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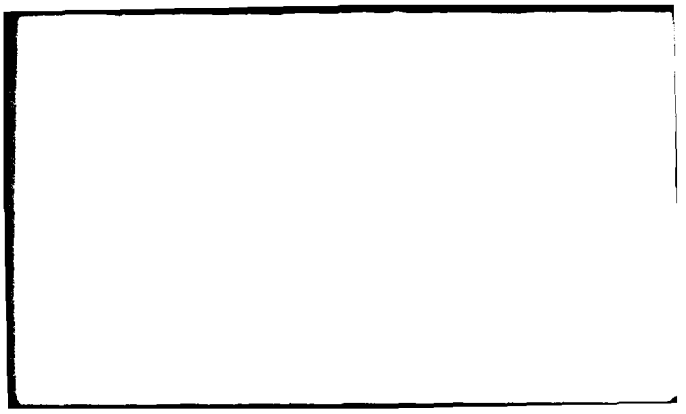

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Applied Research in Statistics - Mathematics - Operations Research

VALIDATION OF THE COST METHODOLOGIES WITHIN THE WEAPON SYSTEMS SUPPORT COST SYSTEM (D160) OF THE AIR FORCE VAMOSC SYSTEM

by

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TECHNICAL REPORT NO. 115-6

September 1982

Prepared under Air Force Contract No. F33600-80-C-0554
(Presented at the 17th Annual DOD Cost Analysis Symposium)

Introduction

In 1975 Department of Defense Management by Objective MBO 9-2 directed each service to provide the means for identifying and providing visibility of the operating and support (O&S) costs of its major weapons systems. The vehicle for accomplishing this objective is referred to as the Visibility and Management of Operating and Support Costs (VAMOSC) program. Through this program, the Air Force developed its VAMOSC system, a comprehensive management information system.

The Air Force VAMOSC system is designed to collect and display O&S costs at MDS (Mission-Design-Series) and component levels of aircraft and also at TMS (Type-Model-Series) and component levels of ground communications-electronics equipment. It consists of three subsystems:

(1) WSSC (D160), which deals with aircraft,

(2) C-E (D160A), which deals with ground communications-electronics equipment,

and (3) CSCS (D160B), which deals with subsystems and components.

Because the data provided by VAMOSC will be used to support decisions involving large financial commitments, the accuracy of this data and the validity of the VAMOSC logic are of prime importance. Desmatics, Inc., under Air Force Contract No. F33600-80-C-0554, is currently engaged in a technical effort to validate the WSSC subsystem of VAMOSC. This paper addresses that validation effort. Although the paper focuses on WSSC, the general concepts are also applicable to the other two VAMOSC subsystems. Because the validation effort is ongoing, any conclusions in this paper must be regarded as preliminary.

The WSSC Subsystem

WSSC produces two annual reports which list O&S costs for each MDS. These reports, which differ primarily in format, are termed the "DOD/CAIG report" and the "USAF detail report." The former report is designed to satisfy the requirements specified by the DOD Cost Analysis Improvement Group (CAIG)[1]. The latter report provides additional details that are useful to various users within the Air Force. Other special interrogation reports are available by MDS, command, and base.

A major problem faced by WSSC is that most available cost data is not identified directly to an MDS. Most of the data sources used by WSSC are functional data systems that do not relate consumption of resources to weapons systems. Of course, in the case of indirect costs, such as installation support costs, there is no way to identify them by MDS.

Because of the lack of a one-to-one relationship between costs and MDS, much of the cost data must be allocated. It is necessary for WSSC to allocate not only the typical "overhead" types of costs, but also direct costs which the input data systems do not identify by MDS. WSSC uses a series of algorithms that relate functional costs to measures of activity in order to allocate the costs to the weapons systems.

In WSSC four general quantities are used to distribute costs: (a) personnel strengths; (b) the inventory of a particular MDS as measured by possessed hours[2]; (c) the number of flying hours for a particular MDS; and

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[1] "Aircraft Operating and Support Cost Development Guide," Cost Analysis Improvement Group, Office of the Secretary of Defense, 1980.

[2] An aircraft may be "possessed" by different commands or bases during the year. Thus, the 8760 hours in the year are used to determine the inventory of an MDS for each command and base during the year.

(d) reported maintenance direct labor hours. In addition, estimated cost factors (such as annual medical care costs per person) are used in cost allocation.

Validation of WSSC: An Overview

The reports produced by WSSC serve as an important management tool for providing visibility of weapons systems operating and support costs. The extent to which WSSC cost outputs are satisfactory for their intended purpose depends upon two components: (1) the soundness of system design and (2) the accuracy of input data. The accuracy of VAMOSC's output and the validity of its logic are paramount to the utility of the system to the user. For this reason, the Air Force Office of VAMOSC is relying on independent contractors to validate the VAMOSC logic and data sources.

The overall validation of the WSSC system may be viewed as the three-phase process indicated in Figure 1:

(1) Phase I focuses on the allocation algorithms and data selection logic comprising WSSC,

(2) Phase II addresses the accuracy of the WSSC inputs relative to the books of original entry,

and (3) Phase III examines the accuracy of the books of original entry relative to what actually occurred.

Phase I validation, which addresses the system design, is Desmatics' task under its Air Force contract. Actually, Phase I validation concerns itself with two types of validation: internal validation and external validation. Often internal validation is referred to as "verification," i.e., verifying that the system performs as it was designed. Thus, internal validation primarily involves debugging of the associated computer programs. Similarly, external validation is often referred to simply as "validation," and addresses whether the system is designed as it should be. External

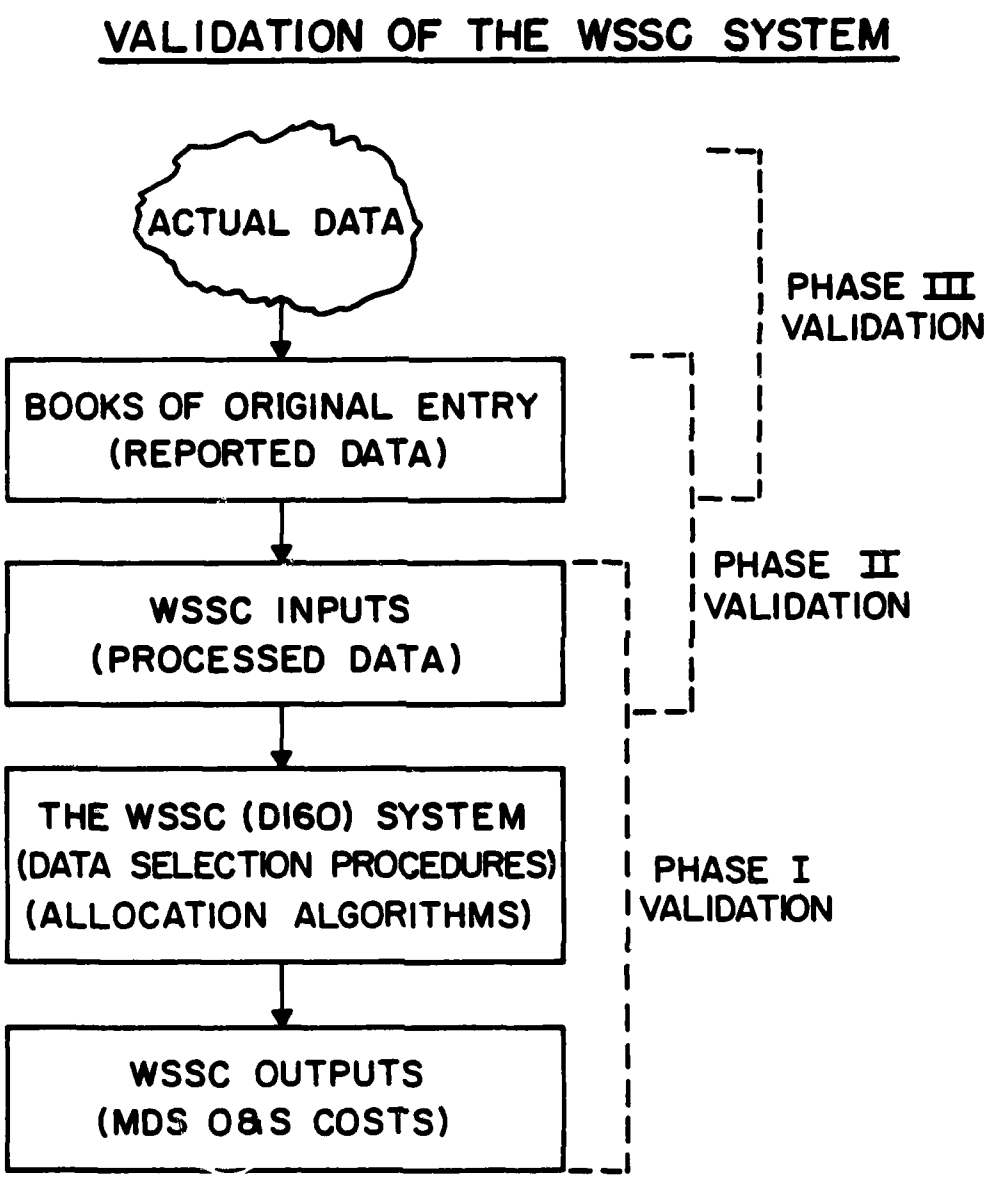


Figure 1: The Three-Phase Validation Process

validation critically examines system logic, input data selection procedures, and output data.

For the most part, internal validation has been accomplished by the Office of VAMOSC in its production test of WSSC. Thus, Desmatics is primarily concerned with external validation. It should be stressed, however, that the overall validation task consists of a large degree of interaction and cooperation between Desmatics and the Office of VAMOSC. This synergistic relationship has had a positive impact on the WSSC system.

Indirect Validation

The best method of validation is, of course, a direct one--that is, one in which the WSSC cost allocations are compared with the true costs. Unfortunately, there is no way to validate the WSSC system directly, because the true costs are unknown. Thus, any validation must be of an indirect nature.

Indirect validation approaches may be classified as dealing with two major types of validity: (1) face validity and (2) mathematical validity. The former is concerned with qualitative assessment, while the latter deals with quantitative assessment. Our validation of WSSC addresses both of these validity components.

Face validity, in essence, is the examination of the WSSC system on a subjective, common-sense basis. In conducting this qualitative assessment of WSSC, Desmatics focused on whether the algorithms provide equitable allocations, so that no group of MDS's bears an inordinate amount of the allocated costs. Somewhat related was consideration of the allocation framework to determine whether alternative allocation methods might provide better results.

A major check on face validity is to determine whether potential users have any suggestions for modifications to the system. Because such suggestions often result in major improvements, the Office of VAMOSC has worked closely with potential users of WSSC during its development.

In parallel with qualitative face validity, Desmatics is also examining the WSSC system from a quantitative standpoint. This involves evaluation of the mathematical framework of the system (including assessment of the allocation logic), consideration of algorithm sensitivity, and examination of pos-

sible data discrepancies. The following sections provide a brief discussion of some aspects of the ongoing quantitative evaluation.

Sensitivity Analysis

A number of FY81 costs within WSSC were allocated on the basis of flying hours (FH) and possessed hours (PH), combined into an allocation ratio. However, just how FH and PH should be weighted within that ratio is an open question. To determine the impact the weighting has on the resulting cost allocations, a sensitivity analysis may be conducted within each cost category which uses flying hours and possessed hours as allocation variables.

Sensitivity of the WSSC results may be examined at different levels of allocation. For example, WSSC not only allocates costs to the MDS level, but also to the command-base-MDS level. Of course, the amount allocated to a particular MDS is equal to the sum of the amounts allocated to all command-base-MDS combinations involving that particular MDS.

In the cases involving allocation ratios based on FH and PH, sensitivity can be measured by examining the differences in allocated costs that result from using only flying hours as opposed to using only possessed hours. There are three measures that may prove useful in assessing the sensitivity of the cost allocations to the use of flying hours, possessed hours, or a mixture of both. One is an absolute measure; the other two are relative measures.

Consider a specific O&S cost category for which costs are allocated by means of an allocation ratio involving flying hours (FH) and possessed hours (PH). Regardless of the level of allocation, we can define

$$\text{Absolute Sensitivity} = \Delta\$ = \$(\text{FH only}) - \$(\text{PH only}). \quad (1)$$

That is, we are measuring the change in dollar amount (either positive or

negative) that would result from using only flying hours as an allocation basis instead of using only possessed hours. If, for example, we are considering the command-base-MDS level allocation, we would have a set of 435 sensitivity observations since there is a total of 435 command-base-MDS combinations.

In addition to (1), two relative sensitivity measures provide useful information. These are:

Relative Sensitivity #1 = Δ$/Total Cost Category $

and

Relative Sensitivity #2 = Δ$/Total O&S $

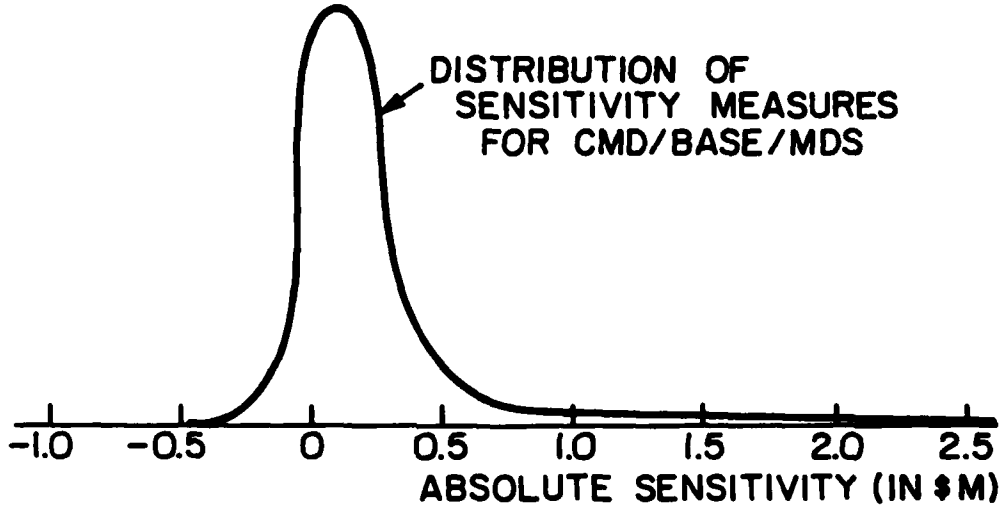
Measure #1 yields an indication of sensitivity of the measures for one command-base-MDS observation relative to the total cost category dollars to be allocated, while measure #2 provides a similar indication relative to the total O&S amount for all command-base-MDS combinations.

As an example, Figure 2 presents, for the general depot support cost category, the distribution of the observed absolute sensitivity measures for each of the 435 command-base-MDS combinations. As can be seen, the distribution is highly skewed to the right, which indicates that a number of command-base-MDS combinations will be allocated a relatively large additional amount of general depot support costs as weighting in the allocation ratio shifts from possessed hours to flying hours.

The maximum observed value in this set of data is $2.56M. Relative to the total general depot costs of $246.1M and to total O&S costs of $11,048.8M, this is 1.04% and 0.02%, respectively.

Results such as these, which provide absolute and relative differences in cost allocations, may be used in conjunction with the results from other

SENSITIVITY (GENERAL DEPOT SUPPORT)



MAXIMUM SENSITIVITY MEASURE:

$2.56M (ABSOLUTE)

1.04% (RELATIVE #1)

0.02% (RELATIVE #2)

Figure 2: Distribution of Absolute Sensitivity Measures for General Depot Support Costs

cost categories to examine the overall sensitivity of cost allocations to the use of flying hours versus possessed hours. Based on this examination, a judgment may be made about the criticality of determining the most appropriate weighting of flying hours and possessed hours. If the overall sensitivity were relatively small, for example, a "ball-park" estimate of the weighting might suffice. However, if the sensitivity were quite large, further investment of effort aimed at homing in on the optimal weighting might be indicated.

Examination of Apparent Discrepancies

To provide a quantitative check on the WSSC results, a number of statistical procedures can be used, including, of course, the calculation of summary statistics such as means and standard deviations. Often graphical presentations are helpful in indicating where there are possible problems within the WSSC logic, because "a picture is worth a thousand words" (or numbers).

Figure 3 depicts a simplified, somewhat diagrammatic, plot of one component of installation support costs (RPM airman pay and allowances) at a base against the number of supported people at that base. Each observation in the plot represents one base. As can be seen, there are a few suspicious data points: data point A and the clump of data points labeled B. Outliers such as these provide a strong indication that something is wrong somewhere.

In this case, it has been determined that the existence of data point A reveals a problem with the input data that must be taken into account by WSSC. Within the Alaskan Air Command, all installation support costs for its three bases are reported in the accounting system at only one base (Elmendorf), while the strengths are reported to the appropriate bases. Thus, the Elmendorf installation costs appear much out of line relative to the base population. In tracking down the second apparent discrepancy, it turned out that data clump B is explained by the fact that these five bases are ones at which depots are located, and a larger share of RPM at depots is done by civilians.

EXAMINATION OF DATA DISCREPANCIES

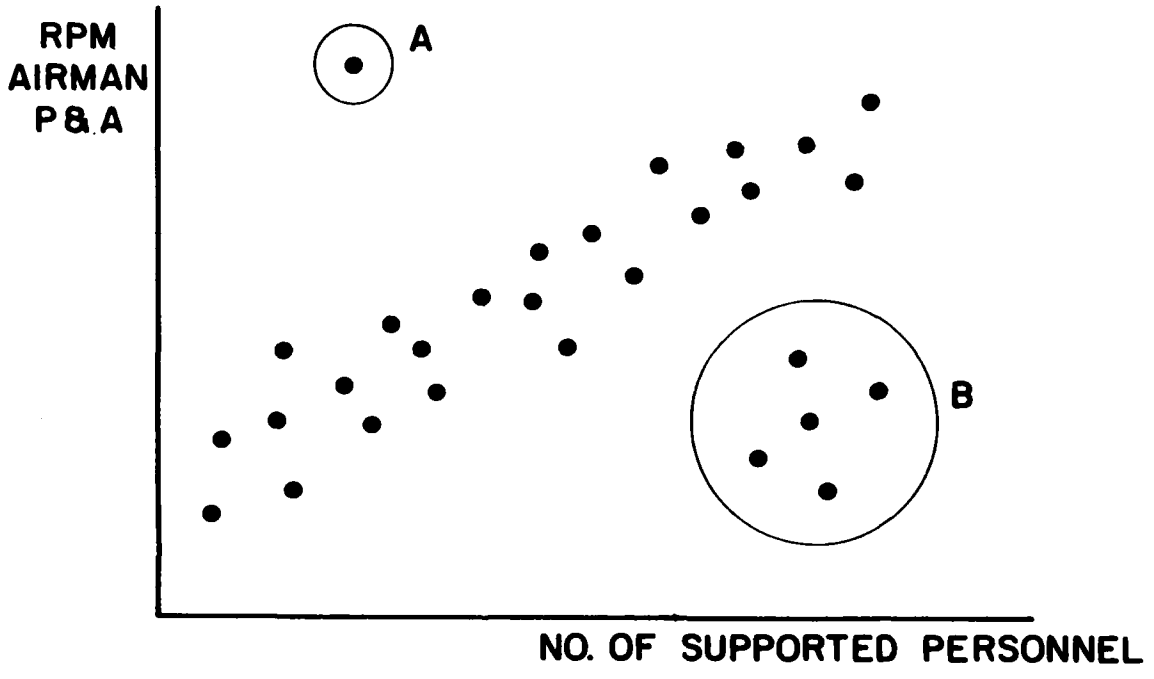


Figure 3: A Diagrammatic Data Plot

Summary

This paper has provided a brief discussion of the WSSC system validation, concentrating on the current research of Desmatics, Inc. That research effort, which deals with Phase I validation, extends through September 1983. Because there is no way in which to validate WSSC directly, Desmatics is using an indirect approach comprised of a qualitative assessment (face validity) and a quantitative assessment (mathematical validity).

To date, the major portion of the Desmatics work has concentrated on the qualitative evaluation and on setting up the framework for the quantitative evaluation effort. Although this paper has discussed some aspects of the quantitative evaluation, a major portion of that evaluation will be completed after the FY82 WSSC data becomes available early in 1983. Nonetheless, a number of recommendations have already been made. For example, Desmatics has suggested:

(1) investigating the application of regression techniques to separate fixed and variable costs in certain cost categories,

(2) replacing allocations based on flying hours and possessed hours with ones based on personnel strength ratios in some algorithms,

(3) revising some personnel strength allocation ratios to make them more appropriate,

(4) providing separate reporting of direct and overhead maintenance costs,

and (5) using a one-stage allocation as opposed to a two-stage allocation in some algorithms.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 115-6	2. GOVT ACCESSION NO. AD-A120006	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) VALIDATION OF THE COST METHODOLOGIES WITHIN THE WEAPONS SYSTEMS SUPPORT COST SYSTEM (D160) OF THE AIR FORCE VAMOSC SYSTEM		5. TYPE OF REPORT & PERIOD COVERED Technical Report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Dennis E. Smith		8. CONTRACT OR GRANT NUMBER(s) F33600-80-C-0554
9. PERFORMING ORGANIZATION NAME AND ADDRESS Desmatics, Inc. P.O. Box 618 State College, PA 16801		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS HQ AFLC/LO (VAMOSC) Wright-Patterson AFB, OH 45433		12. REPORT DATE September 1982 13. NUMBER OF PAGES 15
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this report is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the 17th Annual DOD Cost Analysis Symposium

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

VAMOSC

Cost Allocation

O&S Costs

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Air Force VAMOSC system has been mandated by DOD to aid in decision-making for modification and acquisition of weapons systems. VAMOSC data will be used in cost models that support decisions to obligate millions of dollars. Therefore, the accuracy of VAMOSC's output and the validity of its logic are paramount to the utility of the system to the user. For this reason, the Air Force Office of VAMOSC is relying on independent contractors to validate the VAMOSC logic and data sources.

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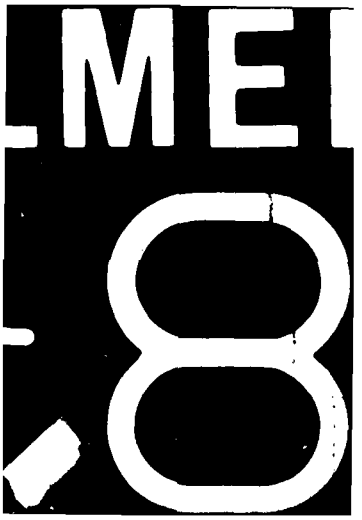
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