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On the Selection of Computer Models to Analyze Support Requirements for Weapon Systems

Lewis A. Litteral
University of Richmond, llittera@richmond.edu

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Lewis A. Litteral, Ph.D.
Assistant Professor of Management Systems
E. Claiborne Robins School of Business
University of Richmond, VA 23173
(804) 285-6408

Abstract

The purpose of this paper is to present guidelines for integrating computer models to perform logistics support analysis. The nature of logistics support analysis is outlined and the need for combining models to perform certain analyses is detailed. The actual construction of such a model set is reported and the features of this set are used as a basis for discussion. Included in the set are the Network Repair Level Analysis, MOD-METRIC and Logistics Support Cost Models.

Introduction

A large portion of the cost of a weapon system is incurred after the hardware is delivered to the user. Ownership costs due to operations, maintenance, support equipment, repairs and spare parts usually exceed the procurement costs of design, development and production. These ownership costs together with procurement costs comprise the life-cycle cost of a weapon system. Clearly the total life-cycle cost of a weapon system must be carefully considered if investments are to be made wisely.

Recognition of the magnitude of ownership costs has resulted in efforts to reduce these costs for present systems, as well as those being developed and those just being designed. Many of these ownership costs are inherent in the design of the system and its components. Therefore, they are largely determined well before the hardware is produced. This observation implies that the greatest potential for cost savings exists at the design stage in the life-cycle for new systems and in possible design changes in the sub-systems and components of existing systems.

Air Force Commitment

The Department of Defense and the Air Force are well aware of the considerations set forth in the preceding paragraphs. The Fitzhugh Report [1], published in 1970, emphasized the need for a thorough investigation of life-cycle costs and the necessity for effective analyses to take place in the early stages of system development. In October of 1970, Department of Defense Directive 4100.35 was issued to describe the Integrated Logistics Support (ILS) concept. This has recently been replaced by DODD 5000.39. MIL-STD-1388 was published in October 1973 as a joint service document outlining a single uniform process for conducting a logistics support analysis program. However, both Air Force Logistics Command and Air Force Systems Command believed that the process outlined in MIL-STD-1388 could not be effectively incorporated into Air Force acquisition activities at that time. Morris [2] argues that as a result, even though Air Force Regulation (AFR) 800-8 was originally issued in July of 1972, there were very few Air Force programs using MIL-STD-1388 as late as 1978. In February 1980, AFR 800-8 was revised and reissued. This revised regulation together with the existence of the Acquisition Logistics Division underscores the Air Force commitment to ILS and logistics support analysis (LSA).

AFR 800-8 defines logistics support analysis as:

> An iterative analytical technique that is the principal means of coordinating the systems engineering process and the logistics support planning process. It is used to provide the data base, to communicate and integrate logistics considerations into the design effort, and to identify, quantify and document all logistics support resources required for the system/equipment throughout its life-cycle.

LSA is to be applied to a program at all stages of the acquisition process starting with the Mission Element Need Statement (MENS), which is the formal initiation of the acquisition process. The acquisition process begins when a MENS is identified and documented based upon deficiencies in existing systems related to operational capabilities, excessive manpower requirements, logistics support requirements, ownership costs or inadequate system readiness.

While there are many logistics models, they are not all suited for trade-off studies. In some cases the models are so wedded to current logistics policy that they cannot be generalized to permit meaningful trade-offs. Still other models are just too large and cumbersome to be applied quickly enough to meaningfully affect design decisions.

The data to be used and the analyses to be performed by LSA are discussed in AFR 800-8, but the techniques and models to be used are not. Partly this is because the development and application of LSA technique is primarily a contractor responsibility. The main reason for this void is less positive however. In fact, there exists no single model (or compatible set of models) that will permit all these analyses. In addition, while there are many special purpose models, each aimed at some particular analysis problem, there is no accepted methodology for combining several models to do LSA.

The problem is to find some acceptable, meaningful method for doing LSA. This is a particularly difficult problem because of the wide scope of LSA. It is also difficult because the method must be usable throughout the acquisition cycle as system definition and data change.

A comment made by Marks et al [3] points out the need for developing integrated model sets. The authors state,

> None of the models discussed here--nor any others that we know of--provides full coverage of the life cycle cost elements or of the major factors driving costs, which means that comprehensive cost estimates require a hybrid combination of generalized models or a combination of models and ad hoc methods.

The Setting

The guidelines presented here were developed as part of a study conducted from December 1980 to May 1982. The purpose of the study was to develop an integrated model set to aid in the evaluation of design alternatives on the availability and logistics support requirements of weapon systems. The system under consideration was the air refueling system of the KC-135A tanker aircraft and the models chosen for integration were the MOD-METRIC, Network Repair Level Analysis (NRLA) and the Logistics Support Cost (LSC) models. Results of the application of the model set as aids in design decisions are reported in [4] and [5].

The setting for the study is the two-echelon, two-indenture inventory system that is often used by the Air Force. This system consists of several operating bases at which weapon systems are deployed and a central depot that serves these bases. Repair level refers to the place at which failed components are repaired and the two echelons are the base level and depot level. There is a two-indenture component structure consisting of line replaceable units (LRUs) and shop replaceable units (SRUs) which are subassemblies of some LRU.

The NRLA model uses a network analysis optimization algorithm to determine the economically optimum set of repair level decisions for a group of LRUs and the associated SRUs. Details regarding this model and its implementation are available in [6].

The objective of the MOD-METRIC model is to determine space stock levels in a two-echelon inventory system subject to a constraint on investment. The model describes the logistics relationship between the LRUs and SRUs and computes base and depot spare stock levels with explicit consideration of this logistics relationship. A complete discussion of the MOD-METRIC model is available in [7].

The LSC model objective is to estimate the support cost that may be incurred by adopting a particular design for a weapon system. The LSC User's Handbook [8] made available by the Air Force Logistics Command provides a complete discussion of this model.

Although the guidelines given below are general, they are at times discussed in the context of the application of these particular models to the air refueling system and the features of the model integration are also discussed in this context.

Guidelines for Model Selection

The purpose of this section is to present and explain the guidelines for integrating models into a set so compatible that the set of models can itself be regarded as a single model. Three general guidelines to be followed are:

1. The model set should be detailed enough to be an aid for design and support planning decisions.
2. The model set should achieve adequate coverage of the factors that influence system quality.

3. Individual models should share common characteristics.

The first two of these guidelines are relevant to the model set as a whole while the third relates specifically to individual models that are candidates for components of the set. Each of these guidelines is discussed below.

Guideline One

There are three closely related decision situations for which the model should be useful. Paulson [9] discusses these situations and points out that it is reasonable to expect that a single model could be developed that could address all these situations.

When system design is considered along with logistics early in the life cycle of a weapon system, the following decision situations arise: .

1. concept design/concept evaluation;

2. detailed system design;

3. support planning.

The first decision above, concept design and concept evaluation, occurs as a result of a documented need for a weapon system. Here the engineering effort required for system development is determined and mission and performance envelopes for the system are established. The decision concerning detailed system design occurs after the conceptual phase and consists of selecting a particular hardware design from a set of alternatives. The support planning decision should also occur very early and here the kind and quantity of resources required to support a particular design are estimated.

Guideline Two

The second guideline given above is that the model set should achieve adequate coverage of factors that influence system quality. Nelson [10] points out that, "For military systems, quality has primarily meant performance, with other characteristics considered secondary." For the purpose of this study system quality is synonymous with system effectiveness. The measures of system effectiveness, which are to be covered by the model set, include performance, availability and cost.

Each of these measures of system effectiveness is influenced by many factors. The basic approach taken here is to group these factors into three areas; component design, usage or operations policy, and support policy. With the factors in these areas as inputs the model set should adequately cover the impacts on life cycle cost, availability and performance.

A particularly difficult area to model effectively is operating and support costs. Task 213 of MIL-STD-1388 specifically requires that the support resources listed in Table 1 be analyzed.

Table 1 MIL-STD-1388 Support Resources

Support and test equipment
Facilities
Personnel skills and manpower
Training devices and programs
Computer resources
Transportation systems
Technical data

Guideline Three

The final guideline is that individual models should be chosen for inclusion in the set on the basis of certain well defined criteria that relate to the compatibility of the individual models. A list of elements to be considered is given in Table 2.

Table 2 Compatibility Considerations

Assumptions
Data requirements
Simplicity
Computer language
Availability of code
Size
Basis of computation
Level of detail
Contribution to coverage

Assumptions of those models that are to interact must be compatible. An example of common assumptions occurs in the consideration of the NRLA model and the MOD-METRIC model. Each of these models makes the assumption that the inventory system is a two-indenture, two-echelon system. The Consolidated Support Model (CSM) is the three-echelon extension of the MOD-METRIC model. NRLA is not compatible with CSM.

The data requirements of a particular model must be considered. In each case both the magnitude of data needed and its availability are important. Those models that have relatively modest data requirements that can be fulfilled with reasonable efforts are favored.

Simplicity is a desirable feature for a model candidate to possess. Integration is an easier task when the component models are relatively simple and a wide variety of users will find the model understandable. Simplicity in component models is especially important since the complexity of the model set is a function of the degree of complexity in the component models.

Computer language and availability of code are important considerations. A large proportion of logistics models are written in FORTRAN while simulation languages such as SIMSCRIPT are also well represented in the modeling literature. The code should be available through reasonable effort. This consideration excludes many privately developed models for which the code is proprietary information.

There are two size considerations, storage required and run time. Storage is relatively inexpensive so a candidate model would probably not be eliminated because of large storage requirements. CPU time is relatively expensive so this consideration would favor efficiently coded models. Each of these size factors is exaggerated in the combined model set since each component model contributes to overall size.

Costs can be accumulated on three basic computational levels. These three levels are groups of systems, system and subsystem. Compatibility is enhanced when models have the same basis of computation. Conversion of a model to the basis of computation showed by other members of the set should be achievable with reasonable effort. Hence incompatibility based on this factor does not necessarily prohibit a model from being included.

The level of detail of a model depends on the function that the model supports and the stage of the acquisition process at which it is applied. Models that are to be applied very early in the acquisition process are necessarily less detailed due to the unavailability of detailed data. Also, models can sometimes be grouped into the design decision or the budget decision area. The difference is that when design decisions are being made, relative cost estimates are sufficient to evaluate alternatives; while budget decisions require absolute cost estimates. Candidates for the model set should be useful in making design decisions.

Integration Features

The model set is designed to be exercised in such a way that the effectiveness of the individual models is extended beyond that level which exists when the component models are exercised separately. This is accomplished by exercising the models in the most logical sequence and by extensively altering the LSC model to eliminate overlap and to include features that close gaps.

The order in which the component models are exercised is NRLA, MOD-METRIC and finally LSC. The LSC model inputs are influenced by the inputs to and outputs of the NRLA and MOD-METRIC models. The MOD-METRIC data requirements are virtually a subset of the NRLA input data set and in addition, they are influenced by the outputs of the NRLA model.

The basic approach to model integration is to apply the NRLA and MOD-METRIC models with little or no alteration and to include a revised version of the LSC model to examine areas that are not covered by NRLA or MOD-METRIC. Alteration of the LSC model included elimination of the equations for the costs of LRU spares, support equipment, facilities, fuel consumption, spare engines and software support. A total of six of the original eleven LSC model equations were eliminated from the version of the LSC model included in the model set.

There are three distinct reasons for excluding these equations. The equations for the cost of LRU spares and the cost of support equipment were excluded to eliminate overlap. MOD-METRIC does a more thorough job of analyzing the spares inventory problem and hence eliminates the need for the LRU spares equation in LSC. The NRLA model explicitly considers the cost of support equipment in its repair level analysis and makes this cost visible to the user. The equation for cost of facilities was eliminated since this cost is viewed as nonincremental with regard to alternative designs of the KC-135A air refueling boom. Finally equations for the costs of fuel consumption, spare engines and software support were not included since these costs are not attributable to the KC-135A air refueling system.

A total of five equations from the original LSC model are employed in the model set. The equation for the cost of on-equipment maintenance accumulates cost in an area that is not addressed by either the MOD-METRIC or NRLA models. Equations for off-equipment maintenance, inventory management and personnel training provide high visibility for these cost categories. These costs are considered in the decisions made with the NRLA and MOD-METRIC models but these two models do not make these costs visible to the user. Finally, since the NRLA model assumes that only one set of technical data is purchased from the contractor and that duplication and distribution costs for additional sets of data are minor and ignored, the LSC equation for the cost of management and technical data was included to cover this area.

Another way in which the LSC model was altered for this application was the elimination of certain propulsion system related elements from the equations for the cost of on-equipment-maintenance, off-equipment maintenance and personnel training.

There are other desirable features which result from the integration of the three models such as the elimination of deficiencies in the individual models. The basic weakness of the LSC model is that the model equations explicitly compute costs associated with the weapon system, subsystem, and LRUs so that SRUs are not included. This weakness is overcome by the detailed analysis of the LRU/SRU relationships in both MOD-METRIC and NRLA.

Also there are certain assumptions made in the MOD-METRIC model for mathematical convenience which do not restrict the overall analysis since the NRLA and LSC models are included. Condemnations of parts are assumed not to occur by MOD-METRIC but both the NRLA and LSC models allow condemnations to be considered. Another assumption of MOD-METRIC is that the level at which repair is performed depends only on the complexity of the repair. Decisions regarding level of repair can be extensively analyzed using the NRLA model and hence this MOD-METRIC assumption does not restrict the sensitivity of the model set to factors that have an impact on repair level decisions.

Summary

Guidelines have been given for combining logistics models into a compatible set in order to investigate relationships between measures of system effectiveness and design considerations. It should be noted that a useful model set must be tailored to the application at hand. In particular, it is necessary to identify the system to be examined before making final decisions regarding modeling methodology. Once the system is identified, then reasonable and specific measures can be chosen to represent the general tradeoffs of interest for that system.

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