GETTING "REAL" DATA FOR LIFE-CYCLE COSTING

Marco R. Fiorello

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The Rand Corporation

ABSTRACT

The process of identifying, collecting and utilizing historical data for estimating the life-cycle costs of a weapon system is discussed. The focus is on data-related problems which currently constrain the accuracy and reliability of life-cycle cost estimates. Particular attention is given to the costs of ownership. A case example is provided to illustrate the estimation of life-cycle costs using macro cost data for an operational weapon system. Some of the uncertainties inherent in the data collection and analysis processes are also discussed. Currently approximation of aircraft weapon system life-cycle costs is possible, but the process is not straightforward. Major difficulties include using multiple data system products, different data nomenclatures, and insufficient data quality and quantity. Specific recommendations include implementing operationally consistent life-cycle cost estimation procedures, improving weapon system cost visibility in cost data systems, establishing and maintaining a nomenclature directory, implementing better cost allocation rules, anticipation of life-cycle cost decision data requirements, and constructing and maintaining a special data base for life-cycle cost analysis and methodology development.

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INTRODUCTION

This discussion is about the process of identifying, collecting and utilizing historical data for estimating the life-cycle costs (LCCs) of weapon systems.

Our focus is on the data aspects of life-cycle costing and we are interested in recommending remedies for those data related problems which constrain the reliability and accuracy of LCC estimation. Within the context of a case example we will note some typical problems encountered in making LCC estimates. We will also provide an assessment of how well those data systems we used support LCC efforts, and recommend changes in the current data systems to improve LCC estimating for both operational and proposed new weapon systems.

Weapon System Life-Cycle Stages and Costs

Our usage of LCCs is in basic conformity with the definition used by the DOD; namely, that LCCs are the total variable costs associated with the development, acquisition, and ownership of a system. We have illustrated these basic cost categories in Fig. 1. We note that this concept is appropriate for whole systems, their subsystems, and even components.

There are many reasons why we should estimate LCCs. Systematic comparison of weapon system acquisition and utilization alternatives eventually leads one to focus on total or life-cycle resource consumptions and capabilities of the candidate options. The underlying conviction is that consideration of total resource and capability profiles allows a more appropriate "systems" evaluation of candidate weapons, or of management decisions for individual weapon utilization. Life-cycle costing facilitates an acquisition choice, to be made among competing candidate weapon systems on the basis of cost.

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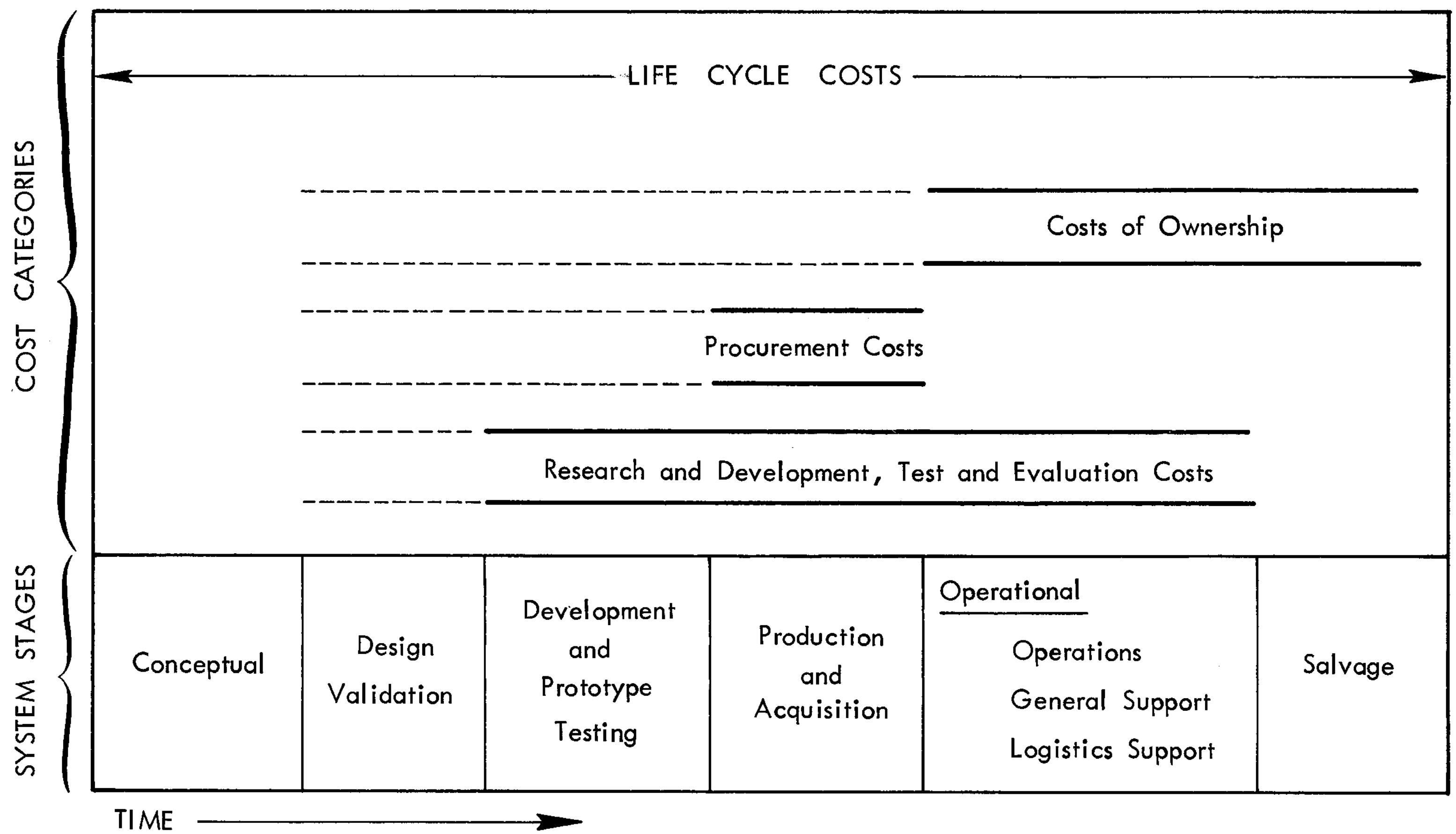

Fig. 1 — Weapon system life-cycle stages and costs

Also, LCCs can be used by logistics managers to assess system resource requirements and, most importantly, to identify those items or subsystems that will consume a disproportionate amount of resources, so that remedial actions can be planned and implemented in an expeditious manner. With the implementation of LCC considerations, we are beginning to place greater emphasis on the costs associated with operations, maintenance and ground support. In the aggregate, operations, maintenance and support costs now claim over one-half of the DOD budget, and if left unchecked, will seriously compromise the resource availability for future modernization of the force.

As we move forward in time, the future or not yet incurred component of a given weapon's LCC gets smaller, and the available data useful for cost analysis grows both in quantity and quality. In general, we can identify different data requirements and problems with different stages. To place this notion in perspective, we can say that there are two general classes of decisions which utilize LCC consideration, which in turn specify the nature of the data required. In our first class there are those decisions which occur during R&D and acquisition, such as cost comparisons among existing and proposed weapon systems. An example is the comparative fly-off (and related cost and performance analysis) between A-7D and the A-10. Another important set of decisions which fall into this class are weapon system program approval, design validation and production go-ahead, e.g., the DSARC process. These decisions place a strong emphasis on establishing a system design and acquisition program that meets many criteria, including an acceptable (and hopefully low) LCC. Many of these early decisions, particularly those made in the approval process, stress the relationship between design characteristics and costs of ownership, and there is a strong requirement for parametric or aggregate-type data. We will discuss these costs further in our case study.

The second class of decisions which utilize LCC estimations takes place during the post-production stages. An exemplary decision is the evaluation of product improvement and support cost tradeoffs. An example is the evaluation of the Radar Agile Retrofit, Electronically Scanned Antenna that has been proposed as a replacement for the existing antenna on the F-111D. A common theme of these kinds of decisions is the improvement of the cost/capability characteristics of a given design. For this class of decisions, we need cost data at a detailed level.

It is important to recognize that while the decisions on selecting, improving and utilizing candidate weapon systems may occur at different times, there is an important relationship between those decisions (e.g., manning, deployment, mobility, mission, etc.) made early in the weapon's life and subsequent costs incurred by the weapon in the later stages. It has been observed that of those decisions which drive or influence costs of ownership about 70 percent are made in the early stages of acquisition. Proper LCC considerations for these decisions should make their future cost consequences explicit. We have roughly indicated the periods during which cost influencing decisions are made by the dotted lines in Fig. 1. We find that this notion is particularly important for costs of ownership as these costs in general make up over 50 percent of the LCC of aircraft weapon systems. Further, the logistics support costs component which makes up about 75 percent of the costs of ownership is particularly sensitive to early policy decisions. These costs will be the primary area of interest in our case study.

Our focus in this study is on the process of estimating LCCs based on historical data. This task during the weapon system's operational stage however awkward is less difficult than during the earlier stages in the weapon's life cycle, when there is no historical operational data available. Ultimately, we need to be able to estimate LCCs in all the stages of a weapon's life-cycle, and in order to do this we require several estimating techniques as well as the necessary data. Specifically, we need techniques to estimate LCCs in the conceptual stage, during the testing stages, and later on during the operational stage.

We have defined weapon system LCCs as the sum of the costs of RDT&E, acquisition and ownership. Of these categories, the greatest lack of estimating techniques during the pre-production stages is for ownership costs. Limiting our discussion to the costs of ownership, there are basically three cost estimating techniques that can be used: parametric, accounting or direct enumeration, and simulation.* To date, the dominant method used to estimate the costs of ownerships or specific components

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*For the purpose of this discussion, we do not distinguish between the data requirements for the accounting and simulation approaches.

thereof, such as logistics support costs (LSC), is the accounting technique. This approach defines costs as a function of certain logistics variables,* design characteristics and development requirements. We in fact, utilize the basic accounting approach to define the LCC categories in our case example. To the extent that these logistics and other variables can be estimated, then some approximation of the cost of ownership, or components thereof, can be made. The accounting approach can be used in all stages of a weapon system's life-cycle when there is sufficient data or expertise to estimate average values for the logistics variables. The most straightforward application of the accounting approach is in the operational stage where there is "actual" data for the production configuration system. In the earlier stages one has to rely on either test data, usually on prototype configurations, and/or engineering estimates based on analogous equipment histories or theoretical computations.

For any of these estimating techniques it is necessary to define a set of life-cycle cost categories. In Fig. 2, we provide a list of "accounting" categories which we use in our case study to define LCCs. Those items noted by an asterisk were not estimated either because the data were not conveniently available, as in the case of attrition, or because the costs do not exist as in the case for salvage. It is important to note that this definition of weapon system LCCs is intended to capture only the variable costs associated with the weapon system. We make no attempt to reflect any of the "fixed" costs which are necessary for the management of the organization (e.g., HQ/USAF) which uses the system, but which are not incurred by or for the weapon. This stance reflects a basic theme of life-cycle costing--the determination of total variable costs that are encountered only because the weapon is being built and operated.

CASE EXAMPLE

Getting "real" data can mean getting data for design selection and improvement or getting data for the purpose of developing a LCC methodology We will briefly reflect on both aspects of this overall problem in the

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*Mean Time Between Repair (MTBR), Maintenance Man Hours (MMH/FH), Mean Time Between Failure (MTBF), etc.

WEAPON SYSTEM LIFE-CYCLE COST CATEGORIES

RDT&E

1. RESEARCH AND DEVELOPMENT
2. TEST AND EVALUATION (RDT&E)

PROCUREMENT

3. AIRCRAFT (FLY AWAY COST)
4. SUPPORT EQUIPMENT
5. TRAINING EQUIPMENT
6. TECHNICAL MANUALS

* 7. SPO-PERSONNEL
* 8. TEST AND EVALUATION (IOT&E)

OWNERSHIP

9. SPARES: INITIAL, REPLENISHMENT, ENGINES, WRM (HDWR)
10. MAINTENANCE: ON-EQUIPMENT / OFF-EQUIPMENT { - LABOR AND EXPENSE MATERIAL; - AIRCRAFT, TRAINING, SPS EQUIPMENT; - BASE, DEPOT, CONTRACT }
11. MANAGEMENT PERSONNEL: SYSTEM/ITEM MANAGERS
12. TRAINING: TECH TRAINING
13. OPERATIONS: CREW, CMD PERS - { MILITARY AND CIVILIAN; - BASE ONLY }
14. BASE OPERATING SUPPORT
15. FUEL
16. MODIFICATIONS (HDWR)

* 17. TESTING AND EVALUATION (OT&E)
18. ITEM TRANSPORTATION (2nd DSTNTN)
19. MUNITIONS AND MISSILES - TRAINING
* 20. PERSONNEL PCS
* 21. ATTRITION
* 22. NEW FACILITIES

SALVAGE AND DISPOSAL

* 23. DISPOSAL
* 24. MODIFICATIONS

Figure 2

context of a case example when we estimate the LCCs of an operational weapon system using macro costs, that is, highly aggregative costs.

Our choice to utilize macro costs derives in part from our interest in utilizing aggregate data for the development of parametric LCC methodologies. Also, for the purposes of this discussion such costs are convenient to use. We have deliberately selected an operational weapon system so as to provide insight into the adequacy of historical data products for estimating LCCs. Thus in terms of getting current and future data, we explicitly confine our choices to existing historical data products. We do not consider the option of constructing totally new data systems--in general such options are prohibitively expensive in both the time and resources required. Lastly, selecting an operational weapon system is very pragmatic. It is easier to determine the prospective life-cycle costs of an operational weapon system than one in the design stage, in that any problems we encounter in making a cost estimate should be less difficult to deal with when there are historical data available in comparison to where there are none.

In Fig. 3, we provide a life-cycle cost estimate for our case example. The costs are in terms of unit averages in 1973 dollars and are grouped by acquisition and ownership subtotals. The costs of acquisition reflect the expenditures of RDT&E and procurement, and are estimated to be $5.2 million per unit which incorporates a 5 percent rate of discount and inflation adjustment for the pre-1973 expenses. The costs of ownership reflect a steady state linear projection based on FY 1973 costs of operation and support for a hypothetic 15 years of operation. The average per unit cost of ownership is estimated to be $6.8 million per unit with an annual 5 percent rate of discount applied to future costs.*

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*Obviously, such a projection is highly simplified. We are sensitive to the fact that the exercise of projecting costs for a relatively new weapon is fraught with discretionary inputs which are often surrounded by conjecture. For example, different total costs of ownership are derivable depending upon the values used for the number of operational years, the discount coefficient applied to future costs, transient fleet buildup time, fleet size and utilization, mission and support structure, and so on. Moreover, in this example, the R&D costs included here are substantially lower than one might usually expect for new weapon systems.

HYPOTHETIC 15 YEAR LIFE-CYCLE COST IN 1973 DOLLARS

- ACQUISITION[1]

► AIRFRAME	38%	$ 5.2 MILLION/UNIT
► ENGINE	13%	
► PECULIAR EQUIPMENT AND SPARES	20%	
► ELECTRONICS	13%	
► OTHER	16%	

- OWNERSHIP[2]

► OPERATIONS AND MAINTENANCE	48%	$6.8 MILLION/UNIT
► INVESTMENT	15%	
► DEPOT	16%	
► BASE OPERATING SUPPORT	10%	
► FUEL	4%	
► TRAINING	7%	

[1] ADJUSTED FOR INFLATION AND 5% DISCOUNT RATE.

[2] ADJUSTED FOR 5% DISCOUNT RATE.

FIGURE 3

Based on this admittedly simple, steady-state linear projection, we see that at the 5 percent rate of discount over 50 percent of these life-cycle costs will be incurred during ownership. In fact, the average unit cost of ownership is some 30 percent greater than the average unit cost of acquisition. Also, if we include all the peculiar equipment and initial spares costs as part of the ownership cost, which we feel is appropriate, we would decrease the costs of acquisition by some 20 percent and increase the costs of ownership by about 15 percent.

Before leaving this schedule of costs, it is important to note that over 75 percent of the costs of ownership, reflected by operations and maintenance, investment and depot expenditures, are heavily influenced by policy decisions made early in the acquisition stage. These relationships are central to the underlying theme of LCC management, namely, to incorporate in these important decisions an awareness of their contribution to the weapon's LCCs.

In the process of preparing our LCC estimate, we encountered several basic constraints, and indicate two major ones in Fig. 4.

CONSTRAINTS ON LCC ESTIMATING

- IMMATURE METHODOLOGY
- DATA LIMITATIONS
  - INCOMPLETE
  - MULTIPLE NOMENCLATURE
  - POOR QUALITY
  - APPROXIMATE VALUES

Figure 4

The first is that the existing methodology for estimating weapon system LCCs is immature. Most current models deal with only a portion of the total LCCs, they are defined largely in terms of logistics variables, and are of limited use when there is little or no historical data available. Another major constraint and the one we will focus on in this discussion has to do with data limitations. There are problems with poor quality and insufficient data, especially during testing. There is the difficulty of dealing with multiple nomenclatures used in different data systems. For example, an item can be procured under an AN/XXX designation, maintained at the base by work unit codes (WUC), managed in the supply system by federal stock numbers (FSN), maintained at the depot also by FSNs, and tracked by the manufacturer by his own part identification number. With regard to cost data, we can in general only get average and total costs and often they are aggregate values. It is difficult or impossible to identify the true variable or marginal costs at the desired levels of detail.

LCC ESTIMATING PROBLEMS

In this section we will briefly review which data sources we used, how the data were utilized, and what approximations were necessary in order to make the LCC estimate.

Acquisition Costs

Our first category of costs are for acquisition which includes all the expenditures incurred prior to and during production. For the purposes of this analysis we found the Systems Acquisition Report (SAR) from the system program office (SPO) to be sufficient. The only exception was that we prefer the investment spares cost breakout provided by the Air Force Logistics Command (AFLC) budget office. Using the AFLC data, we were able to distinguish engine and non-engine spares expenditures. As we wanted to determine the total fleet expenditures by major categories, the data from the SAR budget summary proved to be useful in its standard form. We note, however, that for those decisions which require more detailed information and analyses, the SAR data would in general be too aggregate and other more appropriate data sources necessarily utilized (e.g., contract information reports).

In this study the acquisition costs were virtually all historical costs due to the operational status of the weapon system. Consequently these aggregate values are fairly certain.

Costs of Ownership

By far, estimating the costs of ownership proved to be the most difficult part of this life-cycle costing exercise. We employed deliberate simplifications in our analysis by first estimating the costs of ownership based on historical data for the current year of operation, and then projected the future costs of ownership based on that sample point.* We assume that the unit average costs derived from our FY 1973 sample are representative of the future costs of ownership, and that a reasonable period of ownership is 15 years. Obviously such a projection is highly simplified, but it does serve the purpose of illustrating a total cost of ownership in terms of unit average costs for our case example.

In each of the ownership categories, indicated in Fig. 5, we experienced data limitation problems of varying difficulty. We will briefly review how we dealt with some of the more severe data analysis problems.

Costs of Ownership. Estimating the operating, logistics and direct support costs for our weapon system proved to be somewhat cumbersome. We found it necessary to utilize the formal and informal data products from seven different data systems and offices. The costs of ownership breakout by the different LCC categories is shown in Fig. 5. These costs are for FY 1973. That is, they reflect one year's cost of ownership for our weapon system.

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*If our aim was to analyze the process of projecting future costs of ownership, then we should necessarily deal explicitly with such variables as: the mean length of the ownership stage, the sensitivity of the projection to different discount factors, transient fleet size and buildup time, steady state characteristics, the proportion of the fleet with different missions, deployment and utilization scenarios, base and depot maintenance volumes, and so on.

FLEET COSTS OF OWNERSHIP FOR FY 1973

COST CATEGORY	DATA SYSTEM	ORGANIZATION	ESTIMATED ANNUAL COST FOR FY 1973 (Millions)	PROBLEMS
BASE--OPERATIONS AND MAINTENANCE	RESOURCE MANAGEMENT SYSTEM	BASE BUDGET OFFICE	$ 70.7	IDENTIFICATION; EXTRAPOLATION
DEPOT - MAINTENANCE	DPEM REPORT	AFLC	22.2	PRORATION
- SYSTEM MGRs	RESOURCE CONTROL SYSTEM	PRIME ALC	2.6	AVERAGING
SPARES				
- REPLENISHMENT	BUDGET DATA	AFLC	16.0	PROJECTED, NOT ACTUAL
- WAR READINESS MATERIAL			2.5	
MOD. HARDWARE (IV)	BUDGET DATA	SYSTEM PROGRAM OFFICE	1.6	BUDGETED TOTALS
(V)			3.3	
BASE OPERATING SUPPORT (VARIABLE)	RESOURCE MANAGEMENT SYSTEM	BASE BUDGET OFFICE	15.5	FIXED BOS ESTIMATION
TRAINING	BUDGET DATA	--	7.5	COST FACTOR
FUEL	OPERATIONS DATA AND COST FACTOR	COMMAND HEADQUARTERS BUDGET OFFICE	6.1	COST FACTOR
MUNITIONS	BUDGET DATA	--	3.3	COST FACTOR
TOTAL (WITHOUT INVESTMENT SPARES)			$ 151.3	APPROXIMATION

Figure 5

Since the weapon system is located at several bases and is under different commands, it was most practical to estimate the base operation and maintenance (O&M) costs for a sample base, and then extrapolate to the fleet. The best data source, at the time of this study, for estimating O&M resources available at the base level is the Resources Management System (RMS).

There are some difficulties with explicitly identifying weapon system costs in the RMS reports. That limitation plus the linear extrapolation employed introduces some uncertainty into our $70.7 million base O&M fleet estimate for FY 1973. Estimating the depot level maintenance costs also entailed some approximations. The most complete data source, at the time of this study, for depot maintenance costs, are the depot purchased equipment maintenance (DPEM) reports. In order to use the DPEM data, it was necessary to prorate the common item costs (those costs not explicitly identified to a weapon system). Of the $22.2 million estimate for our weapon system, we were able to identify 66 percent explicitly and had to estimate the remaining 34 percent by proration of "common-pot" costs. The system/item (SM/IM) manager costs were determined on the basis of an average salary factor and an estimate of the "net" SM/IM resources associated with the weapon item management. The replenishment spares cost of $16 million is a budget estimate for FY 1973, and does not necessarily reflect what was actually expended for the weapon system that year. The War Readiness Material (WRM) estimate is an artificial annual average and is based on an assumed 15 year life over which the WRM buys are averaged. The variable base operating support (BOS) expenditure estimate was arrived at by approximating the cost of a "typical" base opening support package and subtracting that cost from the total BOS at a base where the weapon was located. That single base estimate was then extrapolated to the $15.5 million estimate for the fleet.

Overall we feel that the $151.3 million estimate for FY 1973 is reasonable, but it is the result of many approximations. We estimate that we can only explicitly identify about 70 percent of these costs to our weapon system with the remaining 30 percent arrived at by proration. We note that the investment spares were not included in this FY 1973 total.

STUDY FINDINGS AND RECOMMENDATIONS

We found that a precise "actual" LCC for an operational aircraft weapon system cannot be determined from historical data. However, it is possible to use historical data to approximate the LCCs for an operational weapon system, but it is not straightforward. Some of the major problems encountered include:

Many Data System Products Required. There is no one data system in the Air Force (or for that matter in any of the services) which provides weapon system life-cycle costs. It was necessary to utilize the data products from seven data systems and offices in this study. The Air Force does not have easily accessible LCC data. This is principally because the data systems are generally designed for purposes other than cost accounting.

Different Nomenclature. Specific data problems include differences in nomenclature for the same item, poor data quality, too much aggregation without detail breakouts, omitted data, and the use of standards for predicting variable workloads.

Data Quality and Completeness is a Problem. Given the existing state of historical data products, a major part of any LCC exercise using historical data will be concerned with data collection, analysis and consolidation.

About 70 percent of Ownership Costs Are Known Explicitly. In order to estimate the costs of ownership it was necessary to allocate and extrapolate various costs. Consequently, there are costs used in the LCC estimate about which there is some uncertainty. For example, the depot level maintenance costs that are known with reasonable certainty account for approximately 66 percent of the depot maintenance total. We know with reasonable certainty only 5 percent of the avionics depot maintenance costs.

We also found that it is important to consistently distinguish between resources available and resources utilized in weapon system cost analysis.

In order to advance the current state-of-the-art of LCC estimating, at least the following improvements must be accomplished.

Operational Consistency of LCC Procedures is Needed. In order for the LCC methodology to mature and be used, we need to have greater consensus within the services and the DOD as to what weapon system life-cycle costs consist of, how the costs are defined, and how they are to be computed.

Identify Costs by Weapon System. A fundamental problem with historical data products is that the data systems generally do not provide explicit weapon system visibility. For example, the base-level resource management system (RMS) and the depot-purchased equipment maintenance (DPEM) would be greatly improved if they simply collected weapon system identifiers.

We note the Air Force is currently implementing several new data systems (IROS, MILAPS, PROJECT MAX) which when completed will provide increased weapon system cost visibility.

Better Cost Allocation Rules Are Needed. For those items that are common to several weapon (sub) systems, there is a need for new cost allocation rules for use in estimating weapon system support costs.

Nomenclature Directory Needed. Greater compatibility is needed among the different nomenclature across current data systems. A directory which allows consistent tracking of item costs across supply, base and depot maintenance systems nomenclature would enhance the usefulness of existing data system products for life-cycle cost analysis.

Project LCC Decision Requirements. We need to anticipate the LCC decisions that will be made so as to establish the data requirements early in the weapon system's life.

Construct and Maintain LCC Data Base. As a basic building block toward the development of a family of LCC estimating techniques that can be used at all stages of a weapon's life, we need to construct and maintain a data base on the RDT&E, testing, acquisition and ownership costs for new weapon systems. This data base will provide a basis for validation of existing and new LCC methodologies as well.

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