	2	Production, Construction, Development or Procurement Stage
03.02.01	3	*Activities of the MoD in the Production, Construction, Development of Procurement Stage*
03.02.01.01	4	*Management Tasks*
03.02.01.02	4	*Tecnical Tasks*
03.02.01.03	4	*Administrative Tasks*
03.02.02	3	*Contractor Activities (Production of Armaments and Material)*
03.02.02.01	4	Contractor Activities (Production
03.02.02.02	4	Contractor Management Work
03.02.02.03	4	Contractor Engineering Work
03.02.02.03.01	5	Manufacture of parts
03.02.02.03.02	5	Assembly and Integration
03.02.02.03.03	5	Inspection and Integration
03.02.02.04	4	Testing
03.02.02.05	4	Guarantee work

Table V: Part of a work structure that the Spanish Ministry of Defence has regulated.

WORK BREAKDOWN STRUCTURE

WBS

MINISTRY OF DEFENCE
STATE DEFENCE SECRETARIAT
DIRECTORATE GENERAL FOR ECONOMIC AFFAIRS
SUBDIRECTORATE GENERAL FOR PROCUREMENT
COST EVALUATION GROUP

Codificación	Classification by Nature of Cost	
01	Level 1	*Internal Costs*
01.01	Level 2	*Staffing costs*
01.02	Level 2	*Consumption and other expenditure*
02	Level 1	*External Costs*
02.01	Level 2	Contract Price
02.01.01	Level 3	*Value of services*
02.01.01.01	Level 4	*Production Costs*
02.01.01.02	Level 4	*General expenditure*
02.01.01.03	Level 4	*Profit*
02.01.02	Level 3	*Other concepts to repay according to the contract*
02.01.02.01	Level 4	*Eligible contract costs, specific investment required for the project*
02.01.02.02	Level 4	*Other costs identified and obligations arising from the contract not attributed to the products delivered and/or the services provided*
02.01.02.03	Level 4	*Financial costs for the average maturity period associated with the conversion and charge cycle (calculated in terms of opportunity on the basis of the corresponding financial flow)*
02.01.03	Level 3	*Taxes applicable*
02.02	Level 2	Incremental price increase
02.03	Level 2	Variations in price due to modifications
02.04	Level 2	Variations resulting from potential options
02.05	Level 2	Premiums to tenderers
02.06	Level 2	Price review amount

Table VI: Part of a cost structure for a family of aircraft regulated by the Spanish Ministry of Defence.

For instance the code corresponding to the *production costs* (02.01.01.01 in the CBS) corresponding to *manufacture work* for parts (03.02.02.03.01 in the WBS) of the *aircraft product*, platform (01.01 of the PBS), would become identification 02.01.01.01-03.02.02.03.01-01.01.

A Life Cycle Cost Breakdown Structure (LCCBS) defines the products that should be developed and lists the work elements required to form the final product, also accounting for the costs of this product at each stage of its life cycle. NATO defines a Generic Cost Breakdown Structure (GCBS), which is formulated in publication NATO-SAS-028. In the publications NATO-RTO-TR-054, 058 and 076, one can find definitions and good practice for establishing a cost structure.

ESTIMATION PROCEDURE FOR LIFE CYCLE COST IN SPAIN

We understand procedure to be the sequence of pre-determined actions that set out how to implement a process. The LCC estimation procedure is integrated into the life cycle management, which itself is defined by standards, specifications and templates.

The LCC estimation procedure is very recent in Spain and consists of a stochastic procedure in which procurement alternatives are determined according to certain technical requirements and the LCC estimates are quantified for each. In the decision-making phase, an equivalent measurement is produced for the current cost value of each one and one alternative is selected on the basis of this measurement. In Spain, we have not developed a standard concerning the management of the life cycle as a step prior to drawing up such an estimation procedure. Neither have we referenced other available standards available that could support our work, nor have we established guides, defined processes or drawn up templates. Nonetheless, Instructions 67/2011[37] and 72/2012 from SEDEF present a procedure for approaching a programme. Instruction 67/2011, despite not defining nor referencing the life cycle and its management, includes an outline of a procedure for estimating the LCC of a system. More specifically, the instruction integrates the set of activities that aim to meet the resourcing needs via the definition, design, production, construction, development or procurement, entry into service, modernisation and withdrawal from service. This process is executed in phases and stages. From the conceptual stage of the process onwards, the *estimation of the cost of the solution* is taken into account and the LCC estimation is accounted for from the definition stage onwards.

It is at the stage in which the procurement option is selected that LCC estimation, using the aforementioned structures, becomes hugely relevant since its assessment will accompany the procurement process right through to the implementation stage.

	Conceptual phase		Definition and decision phase			
	1) Definition of operational need stage	2) Operational pre-feasibility stage	3) Definition of requirements stage	4) Selection of procurement option stage	5) Programme establishment stage.	6) Implementation preparation stage
Military planning needs	Doc 1): DINO Valuations	Doc 2): OEM Estimates	Doc 3): RFM LCC Estimates	Doc 4). VD Estimation of Costs elements WBS	Doc 5). PDD We forget estimates	Doc 6). EID Quotes or bids?
Other departmental objectives needs	Doc 1) and 2): DNF		Doc 3): IDR			

Table VII: Conceptual and definition/decision-making phases of the resourcing process in Spain.

37 SPAIN. MINISDEF. Instruction SEDEF 67/2011 of 15 September, Material Resources Procurement Process. BOD 27/09/2011, no. 189/11.

The LCC estimation procedure establishes that in order to designate a procurement option, the Directorates-General of the State Secretariat shall follow *a standardised procedure (not defined),* as presented above, which is based on the (generic) PBS, WBS and CBS. These directorates should draw up the PBS, WBS and CBS (for the solution) by *adapting the generic standardised structures* adopted for this purpose and their level of detail to the operational or functional solution proposed.

Instruction 67/2011 is based upon the publication NATO AAP20-PAPS (2010), which constitutes the framework within the NATO Conference of National Armaments Directors used to promote cooperation programmes on the basis of harmonisation of common military needs. It is also the instrument that facilitates decision making at all levels of management. The aim of PAPS is to convert this need into specific requirements, control the deployment of equipment, modernise it and facilitate its withdrawal from service. Unlike 67/2011, NATO-AAP20-PAPS provides terms and definitions for the sake of common understanding. It also creates best practice for processes and offers a common basis for the planning, implementation and control of projects with a focus on mitigating risk. Moreover, NATO-AAP-20-PAPS includes seven supporting reference publications. Four of these address the management of the life cycle, processes and contractual terms. It also lists 23 documents applicable to the content of the instruction, in particular, engineering systems, life cycle processes, standard project management, quality and various AQAP standards. Instruction NATO AAP-48 serves as a guide to the description of life cycle stages, processes and models in a system.

In order to dispose of an instrument applicable to a rough estimation procedure for LCC, Spain has transposed the official version of the European standard EN-60300 into standard UNE-EN-60300-3-3: 'Dependability management. Life Cycle Costing', which provides a general introduction to the concept of the cost analysis of this cycle and covers all its applications, *although, for now, this standard is little-known and its application is low or non-existent.* Of particular note are the costs associated with the dependability of a product and the purpose and value of LCC is explained. In addition, it identifies the characteristic cost elements in order to facilitate the planning of programmes and projects. It affords a general guide to undertaking a LCC analysis, including the development of a cost model, and it divides the cycle up into phases and stages.[38]

38 *AENOR. UNE EN 60300-3-3. Dependability management. Life cycle costing. Madrid. 2009.* Page 56.

The description and implementation of life cycle management and the cost estimation procedure in Spain is summarised in Figure 3.

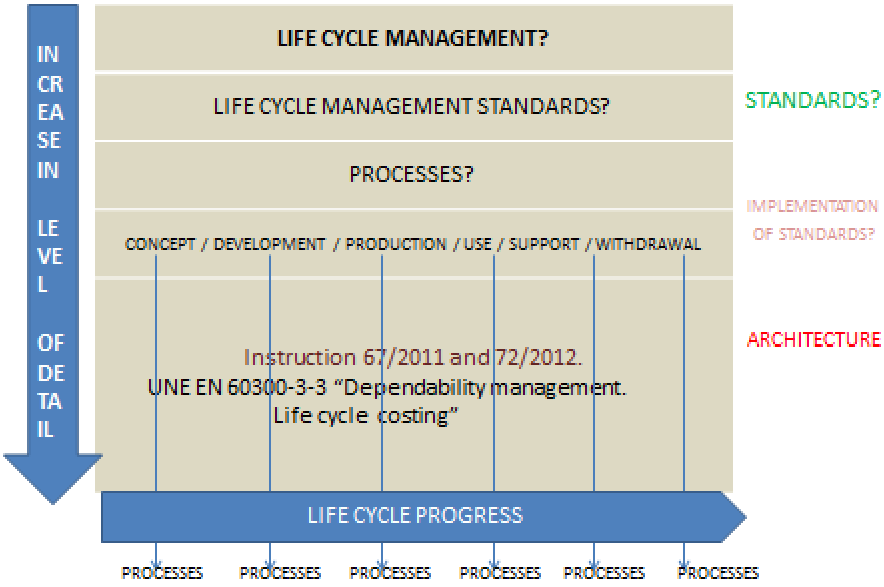
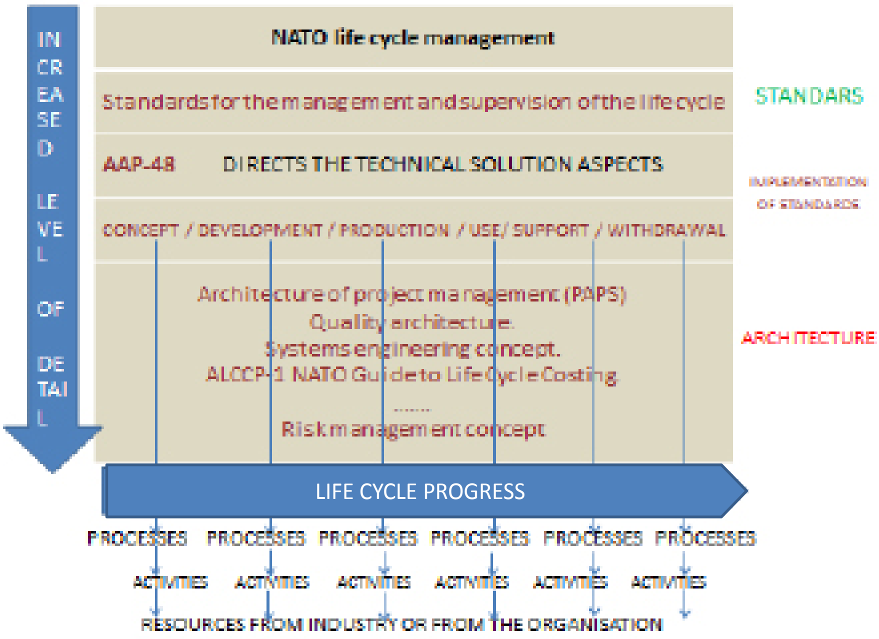


Figure No. 3: Source: Author's own based on NATO-AAP48 (Page 1).

COMPARISON OF ESTIMATION PROCEDURES IN SPAIN, NATO AND OCCAR

Similarly, the description and implementation of life cycle management and the cost estimation procedure used in NATO and OCCAR are summarised in Figures 4 and 5.



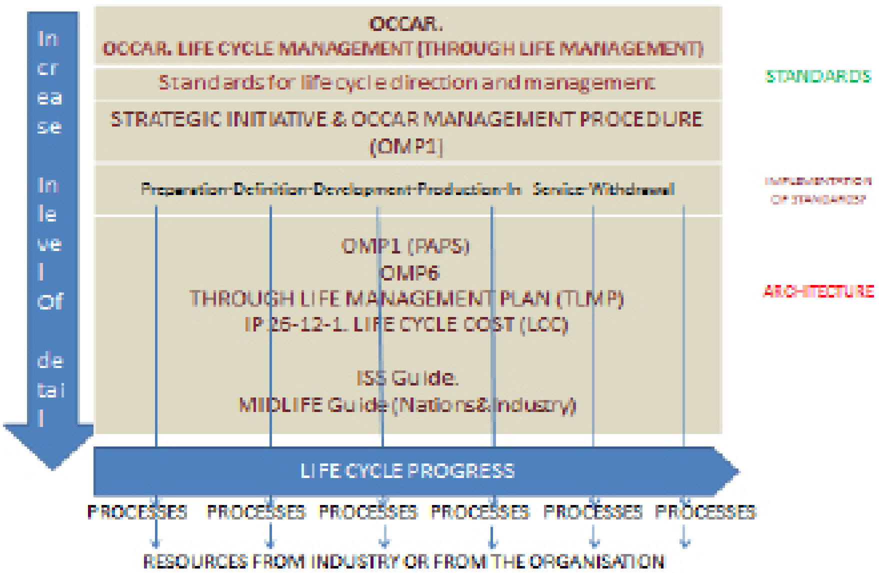


Figure No. 4: NATO Architecture. Figure No. 5: OCCAR architecture. Source Figures 4 and 5: Author's own work based on ALCCP1 (Page 3) and NATO-AAP48 (Page 1).

The three LCC procedures (Table VIII) are summarised comparing the most relevant aspects of each. (Procedures extracted from the standards included in Figures 3, 4 and 5).

	OTAN	OCCAR	ESPAÑA
1) Do guides and criteria exist to adapt the standard procedure to a specific case?	X	x	
2) Are specific organisational standards defined: Policies, Product life cycle etc.?	X	X	
3) Are templates defined?	X	X	
4) Depending on the magnitude and importance of the system. Are cost units formed and integrated into the project or are cost analysts assigned as part of the team that is integrated into the project who coordinate with the leader of the programme, users, engineers, etc.?	X	X	*
5) For larger systems, before beginning an estimate, when planning the LCC calculation, is a cost estimation requirement document (CERD) drawn up?	X	X	
Is it necessary for all participants in a process to agree about its initial content?		X	
The requisite information included in the CERD is: A) Purpose of the cost estimation, time to carry it out and data accessible.	X	X	
B) Acknowledgement, costing boundaries determine the cost elements to be included in the study.	X	X	
C) Input data for the estimation such as:	X	X	*
- Technical description of the system, consisting of a general vision, its main characteristics and components, the technology used, similar existing systems. Important point given that there are a large number of items that must be acknowledged prior to carrying out the estimate, e.g.: Life of the system (this will vary depending on the degeneration of the system, durability, requirements, specifications etc.), operation and upkeep stage (O&U), inflation indices and exchange rate, constant/common currency, conditions of peace/war (usually reflect peace) and scope of the estimates (interfaces with other systems, integration into platforms or other systems, etc.).	X	X	*
- System duration, system quantity. *Defining programme and system content:* is an adequate practice for defining the content of a system (for instance: system characteristics, programme timetable, staff required for operation, support concepts such as maintenance, software or training, special support such as infrastructure or other special aspects to be taken into consideration).	X	X	*
- WBS.	X	X	X
- Speciality of staff controlling the system, training needs, etc.	X	X	*
- Operational concept, operation scenario, operational support elements, sustainability considerations.	X	X	*
- Deployment, areas, estimated duration.	X	X	
- Integrated logistical support process: concept for maintenance, reliability, maintainability, specific spare parts, facilities for specific maintenance work, fuel consumption and other supplies.	X	X	
- Procurement timetable.	X	X	X
- Procurement strategy: Industrial scenario, multinational scenario, software and information, etc.	X	X	X
- System verification and evaluation.	X	X	
- Any prior costing estimate.	X	X	/
D) Supporting documents required for the cost estimation and elements upon which the estimation is based.	X	X	
5) Preparation of the estimation using pre-established templates, execution of the estimation and documentation of outcome.	X	X	
A) Data collection and its analysis that forms the core of the estimate.	X	X	
B) Analysis is undertaken by a specialist since this will obtain a structure of basic costs that should be estimated, according to the compilation and analysis of information, the following tasks should be carried out:	X	X	*
B1) Is the life cycle model developed analysed?	X	X	
B2) Are the WBS and the PBS analysed and reviewed?	X	X	X
B3) Is a GCBS developed?	X	X	X
B4) Are the cost elements identified?	X	X	*
B5) Are appropriate cost estimation methods selected?	X	X	/
B6) Are the quantity of work, timeframes and costs estimated?	X	X	/
B7) Is review, mapping and calibration undertaken to ensure that acknowledgements and the scope has been accounted for?	X	X	

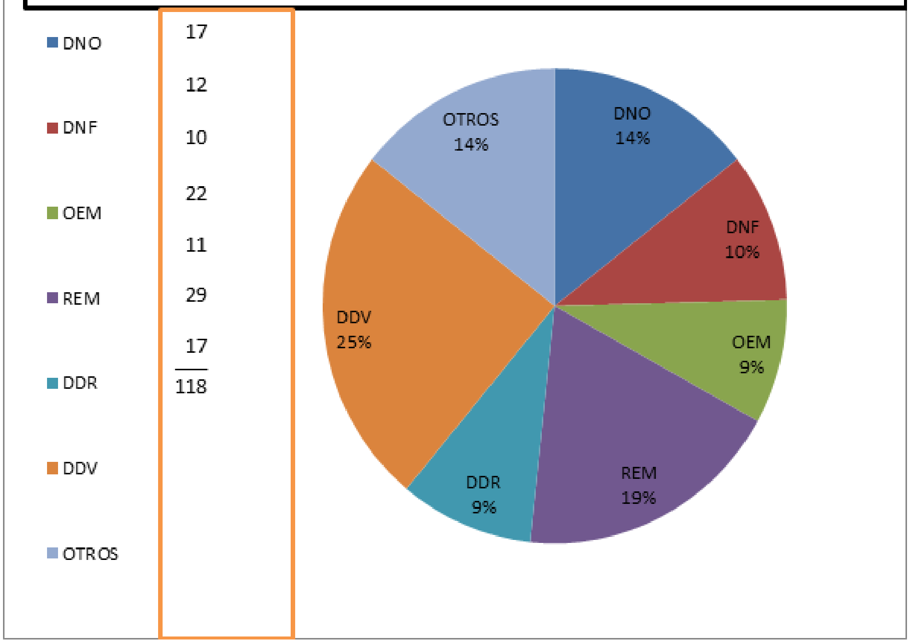
C) Once these tasks are completed, the cost methodology and cost estimation tools are applied.	X	X	/
D) Once the estimation process is completed, the analyst will aggregate the costs produced in each phase of the life cycle in order to produce the LCC estimate	X	/	X
6) Review and validate.	X	X	
- Review.	X	X	
- validation	X	X	
- calibration	X	X	
- documentation	X	X	
- presentation and report for LCC estimate.	X	X	X

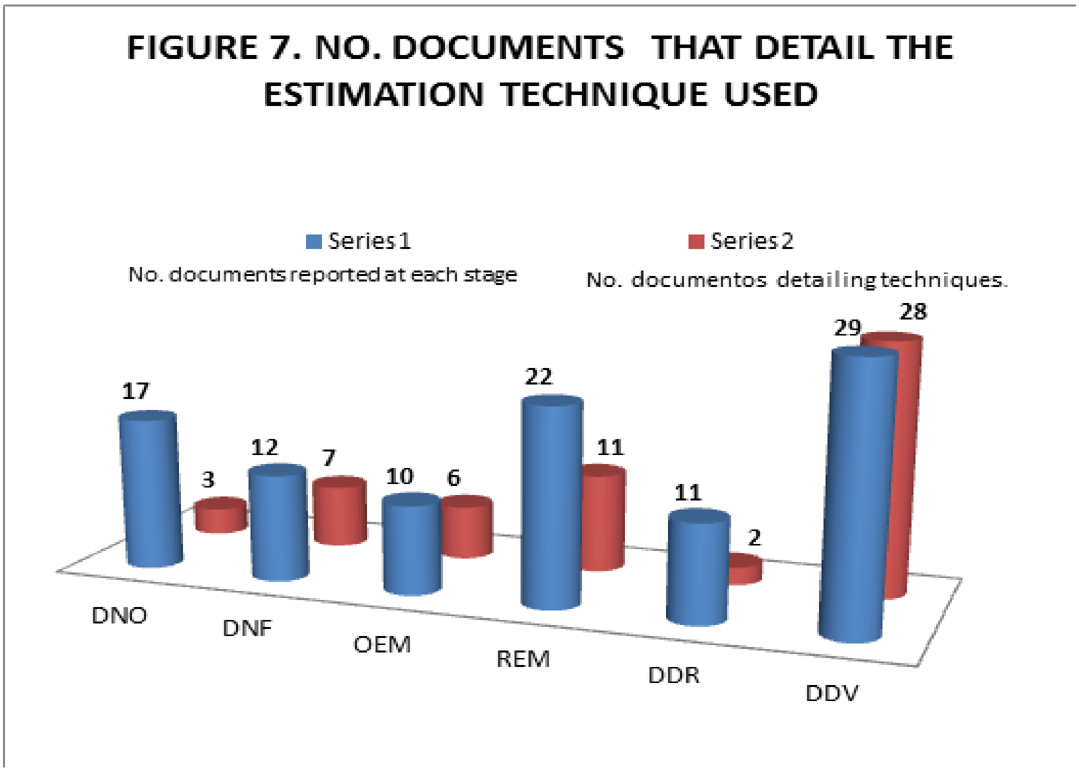
Key. X Meets conditions./: Partially meets conditions (50%). *: Meets conditions in some respects.Blank: Does not meet conditions.

USE OF TECHNIQUES, PARAMETERS AND STRUCTURES IN THE COST ESTIMATES UNDERTAKEN IN SPAIN

In order to respond to part of the purpose of this essay using the information included in each cost estimate reported or drawn up by the GEC pursuant to 67/2011, the researcher has established a database for up to June 2015. By using these data and the 43 interviews undertaken with staff members who play a part in the procurement of resources, we obtain the following results:

FIGURE 6: NO. AND % OF DOCUMENTS REPORTED BY THE GEC BETWEEN 09/2011 AND 06/2015





In the cost estimates reported by the GEC but not produced by the group, for stages DNO (Operational Need Document) to REM-DDR, only 5 out of the 72 reports describe the estimation techniques used for their calculation. Nonetheless, in the reports subsequently issued by the GEC about the cost estimates contained in these reports, additional information was gathered so that 29 of the 72 reports do indeed describe this. In the viability document stage (DDV), practically 100% of estimates, which by this time are produced by the GEC, describe the techniques used.

Upon the basis of the information contained in the database, we ascertain that up until the REM stage, estimates are ROM estimates and the estimation methods used are for the most part analogy and market research. In 6% of cases, we see parametric instruments begin to be used at the DDV stage (such as True Planning) and we see bottom-up tools alongside expert opinion in 3% of cases. The above suggests that historical information across industry, the defence sector and the various defence users is asymmetric and that the will to process this information is not forthcoming. There is also no structured database allowing usable information to be obtained.

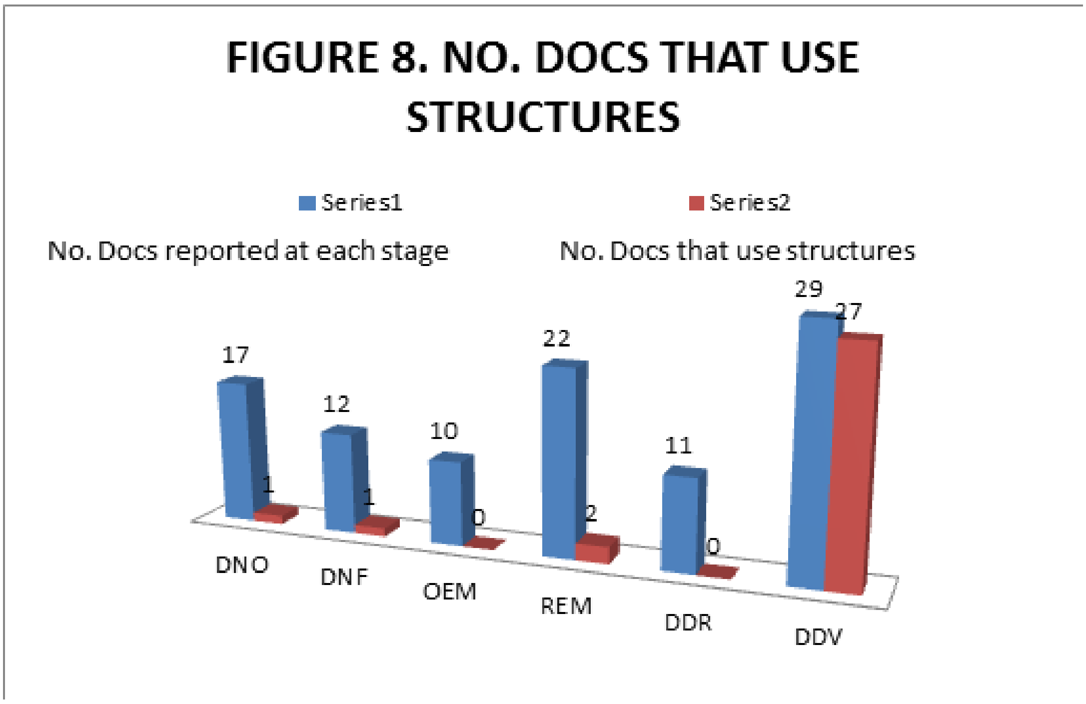


FIGURE 8. NO. DOCS THAT USE STRUCTURES

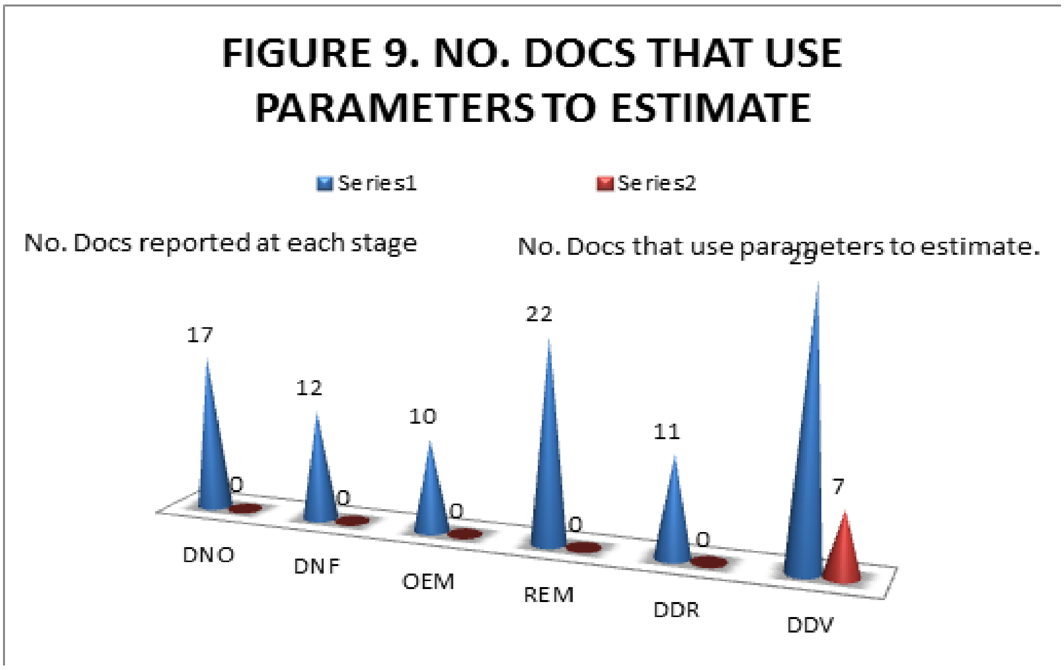


FIGURE 9. NO. DOCS THAT USE PARAMETERS TO ESTIMATE

The product structures, work and costs are obligatory from the Viability Document (DDV) stage and are recommended by the GEC in previous phases. In the corresponding graph, we can observe that these are starting to be used in the DDV stage but not in all cases. Moreover, the level of breakdown is poor. Upon analysis of how these structures are used and the breakdown level applied, we can deduce that the Ministry of Defence, in general, does not have enough knowledge at its disposal to fulfil the management process of each company. As a result, the adaptation of generic structures called for in the DDV, as per Instruction 67/2011, (generic WBS, PBS, CBS), to the specific case (the WBS, PBS, CBS of the contract), without accounting for industry, leads to the same structures and a poor level of breakdown. In general, these structures are not well-known and they are rarely understood. This is the case both in the Ministry of Defence as well as within industry.

In Figure 9, we observe that out of the 101 documents reported or drafted by the GEC, only seven use parameters to undertake estimate calculations, which suggests that historical information is only used to produce parameters that initially help with estimation calculations, reinforcing the symmetry and processing of information conclusion.

We can observe that the average time taken to develop a life cycle cost estimate in the DDV phase is forty-nine days, a very short period of time. This occurs for various reasons: the pressure brought to bear by armed forces, the lack of definition of the scope of the estimate based on the technical baseline, a non-consolidated estimate methodology, insufficient support afforded by industry and DDV reports different to weapon systems.

FIGURE 10. NO. DOCS WHERE SOME PART OF THE LCC HAS BEEN ESTIMATED

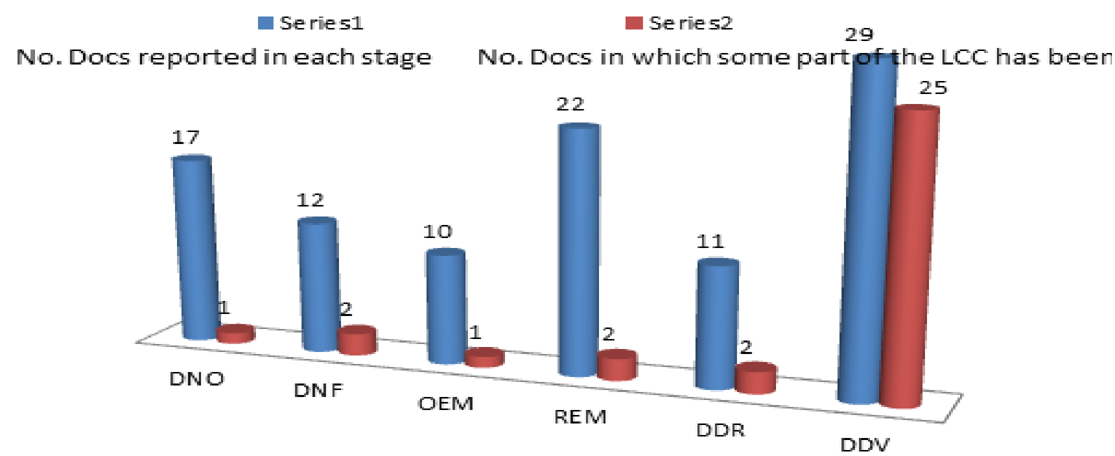
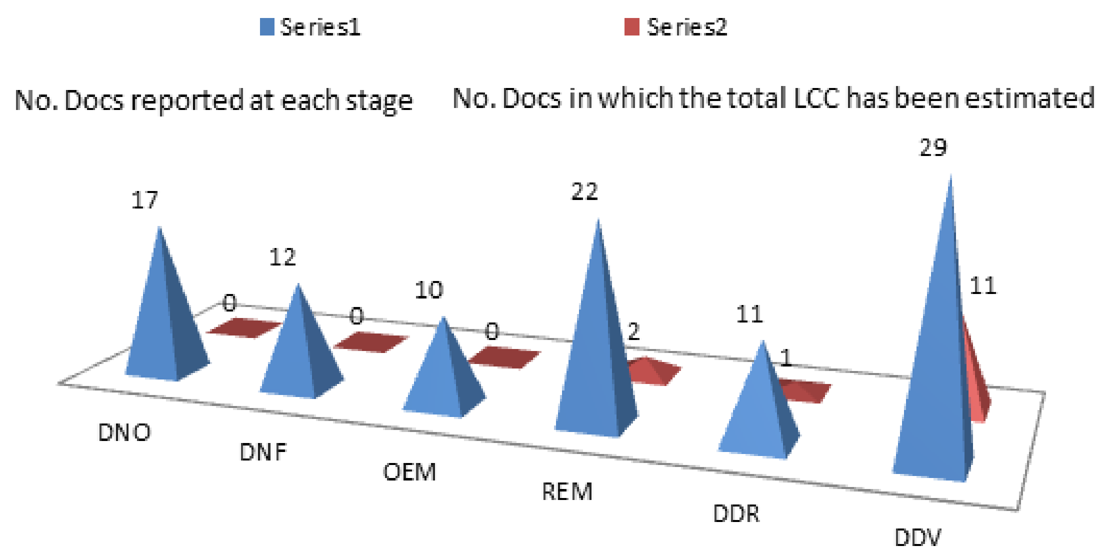


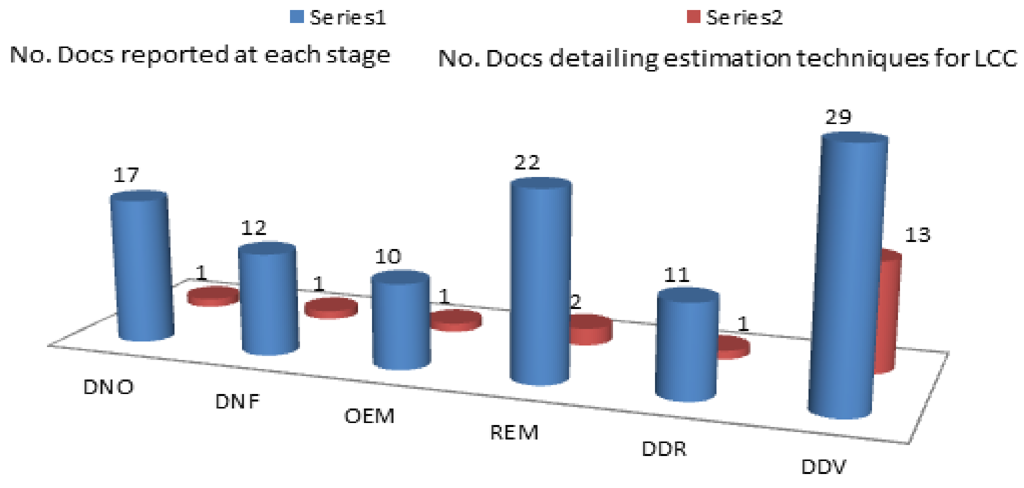
FIGURE 11. NO. DOCUMENTS IN WHICH THE TOTAL LCC HAS BEEN ESTIMATED



In Figures 10 and 11, we observe that the LCC estimates, whether partial or total, for different DDV phases, are practically non-existent despite the fact that Instruction 67/2011 stipulates that this is necessary from REM and DDR onwards. It is striking that the complete LCC estimate has only been calculated in 37.9% of cases (we shall call it complete although this is not the case since the estimates made do not include all logistical support and they exclude operating costs, internal defence costs and system withdrawal costs).

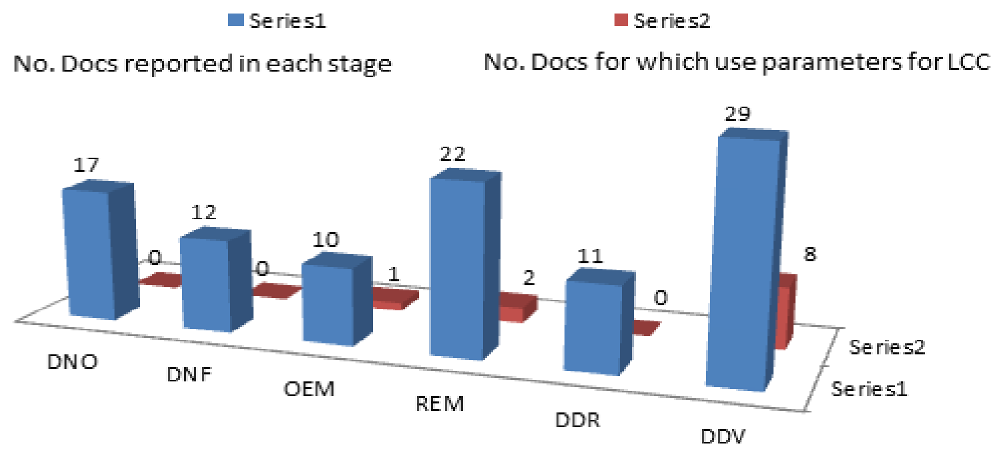
The analysis of information and the interviews conducted indicate that the authority entrusted with the costing until the REM stage does not have at its disposal the qualified personnel needed to pool cost expertise and, moreover, to comprehend the technical engineering parameters defined. (Personnel assigned to the General Staff who could use their resources to produce manual estimates of the ROM ilk).

FIGURE 12. NO. DOCS DETAILING COST ESTIMATION TECHNIQUES FOR THE CALCULATION OF LCC



In the DDV stage, practically 100% of *procurement* estimates produced detail the techniques used (Figure 7), but upon estimation of the rest of the life cycle this percentage drops to 44.8% (Figure 12). In relation to the use of parameters in estimations for the rest of the LCC, this is low as is the case in procurement (Figure 13).

FIGURE 13. NO. DOCS FOR WHICH USE PARAMETERS FOR LCC



Finally, on the basis of the content of the reports that fed into the database and the interviews conducted, we believe that the precision of the cost estimate calculations will depend on the information available, its accessibility and its processing, the rigorous application of an updated cost estimation methodology, the means used by the technical body, the time allocated, the use of lessons learnt and the management of pressure exerted by armed forces on working groups so that the technical bodies issue their reports as swiftly as possible. The lack of precision in life cycle cost estimates could lead to a decision being made that does not meet our needs as part of the best possible economic scenario.

CONCLUSIONS AND RECOMMENDATIONS

In general:

- We have verified that in Spain no information management system exists allowing us to obtain data for total or even partial life cycle costs for the weapon systems we possess. The reliability of the information stored in heterogeneous systems is poor, whilst the effort required to extract and process this information, which is to found in different media and different formats is considerable, since there are problems that arise from collecting the information and then processing and storing it. Moreover, the information acquired from companies is one-sided and provided in formats that are difficult to handle.
- Progress needs to be made as regards the symmetry of information with industry. Since 80% of defence invoicing in Spain is concentrated within a limited group of six companies,[39] in order to advance this symmetry, it would be advisable to integrate a defence programme management team, which would include cost estimation experts, within the programme management teams in the six main companies that it has contractual relations with. Moreover, the majority of the Spanish public companies who supply the defence ministry are overinflated. The salaries that they pay are higher than the rest of the sector and working conditions are favourable etc. The objective of their directors is to aim to avoid their cost being compared with an efficient cost and thus it is advisable to isolate the additional costs generated by such inefficiencies so that they are covered by the Ministry of Industry.

39 www.defensa.gob.es/politica/armamento_material/industriaespañoladedefensa. La Industria de defensa en España [The Defence Industry in Spain]. 2010, 2011, 2012 and 2013: EADS-CASA (AIRBUS), NAVANTIA, AIRBUS MILITARY, INDRA SISTEMAS, INDUSTRIA DE TURBOPROPULSORES and SANTA BÁRBARA SISTEMAS are responsible for between 78 and 81% of defence invoicing.

- The codification of information using breakdown structures and its appropriate storage and processing in centralised management systems are primordial elements in order to obtain historical comparable data and develop parameters and CERs, with which cost estimation models may be created.
- As part of the LCC estimation procedure it is necessary to define and develop a planning guidance paper for the calculation of LCC estimation along the lines of US CARD, UK MDAL or DADD, which would be applicable from the DDV stage onwards.
- Generic LCC templates, such as the one defined in UNE-EN-60300 or by Ortuzar,[40] need to be customised for each family of systems incorporating the parameters, CERs etc. obtained for each family of systems into the specific template, using the most appropriate estimation method to obtain this.
- A standing office for the management of programmes should be created. This would be manned by staff specialised in management and would channel know-how such as organisation, coordination between programmes, the media and lessons learnt as well as support programme leaders and develop and manage policies, procedures, templates and other documentation. In addition, it would be tasked with managing the integrated management teams of the six aforementioned companies. Spanish staff who occupy management positions in OCCAR/NATO should be required to undertake subsequent service in this office in Spain. Those staff in the armed forces who so desire should be encouraged to develop their career path within programme management. Their institutional training should be supported, as well as training in prestigious international centres, and they should acquire further qualifications outside of the Spanish Ministry of Defence.
- It would be advisable to implement the LCC analysis technique as part of procedures for the award of contracts.
- In particular, as part of our resourcing process:[41]

1. It would be advisable to regulate Life Cycle Management and complete the rough estimate procedure for LCC contained within Instruction 67/2011, using the comparison made with OCCAR and NATO as a reference point.

40 ORTUZAR, R. University of Granada. Una propuesta metodológica para la estimación del coste del ciclo de vida en inversiones militares [A methodological Proposal for Estimating the Life Cycle Cost of Military Investment]. Granada. 2008, pp. 283-405.

41 The majority of the conclusions and recommendations reached here coincide with those obtained in the report produced by the NATO working group SAS-054.

2. On the basis of the database of cost estimate reports and the experience gained over these four years, it would be advisable to:

- Require the involvement of the technical body that would have the LCC estimation competence for each and every stage of the procurement process until the resource was contracted and compliance with the recommendations it sets out in its reports;
- Promote the formulation of factors, coefficients, parameters and CERs by all those involved in the life cycle;
- Regulate the minimum times, depending on the type of programme, available to experts at each stage for the purposes of estimation with a certain number of guarantees;
- Limit the urgency procedure in the processing of documents that result from each phase of the life cycle, since it causes cost estimates to be done using rough order of magnitude (ROM) or not at all;
- Draft a publication that serves as a set of guidelines for the production of the PBS, the WBS and the CBS;
- The calculations, formats, techniques and tools used in estimates should be accessible and accompany the documents drafted at each stage.
- The working groups established for the DDV must be flexible, non-bureaucratic and controlled by the standing office for the management of programmes or a professional specialist. The technical criteria of the members of a group must prevail over the rank they hold in this group, thereby disassociating these experts from any hierarchical relationship with the group and its parent body.
- The functional structure of the organisation should evolve to be geared towards projects.

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