SIMULATION SYSTEMS FOR LOGISTICS SUPPORT PLANNING

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I. INTRODUCTION

Many organizations now operate, or are planning the operation of complex logistics and maintenance support systems that defy analysis by any of the existing analytical techniques and inventory models. These logistics systems are characterized by having a mix of high-value reparable parts with relatively low demand over time. In addition, such complex support systems are generally composed of several locations where the repair and stock locations may not be the same. The given problem is to specify inventory levels at the several locations that will maximize the total system effectiveness, as well as to specify optimal maintenance and logistics operations policies and procedures. The achievement of this goal is further complicated by the fact that any one location can, in time, draw upon the stock and maintenance capabilities of any other location. Because of this, it is impossible to maximize the system effectiveness by optimizing the stock and maintenance activity at each location independently of that at the other locations.

Using existing inventory models, it is possible to optimize the stock levels for any one location. However, such models do not consider other dynamic conditions that affect the long range logistics and maintenance support system performance. Existing models also do not consider such factors as:

- ° Variable repair capability by locations
- ° Personnel levels, skills and capabilities available and utilized
- ° Interaction of low-value stock policy and high-value stock policy
- ° Fixed and variable order cycles
- ° Stock redistribution
- ° Length of stock review period

The ability to evaluate such interacting questions in the light of cost implications and ultimate logistics support effectiveness is most desirable. The Logistics Analysis Simulation System described in this paper, which is programmed on a large scale computer system, is directed towards that objective.

Simulation and related techniques in the field of Operations Research can be applied to the management and organization of logistical systems of any complexity and size. These techniques provide a flexible and analytic tool that can be used to determine the most effective support for a given logistics system budget.

Increased effectiveness will result from:

- Reduction in spares procurement costs for high-cost, low-demand spare parts.
- Maintenance or improvement in performance regardless of uncertainties of forecasting, obsolescence, ordering, holding, distributing, and activity phase-in/phase out.
- Ability to obtain maximum system performance at any given level of system investment.
- Ability to continuously evaluate alternative logistics policies and procedures in light of experience.

Experience in utilizing logistics simulation techniques indicates that sizable reductions in logistics costs can be achieved at the same time that systems effectiveness is maintained or improved. In general, the simulation model approach offers these advantages:

- Allows analysis of systems having complex interrelationships and variables.
- Makes it easy to communicate the effects of alternative operational doctrine and system processes to management and command.
- Is flexible and adaptable to continuing system changes.
- Allows examination of total system dynamics and costs/budgets under varying assumptions.

Particular emphasis has also been given to the need for "self-learning" in the design of such an advanced analytical tool. The model design provides for continuous feedback from previous simulation runs which, in conjunction with data derived from the field, allows the analysis system to refine its own results. Thus, the simulation incorporates the capability to become increasingly accurate through use, evolving a realistic provisioning and maintenance policy.

In summary, the logistics simulation described is an advanced analytical tool which can serve logistics analysts and managers. It reduces computational time, it increases the number of alternative policies and concepts which can be efficiently evaluated, and it serves as an aid to studying extremely complex situations as portrayed by an orderly and logical model. However, the system is only a tool. It is designed only as an aid to, rather than a replacement for, competent logistics judgement and experience.

The system has also been designed to form the basis for a logistics management information system for continuous control and monitoring of Logistics Operations.

II. OVERVIEW OF LOGISTICS ANALYSIS SYSTEM REQUIREMENTS

Unnecessary costs are being incurred today by industrial and governmental supply organizations which fail to operate at maximum efficiency. Unless there is total integration of the complex logistics systems and numerous subsystems that exist in these organizations, their operations cannot be totally effective. While they give desired customer service, they may not necessarily be doing it at minimal cost.

For example, a problem may occur when there are several stock locations of high-value expendable parts with high demand over time, where stockage and repairing are not being performed at the same location. An additional complication occurs when any one location can draw upon the stock of another location. Under these conditions, it is difficult for management to consider all aspects of the system and set stockage and maintenance levels that will achieve the service goals at a minimum cost. Inventory levels and maintenance capabilities at the several locations must be determined jointly in light of demands and costs, if a totally effective policy to minimize systems costs is to be achieved.

Some typical policy questions that must be faced by the logistics manager in the above situation are:

- ° What budget should be allocated to logistic support to achieve desired support objectives?
- ° For given level of investment, what are optimum stock levels for high-value items? For low-value items?
- ° What is best distribution of these stocks?
- ° What is most effective distribution of maintenance and repair skills and capabilities?
- ° Should local purchase be used?

- What is best shipping and routing policy?
- What is optimal policy for facility, site, or equipment phase-in/phase-out?
- How often should stock levels be reviewed?
- How many echelons of repair and stockage are required?
- How many parts should be buffered by the manufacturer?
- How much should be invested in test and repair equipment?

Many logistics management organizations set stock levels improperly by only considering each location as a self-contained unit. In complex situations such as described previously, there must be a consideration of interaction of the entire system and also those conditions which affect total system performance. Consideration must be given to such factors as:

- Variable maintenance and repair capability at locations
- Interaction of low-value and high-value stock policies
- Effects of different order cycles
- Stock redistribution
- Time between stock reviews, to reset stock levels

Simulation, in conjunction with supporting mathematical models, offer a unique method for examining effects of varying alternatives in complex systems. The simulation program, together with mathematical models, can be run under varying assumptions and parameters until a proper mix of inventory levels, maintenance capability, shipping policies, etc. are determined which minimize total system cost. By using a computerized simulation as a tool, a logistics support concept can be fully analyzed before it is implemented. This is done through developing a simulation model; working first with derived demand and cost data synthesized from historical data drawn from previous and maintenance systems. After the logistics support system is initiated, real data gradually can replace artificial data and further adjustments can be made in the system. The derived data aids in setting initial stock levels and maintenance capabilities, and also helps specify the "best" layout of the system (i.e., such elements as the number of repair depots, stock depots, and their locations). These decisions are continually refined, as real data is collected from the field during the course of the operations of the logistics support system.

The analysis of complex logistics support system using computerized simulation and mathematical modeling thus equips the logistics manager with a fast and incisive tool for evaluating interrelated policy decisions in an aggregate manner. Such policy decisions involve:

- ° Proportion of investment to be allocated to high value parts, low-value parts
- ° Levels of stocks by location
- ° Repair capability requirement
  - ° Number and type of personnel
  - ° Investment in test and repair equipment
- ° Operation and maintenance procedures
- ° Echelons of stockage and repair between sites and source manufacturers
- ° Transportation shipping and routing procedures
- ° Recorder periods (low and high priority cycles)
- ° Stock review periods
- ° Amount of buffered parts (expressed as a percent of total parts)
- ° Optimal timing of site facility and equipment Phase-In and Phase-Out

A. METHODS OF LOGISTICS SYSTEMS MODELING

There are two kinds of simulation modeling techniques which are of interest from the standpoint of incorporating, either directly or indirectly, relevant logistics factors into the environment. These are: (1) a Markov process model approximation to an inventory problem which has characteristics, particularly relevant to less expensive nonreparable parts*; and (2) a model relevant to higher priced reparable spare parts**, developed by the RAND Corporation Logistics Department, involving the estimating of system effectiveness from a given overall spares budget allocated in a most efficient way. In both models, particularly the first, the value of each spare part to the system and the decline in this value over time through obsolescence or system phase-out, is regarded as an important factor.

The reasons for selecting these particular formulations as components of the overall model should be briefly noted. For less expensive items, well-known and widely

* John Y. Lu, and R.J.Wolfson, Dynamic Modeling of Inventories Subject to Obsolescence, C-E-I-R, Inc. (Los Angeles Center) June 14,1962; R.J.Wolfson, John Y.Lu, George W. Brown, "Dynamic Modeling of Inventories Subject to Obsolescence, "Management Science, September 1964, Vol. XI, No. 1, pp.51-63. This modeling activity was originally conducted as research performed for the Office of Advanced Logistics Research, Bureau of Supply and Accounts, U. S. Navy.

** G.J.Feeney and C.C.Sherbrooke, "Systems Analysis and Supply Management," The RAND Corporation RAND Memorandum RM-4054-PR, April 1964; "The (s-1, s) Inventory Policy under Compound Poisson Demand: A Theory of Recoverable Item Stockage, "RAND Memorandum RM-4176-PR, September 1964.

used policies lead to ordering whenever stock levels fall below a certain level, and enough stock is ordered to bring the level up to another prespecified level. Disposal of specified quantities also takes place when stock levels exceed certain quantities. Models based on this operating hypothesis (sometimes identified as (s, S) policies) have been consistently improved over the last decade, giving increasing ability to users to comprehend such factors as: changing and improved estimates of demand rates; items becoming obsolete over time at a predictable rate; and various types of logistics costs. These have, generally, been described as Markov models. Computations have recently been developed which substantially reduce the computer time required for solution. With appropriate modification, this model implementing (s, S) policy is an attractive version for incorporation into a larger, total logistics systems analysis framework.

Expensive (hi-value) spares, however, require significantly more complex management because of their reparable nature. In research on hi-value parts, significant advances have also been made in recent years, a major step being taken in the development of the (s-1, s) policy by Feeney and Sherbrooke of the Rand Corporation.

Unlike the research conducted for the (s, S) policy no program presently exists to implement this policy in a realistic context. The research has indicated the steady state solution (the result of a queuing theory application) demand conditions of a compound poisson probability distribution. However, this solution, while analytic, is insufficiently rich to handle realistic problems of site phase-in and phase-out, multi-echelon and, indeed, systemwide (multi-item) demands, including that of related low-cost items. Thus, a master simulation for (s-1, s) type item is required which can reflect the dynamic context in which these items are used.

III. THE LOGISTICS ANALYSIS SIMULATION SYSTEM

A schematic representation of the role of these models in logistics analysis is depicted in exhibit 1. The overall model is composed of three submodels linked by an executive routine. The main submodel is identified as the "systems operation submodel"; it represents the operation of the real system. It is a simulation model which is applied to hi-value, reparable parts. The simulation model replicates, over various time periods, the physical system of items failing, being replaced and repaired, and transported between various depots and sites, for different parametric inputs. At intervals pre-set by the model analyst or decision maker, stock levels are reviewed in the light of past demand, then reset to reflect changes in demand. It is a "mult-echelon" model in which demand, repair time, and transportation are all treated as probabilistic events. Site phase-in and phase-out, as well as unit costs, are treated as known quantities with little or no uncertainty. The simulation permits the determination, for each different logistics budget, of the cost and fill-rate implications spread over a realistic time period. The user must choose the fill-rate and minimum avoidable costs he would like to achieve: the model does the remainder of the job.

Stock levels for high-value parts are set periodically by an (s-1, s) submodel. This model reflects the situation that few, if any, high-value items are bought; they are used most efficiently by quickly repairing them, keeping them in strategic locations and/or ordering them from production "buffers."

Stock levels for low-value parts are set by a standard single item (s, S) inventory submodel. The (s, S) policy is a more traditional usage of inventory theory. Here, given demands on the outputs of the first model, since low-value item stockage policy is dependent on where the repair of high-value items takes place.

A standard linear programming transportation technique operating in the systems operation model is used for redistribution of stocks.

The overall flow chart for the logistics model also describes the relationship required for the submodels. These determine the demands for hi-value parts and specific characteristics of the simulated logistical support system under examination at any point in time (e.g., what sites, depots and echelons exist, what capability exists at various echelons, etc.). The demand for hi-value parts is automatically processed through the simulation to determine repair location and spares replacement as well as update system status. The (s, S) model determines the availability of lo-value parts which in turn help determine the repair location for hi-value parts. The cost and performance measures are computed from both models. Manual intervention is required to develop the "system revisions" which can be made for testing purposes as well as to introduce logistic policy changes.

IV. PROFILE OF SIMULATION RESULTS

As new stock assignments result, parts are redistributed. During the model run, cumulative costs of the operation are determined and are used to compare the effectiveness of operating the system alternative ways. The outputs from the model provide the capability to evaluate logistics inter-relationships.

The simulation can compute the relationship between fill-rate (or systems risk) and the total logistic systems budget consisting of initial investment in inventories and related capital expenditures such as test equipment, and operating costs such as personnel, transportation, etc. This can be done for any given logistics support concept at various total budget levels. The simulation can also compute the relationship between logistics system budget and the cost of refilling the system in the event of a stock-out (i.e., those situations in which requests are not filled - or the "non-fill" rate*). This can be done for the same given logistics support concept.

These curves can be computed for a wide range of logistic support concepts.

* The "non-fill" rate is, in fact the systems risk. It is equivalent to 1 - fill-rate.

Exhibit 2 depicts a family of relationships (between the minimum operating cost concept, and minimum risk concept) for various logistics support concepts at increasing systems budgets. This summary output can be used to evaluate the optimal logistics support concept, given either defined objectives for:

° Actual fill-rate (risk) and future stock/out cost to fill, or

° A fixed logistics budget and weight or values relating fill-rate and future stock-out cost/fill.

V. SUMMARY

This paper describes a system of logical and mathematical models for analyzing and comparing alternative logistical operations and policies in support of equipment and systems located on a world-wide or regional basis. The Logistics Analysis Simulation System is an integrated family of optimizing and simulation submodels whose unified objective is to achieve total systems effectiveness in logistics operations. The modeling of the complex logistics system is intended for use in both pre-planning and management control. Logistics support problems for which this system is best used are characterized by:

° Specified equipment or systems to be maintained and supported involving,

- Multi-item, multi-echelon inventories,
- Subject to continuing technological obsolesense, and uncertainty in demand or failure
- In world-wide, or regional environment.

The simulation system described is a good example of the advanced tools for analyzing logistics siutations which are now available to the executive.

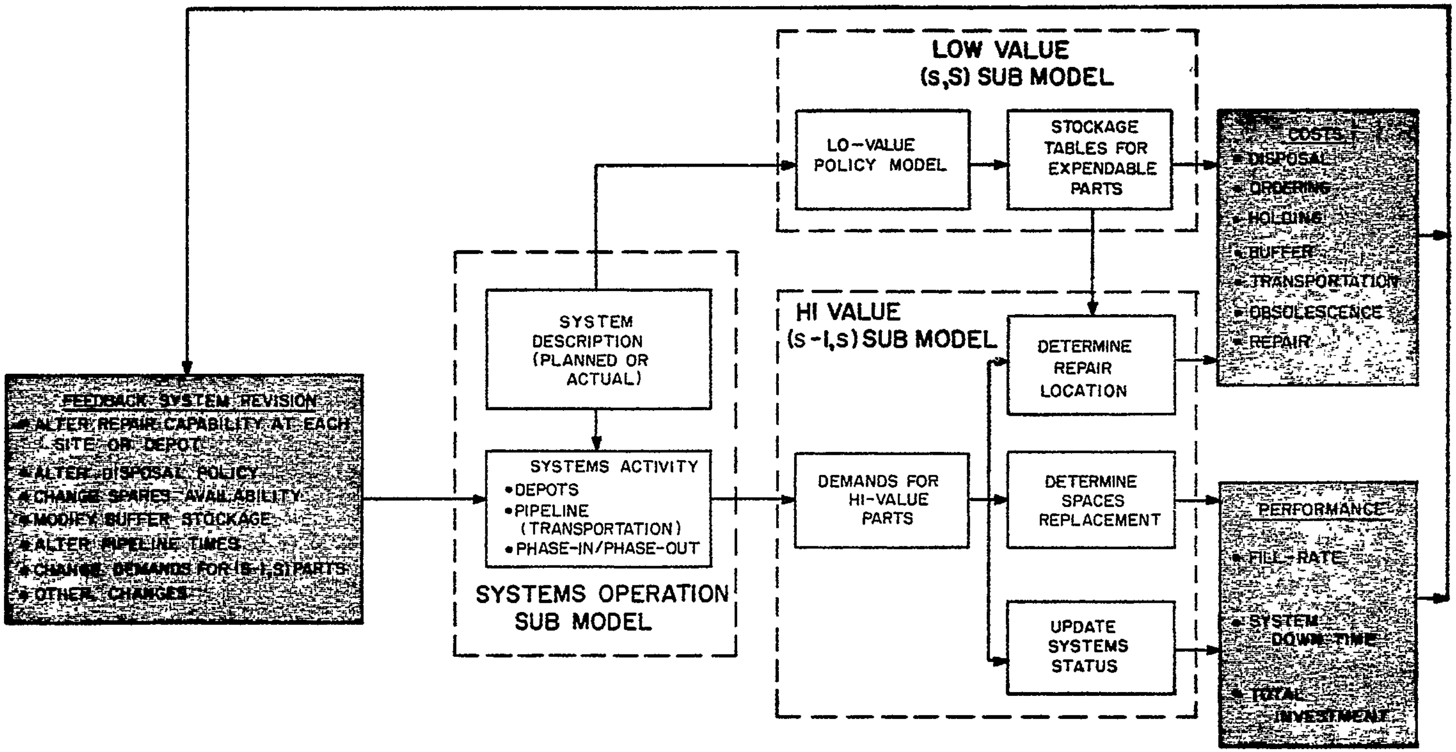

Exhibit 1. Logistics Analysis Simulation System Model

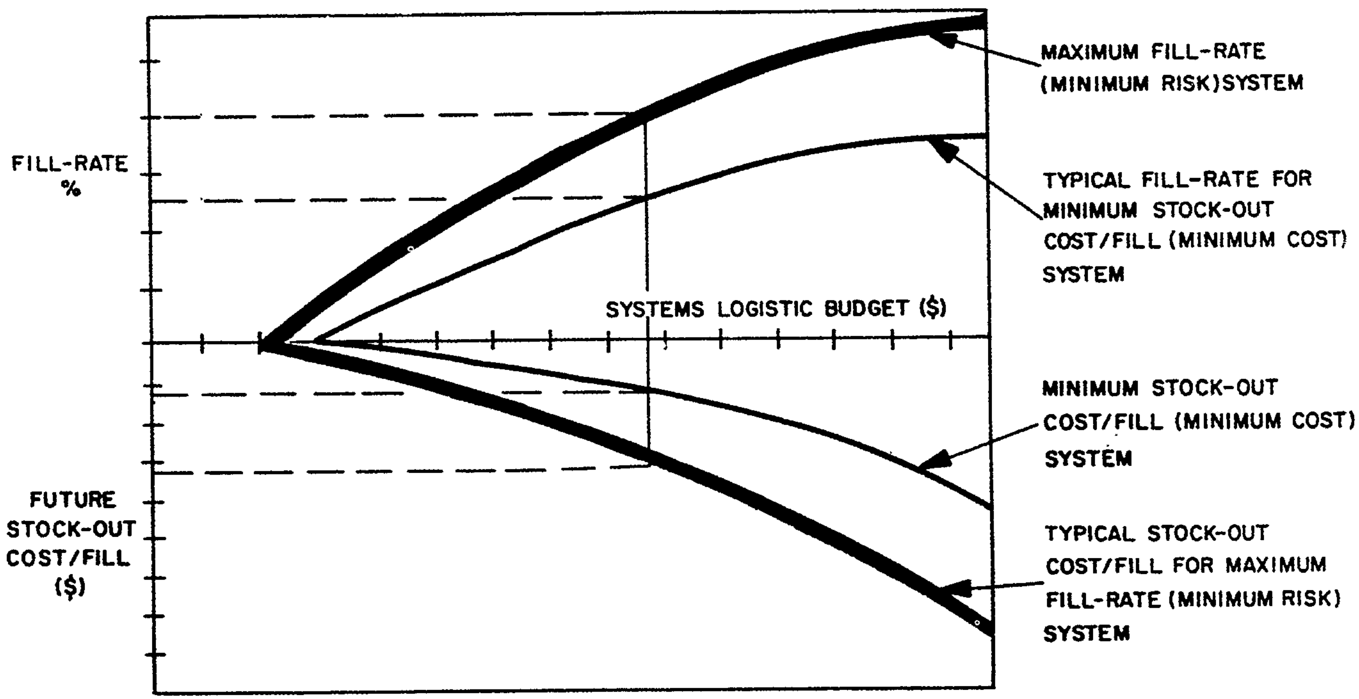

Exhibit 2. Trade-Off of Systems Fill Rate, Stock Out, Cost/Fill and the Systems Logistics Budget

BIOGRAPHY

Mr. Blumberg, President of Decision Sciences Corporation, has an interdisciplinary background in the decision sciences. He graduated from the University of Pennsylvania with a Bachelor's degree in Electrical Engineering and a Master's in industrial Management and has completed all course work for a Doctorate in Applied Economics from the same institution.

Mr. Blumberg has had over ten years of experience in all aspects of operations research, management science, and systems engineering, and has been a consultant to many industrial firms and government agencies in the United States and abroad on a wide variety of decision issues ranging from strategic planning to information systems design. He is nationally known as an author and lecturer, is a member of a number of professional organizations in the decision sciences field including the Institute of Management Sciences and the Operations Research Society of America.