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A STUDY OF SPARE PARTS PROVISIONING.(U)

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A STUDY OF SPARE PARTS
PROVISIONING

by

Mehmet Tokmak

March 1979

Thesis Advisor: M. B. Kline

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A second user has to determine what his position is in the System Life Cycle, how much control he has over system life cycle cost, his needs with respect to spare part provisioning and what the crucial issues

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In the second part, two maintenance-related provisioning models (MDETRIC and OPUS) are described and compared. Finally, a sensitivity analysis utilizing the OPUS model was attempted for a hypothetical maintenance and support organization with supplemental data. Difficulties with the OPUS program precluded completion of this phase.

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A Study of Spare Parts Provisioning

by

Mehmet Tokmak
Lieutenant J.G., Turkish Navy
Turkish Naval Academy, 1973

Submitted in partial fulfillment of the
requirements for the degree of

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Author ______________________

Approved by: ______________________
Thesis Advisor

____
Second Reader

____
Chairman, Department of Administrative Science

____
Dean of Information and Policy Sciences

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The position of a second user (not the producing country) in Spare Part Provisioning and the utilization of maintenance related provisioning models are studied in this thesis.

A second user has to determine what his position is in the System Life Cycle, how much control he has over system life cycle cost, his needs with respect to spare part provisioning and what the crucial issues are. In the first part of the thesis, the concepts, activities and expenditures on these subjects are studied and modified from a second user's position.

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I. INTRODUCTION

In today's world, while almost all systems are becoming more and more sophisticated, the need for spare parts is increasing and even becoming operationally unbearable. The more the systems become sophisticated, the less durable and more delicate they become. Technological break-throughs are making it possible to realize better our logistics needs.

During the design phase, systems are subject to reliability (R) and maintainability (M) trade-off analyses [Ref. 1]. A few systems have to be almost totally reliable but not maintainable (e.g. space rockets, missiles, unmanned space capsules), but most systems have to depend on maintenance and support during their system life cycles. This is because:

- One can not totally eliminate operator errors that can cause a system failure.
- Even though the system is the most reliable system in existence, it is never 100% reliable.
- Cost constraints are such that very high levels of reliability are not affordable.

A. PURPOSE

In the light of these facts, the purposes of this thesis are;

- To clarify some issues concerning spare parts and spare parts provisioning.
- To explore computerized models and their utilization for spare part provisioning.

The former matter is especially pertinent for the Turkish Navy. The main purpose of this is to introduce the general concepts, decisions and activities concerning spare part provisioning. During this process, the position of a second user (this is a user like Turkey who most likely buys systems "off-the-shelf" from foreign countries) are discussed and concepts and activities are directed toward repair parts modified for a second user.

The latter matter has a more general purpose and is applicable to all users. The computerized models considered in this part are maintenance and supply support-related types, rather than stockage-related (inventory) types.

B. APPROACH

A progressive manner is chosen as an approach for this thesis. First the big picture, the life cycle of a system and its parts, is discussed. The cost consideration during the life cycle of the system and the position of spare part provisioning are identified for a second user.

After that, classification of spare parts and appropriate provisioning models for each class are identified. Since the cost of repair (reparable) parts is a greater percentage of total spare part provisioning cost than are the consumable (non-reparable) parts [Ref. 19], further discussions and analyses are directed toward repair parts provisioning and computerized models for this purpose.

In the part on utilization of the models a sensitivity analysis on the structure of maintenance and support organization is performed using the OPUS model to show how a second user can utilize the model to optimize the organization structure, and simultaneously to determine the appropriate repair and stockage policy within the organization for a given system (or systems). This would ensure the best availability for the systems at operational sites.

C. BACKGROUND

U. S. Department of Defense Instruction (DODINST) 4140.42 defines the DOD policy for spare part provisioning [Ref. 2]. OPNAVINST 4423.5 is the Navy version of the DOD instruction. This document establishes the policy for stockage criteria and determination of requirements for spare parts. The model utilized by the U. S. Navy Ships Parts Control Center (SPCC), the Time Weighted Average Months Program (TWAMP) and Cost Difference (COSDIF) which establishes range for TWAMP are based on this policy [Ref. 18]. TWAMP is fundamentally a demand tracking model for spare part stockage which is applied to a single item at a time at a supply station. The model basically tries to ensure that the user is able to find the spare part within the supply system without the system overstocking the item. Therefore, the supply system as a whole is the major concern in this model rather than just the operational units.

Another policy, which takes maintenance into consideration as well as supply support (total logistics concept) has been attracting the attention of logisticians. But its early implementations (METRIC) by USAF in the 1960's has not been very successful because of practicality reasons. However recent improvements in this type of model (e.g. OPUS) are receiving increasing utilization.

These are fundamentally logistic support models, and can also be applied to a system at the operational site by taking the entire maintenance and supply support organization structure and its capabilities into consideration. These models permit selection and allocation of spare parts to supply stations and calculation of the effectiveness of the system for a given amount of investment. The major concern in these models is the system and the operational site rather than supply stations.

Since the prospect of using this policy and the models related to it was considered encouraging, these models are discussed in detail in this thesis.

II. SPARE PART PROVISIONING AS A PART OF SYSTEM LIFE CYCLE AND LIFE CYCLE COST

Spare part provisioning may occur at several points in the life cycle of a weapon system. So what is the life cycle?

A. SYSTEM LIFE CYCLE

Reference 3 gives the concept of the system life cycle as;

"A system, to be useful, must satisfy a need. However, designing a system to just meed the need is not usually sufficient. With few exceptions, the system must be able to continue to meet the need over a specified period of time in order to justify the investment in time, money and effort. Thus, one must consider a system in a dynamic sense-the life cycle or so called "cradle-to-grave" viewpoint. The system life cycle may be said to originate in the perception of a need and terminate when the system is retired as obsolete."

Specifically, for a weapon system the life cycle is the period which begins with threat analysis and the need for the weapon system and ends with its disposition. The major time periods in the life cycle include (Fig. 1)

- Planning Period
    - Concept Formulation Phase
    - System Definition Phase
- Acquisition Period
    - Design and Development Phase
    - Production and Installation Phase
- Use Period
    - Operations and Support Phase

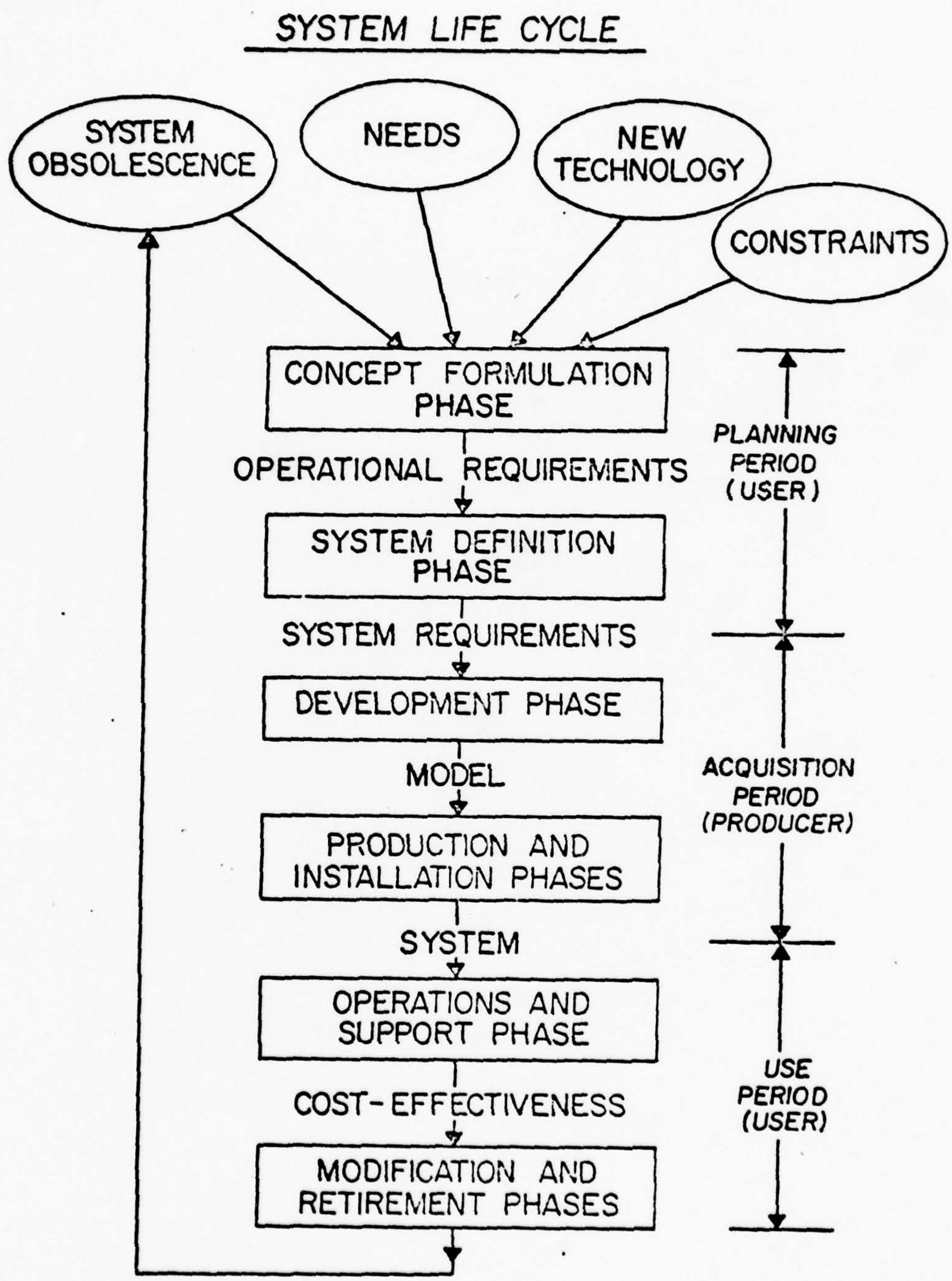

Figure 1. Major Time Periods of System Life Cycle [Ref. 3].

- Modification and Disposition Phase

1. Concept Formulation Phase

This is the initial phase of the life cycle in which efforts are directed toward analyzing the need (threat), identifying and evaluating the feasibility of possible solutions to the need, and developing the system operational requirements in sufficient detail to form a basis for the system definition phase [Ref. 3].

2. System Definition Phase

In this phase, the selected approach defined in the concept formulation phase is further refined, and its technical, economic, and financial feasibility is investigated in greater detail. The output is a set of system requirements communicated in a system specification for the proposed follow-on engineering development (system design) effort. System definition, therefore, translates system operational requirements into system design requirements [Ref. 3].

3. Design and Development Phase:

The design phase (sometimes called Research Development, Test and Evaluation—RDTE) encompasses that portion of the Acquisition Period of the life cycle during which the major system design cost and time occurs. The requirements specifications identified in the Planning Period are the inputs to the engineering effort. The output is a model of a system configuration, demonstrated and evaluated to optimally meet requirements based on the specifications generated in the system definition phase [Ref. 3].

4. Production and Installation Phase

The production phase is the portion of the system life cycle wherein the system is authorized for mass production. During the production phase, production quality assurance and other tests under various environmental conditions are the important activities. Sometimes statistical sampling plans (a sample out of the manufactured systems) are used instead of 100% production inspection, to avoid large inspection cost. Design improvements may also be introduced during this stage, if necessary, based on the quality assurance and the reliability measurements of the produced systems.

The installation phase follows the production phase. The system can not be considered to be operational (ready for use) until installation has been completed and the system checked-out. The system first exists as a complete usable entity only after it has been installed with all its required resources (prime equipment, support equipment, facilities, trained operating and support data) [Ref. 3].

5. Use Period

The last period of the life cycle of a system is the use period. It is considered in two phases, (as Operations and Support Phase and Modification Phase) but here it is discussed as one period instead of two phases.

The use period of the system life cycle is that long period of time where the system can now be operated to fulfill its mission requirements. It is during this period that the true cost-effectiveness of the system can be measured [Ref. 3].

During this period is when the user has the absolute responsibility for the system. The system must be given logistics support. The failures of the system have to be restored, and also it should be prevented from failure by doing periodic tests and check-outs and other required preventive maintenance. The problems, not previously encountered with the system result in engineering change. New usage requirements for the system will give rise to modification needs for the system. In this way, early obsolescence is minimized.

Finally, when the system no longer proves to be cost-effectively used to meet either existing or modified new operational requirements, it is retired. The obsolescence of an old system usually generates new system requirements, and another system life cycle starts over again [Ref. 3].

B. COST CONSIDERATIONS

The cost incurred during these time periods is referred to as "System Life Cycle Cost", and it can be defined as follows:

"Life cycle cost means the sum total of the direct, indirect, recurring, nonrecurring, and other related costs incurred, or estimated to be incurred, in the design, development, production, operation, maintenance and support of a major system over its anticipated useful life span" [Ref. 4].

In the situation of Turkey, most of the major weapon systems are bought from foreign sources, and almost all these purchases involve existing systems. That means these systems have been already planned, developed, manufactured, deployed and are in use in other countries. This creates the situation in which the Turkish Armed Forces have to concentrate on the production portion of the Acquisition Period and the Use Period of the Life Cycle of a major weapon system.

Some weapon systems have been developed and manufactured domestically, but even those systems are an application of technologies and design efforts of other countries. Thus, Turkey does not really become involved in RDTE efforts. All the major weapon systems produced in Turkey have already been proven feasible and evaluated by other sources.

Therefore, in the following parts, only the Acquisition and Use periods are discussed.

1. Acquisition Period

In Turkey, this period includes procurement and deployment of the weapon systems. Because of the reasons stated above, the weapon systems which Turkey is going to buy can be considered as "off-the-shelf" items in a practical sense. Although off the shelf items are commercially catalogued and hence fixed price items, in the case of major weapon systems procurement this fixed price clause is not realistic because of the large amount of money it would involve. Thus, this kind of item procurement cost should always be subject to negotiations between vendor and a second user, like Turkey.

In most cases, the producer company tends to price its product based on what it could charge a second buyer, rather than what the cost is for the initial buyer [Ref. 5]. This means that the company is looking for higher profit than it gets from the initial buyer. This happens most of the time when a foreign country buys a weapon system from USA by FMS (Foreign Military Sales). Although contracting is a vast subject in its entirety, there are some aspects occasionally ignored or forgotten. For example, it is important to have a clause in the contract that ensures that the vendor will deliver follow-on spare part needs when they are required in the future.

The important thing that the user has to realize is that signing the contract may not include all the acquisition cost of a system, as it has sometimes been assumed in Turkey. The acquisition cost should include the following [Ref. 3]:

- Prime equipment cost,
- Support equipment cost,

- Initial provisioning of spare and repair parts cost,
- Technical data and information cost,
- Facilities cost,
- Personnel training cost.

In the following paragraphs, these costs are examined with respect to second user's control over them.

a. Prime Equipment Cost

Although the buyer has almost no control over this cost since the vendor tends to price its product commercially to a second buyer, it is possible to negotiate it. Besides that, if the vendor is going to manufacture the items after the agreement, the item price can be negotiated to take into account price discounts, when the number of items to be manufactured increases. What it really means is that if a fixed set-up cost will incur for production, the effect of this cost on each item price decreases when the number of items increases.

b. Support Equipment Cost

This is the cost of preventive and corrective maintenance equipment. It depends on the maintenance policy of the user. For example, if the user decides that corrective maintenance is going to be done by maintenance stations instead of the operational unit itself, then the cost decreases significantly since only a few equipments have to be bought instead of one equipment for each operational site. Thus the user has some control on this cost.

c. Initial Provisioning of Spare Part Cost

This is so called "initial provisioning of spare parts" and its cost. Generally, new systems require new spare parts, and the user has to make several decisions concerning these spare parts. But most of the time the user chooses the easy, such as

- Order the spare parts as a total of 10% of prime equipment price for each equipment.

- Buy the spare parts as suggested by the vendor.

But, there is a deficiency in such a kind of initial provisioning. It doesnot result in optimal use of investment and causes problems such as

- In a short time period after the system becomes operational, a spare part shortage can be most likely.

- In the long run, the user can wind up with a dead stock of spare parts.

Thus the user has to make decisions himself as to what to do concerning the quantity and, in accordance with it, the cost of the initial provisioning. Then he has to find the best available fit of spare parts allocation among the support organizations. On making these decisions, the user desires to achieve the highest operational readiness of the end-item (system) with the money available.

Fundamentally there are three factors to be considered during initial provisioning.

(1) Time period: The user has to decide for how long the initial spare and repair parts should be able to support systems before a replenishment procurement. The major factor in this decision is procurement lead time (How long will it take to receive the shipment after the purchase order is sent to the manufacturer or the vendor). This period is normally 18 months in USA, but it may extend for an additional 1 to 2 years depending on the nature of the spare parts, transportation time, and the manufacturer.

But, one must not forget that the USA procures almost all of its systems domestically. For another country which does its procurement from outside, this time period may be much longer and is dependent on several factors including the future political situation between the manufacturer and user countries.

(2) Reliability: The user has to consider the failure rate of spare parts, while deciding how many spare parts he has to buy of a particular type. The time period between replenishment procurements and spare part MTBF can give a rough idea of how much of a particular spare part will be needed before the next replenishment.

(3) The price of the spare part: It is important to make distinctions among spare parts based on their prices. An expensive and a relatively cheap spare part can not be treated equally during the selection of spare parts to be procured. Expensive spare parts require more attention than the cheaper ones since procurement of these expensive parts dominate the cost of initial provisioning.

d. Technical Data and Information Cost

Sometimes the vendor or the manufacturer sells the maintenance and operation manuals of the system separately. Although this cost is generally the least one among the other costs, a user who wants to operate or maintain the system effectively has to buy all these documents.

e. Facilities Cost

A new system requires more than operational resources with respect to personnel, services, and buildings during the use period. These additional resources can be training, maintenance, supply support facilities, which are not necessarily a part of the operational system. This cost covers all the spending related to this kind of hardware (and sometimes software). It is usually a high cost (but non-recurring) item, and the user should try to reduce it as much as he can. The most common practice is to modify the old facilities for new system purposes.

f. Personnel Training Cost

The user has to have trained maintenance and operating personnel to get the expected benefit out of the new system. Even though the latest systems are becoming more and more automatic the need for personnel can not be totally eliminated. Personnel errors while operating or maintaining the system will decrease the system performance. Thus, to get the most out of a new system, the user has to spend quite a bit of money to train his personnel to operate and to maintain the system effectively. Since this issue is directly related to the personnel policy of user, he has a certain control over this cost.

2. Use Period

This period includes 40% to 60% of total life cycle cost and almost 75%-80% of the life cycle time-span. The cost incurred in this period is affected by the planning of the system [Ref. 3]. If the system requirements have been developed very carefully and efficiently in the planning phases, the cost savings realized during the use period should be many times of that amount spent in planning.

Another factor that would affect the amounts spent in the use period is the reliability-maintainability trade-off analysis in the planning and design phases. Sometimes highly reliable but low-maintenance type of systems (e.g. spacecrafts) are much more cost-effective for the user than low-reliable but highly maintainable types. Those factors are inherent factors in the system when it is bought and a second user has almost no control over them. The cost of use periods which draw the user's attention in general, are:

- Maintenance Cost
- Logistic Support Cost (other than spare parts)
- Replenishment Procurement of Spare Parts Cost
- Operation Cost
- Personnel Cost

In the following paragraphs, these costs are examined with respect to second user's control over them.

a. Maintenance Cost

During the use period, the system needs periodic preventive and corrective maintenance actions when it fails. The cost of maintenance can be controlled by planning these maintenance actions. A good planned preventive maintenance decreases the number of corrective maintenance actions and the cost of maintenance in the long run.

b. Logistic Support Cost

All the supply materials and activities, such as consumables (cleaning material, utilities, etc.) and the personnel who administer these items constitute this cost. The user has to make all the decisions concerning this cost. Effective planning and execution can decrease it. Spare parts cost is separated from this item only because the thesis is intended to study it in depth.

c. Spare Parts Cost

This cost occurs when the "follow-on" or "replenishment procurement" of spares is done. Since this action would take place at certain time intervals during the Use Period and after the initial provisioning the user has to minimize the deficiencies occurred during the initial procurement of spares. If it is necessary he has to reallocate second user can utilize the model to

the spares, redetermine the types of spares to be procured, and so on. The important point is that the replenishment spare parts prices are most likely to be higher than previous (initial procurement) prices and this can require a new agreement between the user and manufacturer or the vendor.

d. Operation Cost

The operation cost occurs only when the system is in operation. It can be controlled by the user by scheduling operational and non-operational times of the system.

e. Personnel Cost

Every user realizes that he has to employ a certain number of personnel to keep the system in use (operators, maintenance personnel). But even though the total personnel cost can be computed for an operational site, it is hard to determine how much of this total is spent for a particular system.* For instance, a destroyer carries 250 personnel, and they cost a certain amount of money to the Navy, but what is the personnel cost for the air search radar? But user's personnel policy has a significant effect on the total personnel cost and thus the user has an apparent control over personnel cost as a sum but not individually to a system.

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*In the USA Navy, the Ship Manning Documents determine these cost figures for each system on board.

III. TYPES OF SPARE PARTS TO BE CONSIDERED

It is important to define spare parts and clarify what it means:

"Spare parts: Spares and repair parts, reparable and consumable, purchased for use in the maintenance, overhaul, and repair of equipment such as ships, tanks, guns, aircraft, missiles, ground communications and electronic systems, ground support and associated test equipment. As used in this thesis, except when distinction is necessary, it includes spare parts, repair parts, subassemblies, components, and subsystems, but excludes end items such as aircraft, ships, tanks, guns, and missiles" [Ref. 6].

Since this thesis is intended to be a maintenance oriented study of spare part provisioning, only the reparable and non-reparable types of spare parts are considered and studied (Figure 2).

Spare parts can be classified based on several characteristics of their own or their usage. It is possible to clarify them as high-cost and low cost, or high-demand and low-demand, or reparable and non-reparable (consumable) and finally high-reliability and low-reliability. These classifications depend entirely on the user's assumptions and criteria. He has to give answers to several questions. Some questions are as follows:

- What is the criterion for a high-cost or a low-cost spare part?
- What is the criterion for high-demand or low-demand?
- What is the criterion for repair-discard decision?

The answers to these questions can be different for different users of the same type of spare parts.

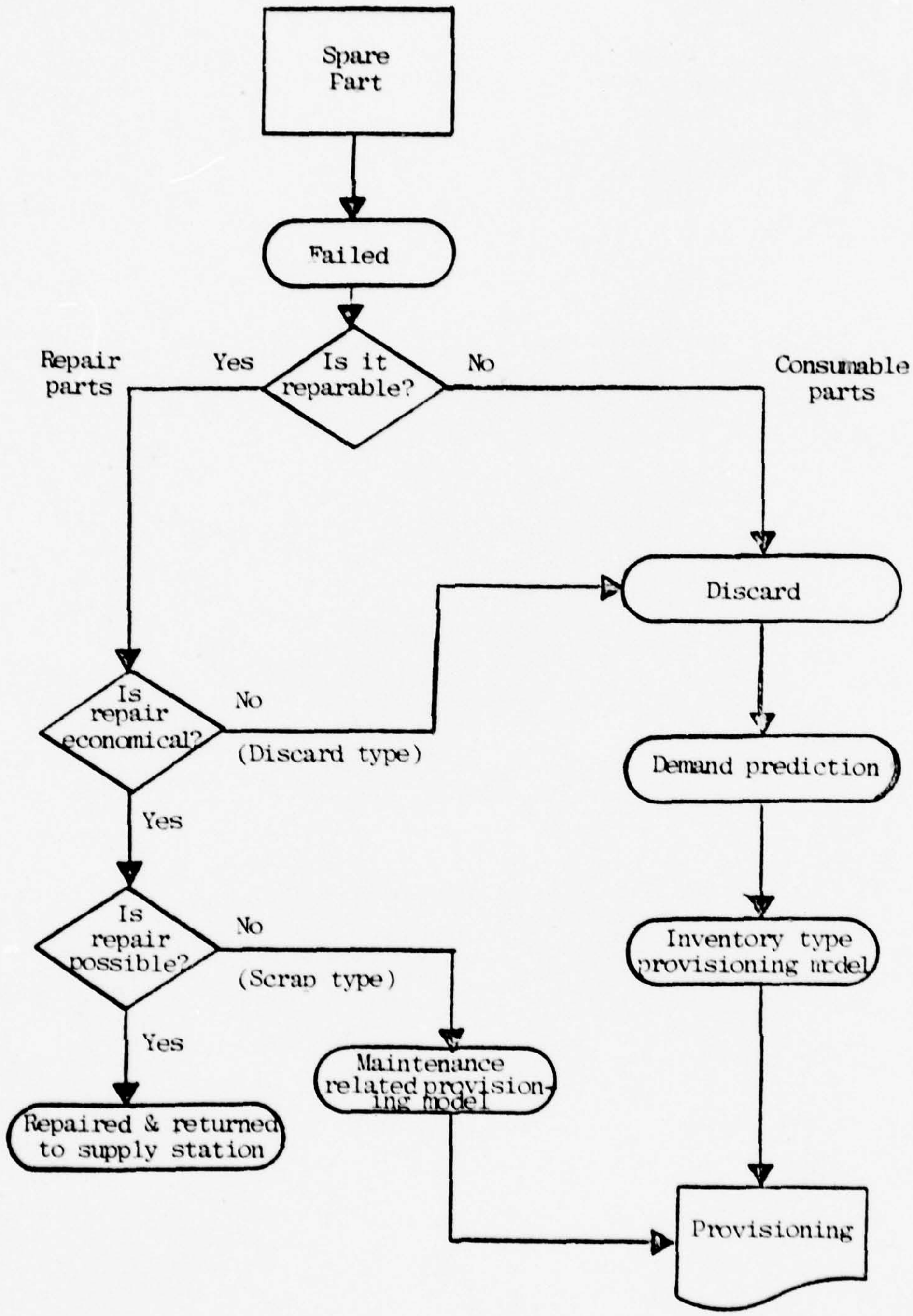

Figure 2. A Flow Diagram of Spares Classification and Provisioning

A. NON-REPARABLE SPARE PARTS

This term includes "pieceparts" or "components". But it is appropriate to call these spares "consumable parts", because they are mostly inexpensive to be used for repairs. As examples, resistors, capacitors, diodes, transistors, electron tubes, bearings, and some type of values and gauges. After failure, used parts can not be reused and would be discarded. Mostly they are relatively cheaper than reparable spare parts, but in some instances they can be very expensive; for example, radar transmitter tubes (Magnetron, and some other microwave tubes).

Other than the exceptionally expensive consumable parts, the rest of them constitute 75-80% of the total stockage of spare parts in quantity, while they represent only 20-25% of the total investment in spare parts [Ref. 19] (Fig. 3). Thus a little overpurchase of these consumable parts would not hurt the budget. Therefore, during provisioning the quantity of low-cost consumable parts is decided simply based on their demand rate.

There are several spare parts provisioning models that are based on the demand rate. The most simple one is the EOQ (Economic Order Quantity) model [Ref. 17]. A more complex one that is utilized by SPCC (Ships Parts Control Center) of the US Navy is TWAMP (Time Weighted Average Months Program) model combined with the COSDIF equation. These models are explained in Appendix (A).

B. REPARABLE SPARE PARTS

These parts will be called "repair parts" for convenience to distinguish reparable spare parts from non-reparable ones. This type of spares can be in the form of subassemblies, subunits, printed circuits,

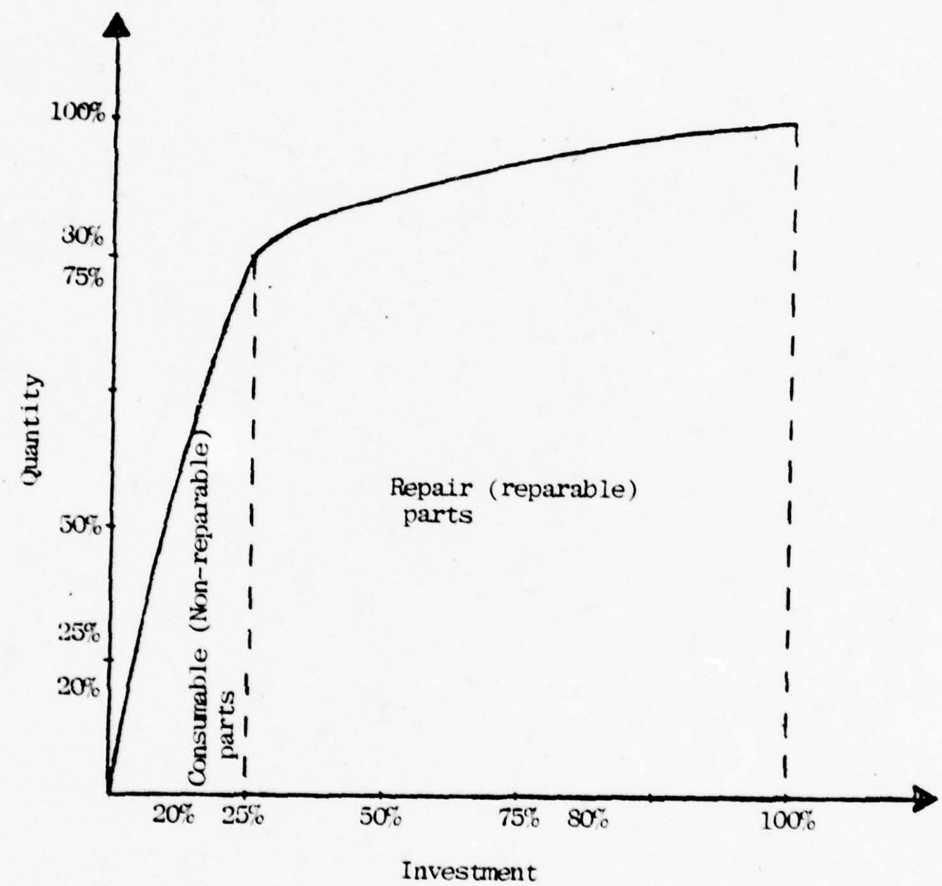

Figure 3. Total Provisioning Cost [Ref. 19]

electric motors, pump shafts, and so on. They can be repaired by maintenance personnel, using the consumable (non-reparable spare) parts. They have an estimated failure rate as do the consumable parts. But, inasmuch as the repair parts are usually designed as assemblies of other parts, their failure rates are higher than consumable parts.

In contrast to what is stated for consumable parts earlier, repair parts are much more expensive than consumable parts and constitute 80% of total investment and only 20% of whole spare parts in quantity [Ref. 19]. Therefore, their total cost is several times that of the consumable parts total cost (Fig. 3).

This is why the user has to give much more attention to the selection of repair parts rather than consumable parts, and this thesis is intended to put more emphasis on repair parts than consumable parts.

Since the repair parts are defined reparable, maintenance of the repair parts has to be considered as well as supply-support. What this means is that when a repair part fails at an operational site, it is sent to a maintenance site to be repaired and reused, but when a consumable part fails, it is removed from the system or subsystem or repair part and it is thrown away since it is dead (not reusable). In each case a replacement has to be requested from a support site to replace the old one. In the case of a repair part, the lack of one spare part at the support site can be filled by a repaired one; for a consumable part a new consumable part has to be requisitioned from spare parts stock or purchased to fill the support station.

There are several repair parts provisioning models in existence, but only two of them will be examined in this thesis, METRIC and OPUS computerized provisioning models. OPUS is examined more profoundly than

METRIC because it is more applicable in Navy type of organizations. The main objective for both programs is to minimize the cost of provisioning while maximizing the readiness of the end item (or minimizing the waiting time for repair parts at operational and support stations).

IV. SPECIAL CONSIDERATIONS FOR SECOND USER

A second user has a disadvantage when he buys a new system. That is because, in spite of the fact that the system has been planned and designed considering the original (first) user's environment, a second user does not necessarily have the same environment. The term environment covers users' financial resources, logistics capabilities, and operational conditions that the system is going to perform in. So the second user has to fit the system into his environment or has to make modify his environment to fit the system. In this respect his concern for spare part provisioning is going to be different, probably more difficult than the first user's.

Spare parts generally are designed by the manufacturer to meet the first user's economical and technical criteria. Perhaps it is appropriate to clarify this statement. Two of the most important factors for a repair part are its price and failure rate, because these two factors directly affect the decision on quantity to be bought. To be explicit, while a higher failure rate requires more in quantity, the price and overall cost increase limits this. Thus a financially restricted user often buys spare parts with lower failure rate or less cost, even though this would increase the corrective maintenance burden and prolong the system down time.

Besides that, the original user makes some classifications for spare parts (Fig. 2). The figure shows how the classification can be done theoretically, but in application the user has to justify the criteria for this classification. And these criteria can change from one user to

• Support equipment cost,

another, depending upon their environment. Thus, a second user has to reclassify spare parts for his own use. But the second user does not have the opportunity to classify a non-reparable part as a reparable, because its design usually does not make it possible to repair. Thus such parts are excluded from discussion.

Theoretically the second user has three alternatives in the reparable parts arena.

A. ACCEPT SAME LEVEL OF REPAIR (LOR) AS FIRST USER

If the second user's financial resources, logistics, and operational capabilities allow this, it is the best solution, because there will not be an extra cost to restructure the spare parts or his organization.

B. GO TO LOWEST LOR ALLOWABLE BY DESIGN

Basically the idea is to classify original SRU's as LRU's and identify new SRU's which would fit the user's maintenance and support organization and would allow him to spend less mony.

LRU's are fairly complex, high cost units that are completely recoverable (after repair are like new). Having been replaced on the system when it is defective (i.e. at the operational maintenance level), they are sent to the intermediate or to the depot level for repair. After repair they are returned to the original stockage station.

The repair of a defective LRU at the intermediate or the depot level might often be affected by the replacement of a recoverable and high cost module. This class of spares will be called SRU. A shortage of such a spare will mean that the repair time of the LRU will be longer if that LRU contains that particular SRU, and it will increase the risk of the shortage of this type of LRU at operational maintenance levels. Thus

SRU's have an impact on the availability of the end item. A defective SRU is usually sent to the depot level for repair; after that it is returned to the intermediate level or kept at the depot level [Ref. 8]. This would seem to be the most practical solution in this kind of a conflict resolution, but while doing this the second user may have to make a trade-off analysis on his logistic organization.

1. LSA (Logistics Support Analysis)

This analysis includes both supply support and maintenance support actions. The user has to make the comparison between the two sets of analysis results, one by using original LOR and another by using lower LOR. Theoretically LSA can be done in the following steps: (Fig. 4)

a. Specify Maintenance and Supply Support Concepts

They are directly related to system mission requirements and are derived from the system's mission profiles, effectiveness requirements, operational states, and overall logistics concept, and from policy statements which form theconstraints or boundaries of the support system. They dictate the maintenance and supply support activities allowable at the specified maintenance levels, such as, for example: no preventive maintenance, or only simple check out and module (LRU) replacement at organizational level, allowable personnel rates and numbers, range and depth of spares, supply replenishment intervals, and inventory control points [Ref. 3].

For example, if the operational requirements for a ship are that "three systems will be available for mission effort at any time", then the maintenance concept with original LOR and original LRU and SRU classification, will be designed to meet this requirement. The concept selected may be "on-line maintenance," or "remove-and-replace, with

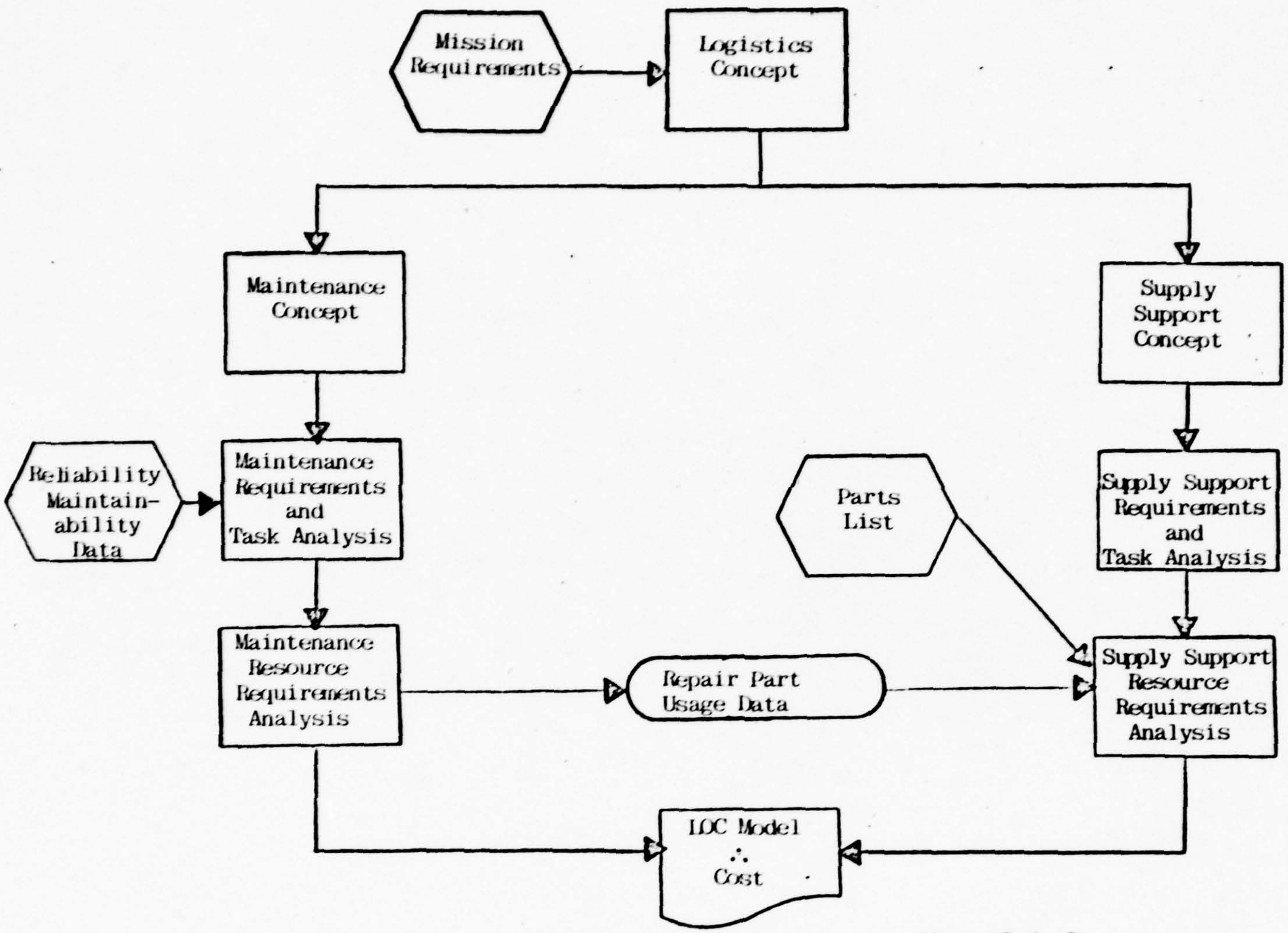

Figure 4. LSA flow chart to study LOR's economic effect [Ref. 3].

off-line maintenance support". But with lower LOR (assuming the SRU's sill be replaced instead of LRU's at the operational station), the concept may change to "remove-and-discard." This is an extreme example, but the user has to figure out which alternative would be economically optimal for his organization.

b. Specify Maintenance and Supply Support Requirements and Task Analysis

Maintenance and supply support requirements and tasks are an elaboration of the maintenance activities to be performed and resource required. These are completely determinable from the maintenance concepts.

Reliability (failure rate or MTBF and maintainability)(MTTR, MDT) data also influence maintenance requirements and tasks [Ref. 3].

Maintenance requirements include such items as:

- What is to be periodically inspected and serviced,
- What spare parts are to be replaced and repaired,
- What types of test and check out equipment are required for different LOR's.

Maintenance task descriptions dictate such items as:

- Maintenance action to be taken at each maintenance level (operational, intermediate and depot).
- Personnel who perform them (operators or maintenance technicians) for both preventive (scheduled) and corrective (unscheduled) maintenance.
- And the frequency or time profiles for performing scheduled maintenance on the system, for different LOR's.

Similarly, supply support requirements and task analysis will include [Ref. 3]

- The determination of the replenishment intervals, inventory reorder levels at various inventory stock control points,

- Repair/discard criteria,

- The supply system (logistic pipeline) which will be used to acquire, transport, store and distribute spare parts for different LOR's.

c. Specify Maintenance and Supply Support Resource Requirements

From the above analyses, one finally arrives at an analysis and enumeration of the maintenance and supply support resources required for the system. These include

- Personnel requirements including personnel ratings, skill levels, and training requirements,

- Maintenance information including maintenance manuals, aids, spare parts lists, and other technical data required for maintenance,

- Support equipment including tools, test and handling equipment,

- Maintenance and supply support facilities such as buildings, shops, storage,

- Provisioning data and allowance lists. These also include the supplying of operating consumables such as fuel, food, and ammunition as well as repair and consumable (component) parts [Ref. 3].

In the preceding paragraphs, all aspects of LSA have been included, but to study different LOR's for the system and to make an economical comparison between them, the user has to study only the specific items pertinent to the LOR change and make an incremental comparison between the LOR's.

C. GO TO LOWER LOR BY REDESIGN

If none of the previous alternatives is applicable, the last chance for the second user is to have the manufacturer reclassify the spare parts. Thus, this may require some new design effort by the manufacturer and certainly it will result in additional cost to the user. By doing this, the manufacturer might be able to design new LRU's to lower levels of the system than that used to be. Hopefully, thus these LRU's will be cheaper and have lower failure rates than the old ones.

If cost saving in the resultant redesign associated with provisioning and the operational life of the system is more than the redesign expenditure, it is the best way to go. But in most cases, a saving will not generally occur because the first user normally has performed an analysis of the system and chosen an optimal solution. Nevertheless, the storage cost and labor cost difference between the first and second users can make the difference.

D. REPAIR-DISCARD DECISIONS

Decisions to repair or discard the spare parts when they fail or malfunction are major support decisions which should be considered prior to the time of failure. This analysis should be included during LSA, since various other support decisions affect the economics of the repair/discard decision and conversely. The decision to repair or discard can have a significant impact on operational readiness postures to sustain military missions as a consequence, the objective of the analysis should be to maximize military effectiveness or operational readiness without sacrificing economic balance among major facets of logistic support.

1. Decision Points

Five major decision points can be identified in the life cycle where the repair/discard decision might logically be considered and are shown as circles in Figure 5.

a. Development of Design Specifications

This is thedevelopment of design procurement specifications which may include specific requirements for spare parts to be designed as a reparable or as a discard.

b. Initial Design or Spare Selection

This is the actual design or selection of spare parts which are either capable of being repaired or specifically designed as discards. For a second user, unless he considers a redesign of the spare parts, these first two decisions have already been done.

c. Initial Source Coding (for Provisioning)

This is designating the spare parts as a reparable or as a non-reparable, generally at the time of initial provisioning. As it is stated in earlier chapters, the second user can make his decision, as much as the spare part configurations allow.

d. Coding/Design Review

This is a review of the repairability code or the design configuration any time after the spare part has been entered into the military supply system. For example, the repair capabilities of the user's maintenance units can force a repair decision to change to discard.

e. Repair Action

This is a decision to repair or discard an individual repair part at the time it has failed or is malfunctioning, and is usually a function of how many times it has been previously repaired. Most repair

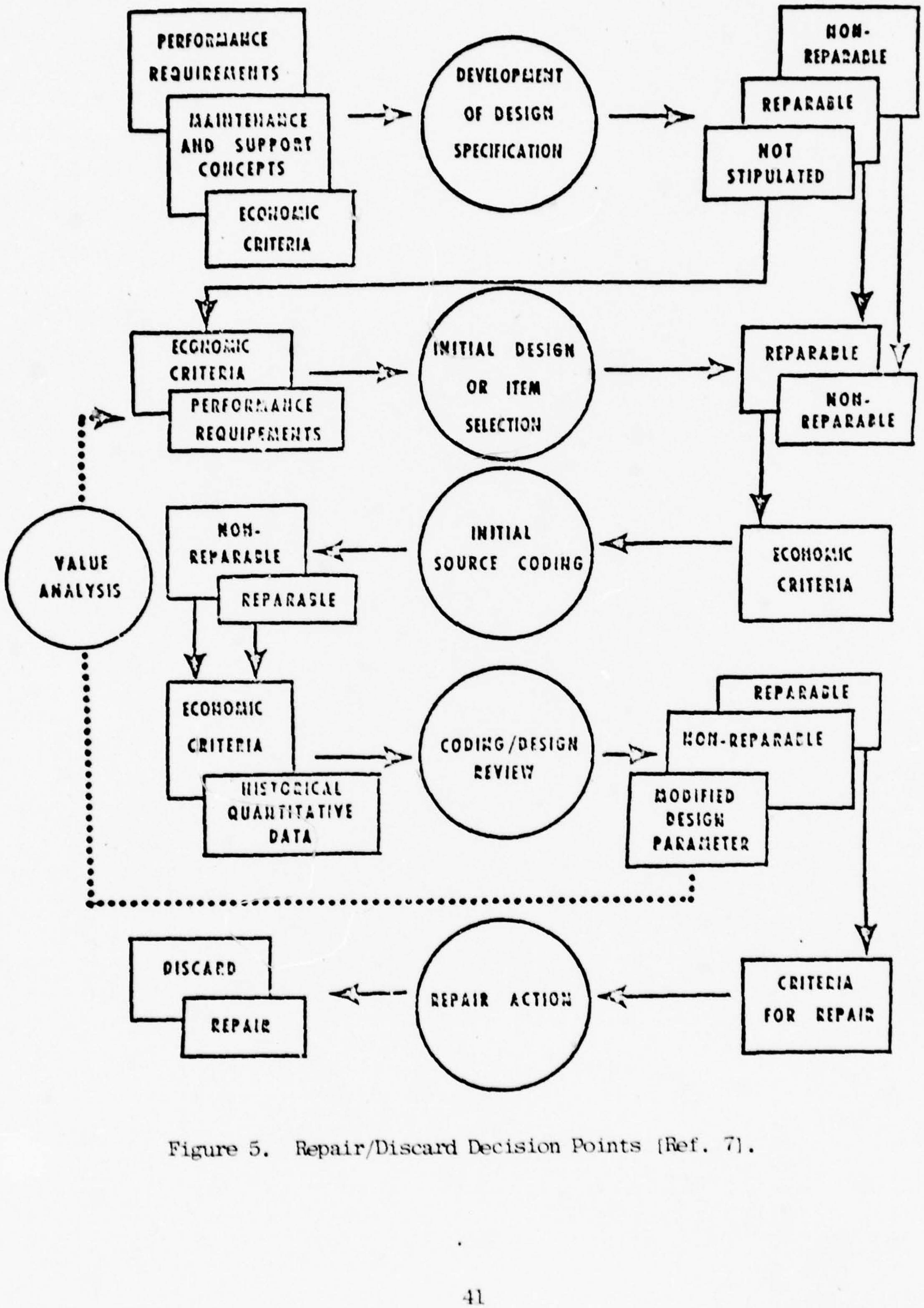

Figure 5. Repair/Discard Decision Points [Ref. 7].

parts eventually reach a point where it is no longer economical to attempt another repair.

2. <u>The Decision Process</u>

A mathematical decision model can be developed which depends on applicable cost elements. These elements are as follows [Ref. 7]:

- Design cost
- Initial end item procurement cost
- Replacement cost
- Preventive maintenance and operational cost
- Corrective maintenance cost
- Supply cost
- Cost of specialized corrective maintenance, tools and test equipment
- Documentation cost
- Training cost
- Disposal value

For example, a simple mathematical decision model for first decision point (Development of Design Specifications) could be:

$$A_1 + pU_1 > A_2 + (p + F_2)\ U_2$$

where

A_1 = Reparable design cost

p = Spare part population

U_1 = Unit cost of reparable spare part

A_2 = Discard design cost

F_2 = Anticipated number of failures over System Life Cycle for discard design

U_2 = Unit cost of discard type spare part

If the analysis shows that the inequality is correct then it is appropriate to go with a discard type design, otherwise a reparable design is appropriate. Reference 7 presents the whole decision model (for each decision point) in mathematical equations.

But prior to this analysis, an effective screening process should be utilized, because in some case, the screening process can indicate, that there is no economic difference between the repair and discard choices.

The result of this screening process would obviously be one of the following [Ref. 7]:

- An immediate repair or discard choice.
- Exhaustive economic analysis prior to a decision.
- Deferring the decision to the next point in the life cycle where it can be done.

There are two general screening rules applicable to all decision points:

- Assume that the spare part will be repaired until a discard choice has been justified.
- Direct the analysis initially toward the highest level of assembly (i.e. LRU). Then if the decision has been made to repair this spare part direct the analysis to next lower level (i.e. SRU).

Finally, the repair/discard decision process should consist of four major steps [Ref. 7]:

- Determine the constraints over the repair/discard decision.
- Determine the decision prerogatives (i.e. reliability vs. unit cost or preventive vs. corrective maintenance or level of maintenance) which should be exercised.

- Apply screening rules before subjecting items to an exhaustive economic analysis.
- Make the repair/discard decision (if it has not already been made) by conducting an exhaustive economic analysis exercising appropriate related decision prerogatives through integrated decision analysis to obtain an optimum balance among support economy, military effectiveness, and operational readiness.

V. PROVISIONING MODELS*

Numerous computer simulation models have been developed for maintenance and support related provisioning. Two of them have been studied in this thesis;

(1) The SYSTECON AB (Sweden) OPUS procedure; a fairly new model which is becoming popular in the USA in recent years.

(2) The RAND CORP. (US) METRIC models; which were developed during the sixties and are well known in the "logistic community".

Following a description of the general procedures to implement the computer models and brief descriptions of the models, a comparison between them is presented to identify the advantages and disadvantages of each and their applications to real world situations.

A. THE DECISION-MAKING PROCESS

In almost all the computerized models for decision-making, there are basic steps to be made by the analyst and by the decision-maker. These steps are:

- To define and to structure the problem.
- To collect, to screen and to edit the input data.
- To utilize the computer.
- To evaluate the output data.
- To present conclusions and recommendations.

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* The USA Department of Defense does not accept these models for provisioning determination by the Services.

These steps are not necessarily one single, straight through sequence. Iterations must usually take place. The evaluation of the first computer run may show the need for more extended computer runs, and that in turn may necessitate the collection of more input data.

The first step should result in a specification of what should be covered by the model in an actual application. This specification should state:

- The types of spares to be included.
- The organizational structure to be studied, with regard to the maintenance andspares support of the equipment.
- The assumptions to be studied with regard to the deployment and the operation of the equipment.
- The extent to which input data should be tested for the effect that the uncertainty in their estimated values will have on the output data.
- The special conditions to be observed when the computer runs are made and when the output data is evaluated, with regard to the input data, such as:
    - •• The deployment and the operation of the systems.
    - •• The structure of the maintenance and the support organizations.
    - •• The structure of the end items.

The data collection and the screening of the input data are steps which, in any application, require most of the time and the work. The data have to be gathered from different sources, including contractors. The data quality has an immediate impact on the quality of the output. A sensitivity analysis using the model may help in evaluating the relative importance and impact of each type of input data.

The computer utilization and the output data evaluation are usually an iterative process which requires further analysis.

The final step is usually part of a broader process of decision trade-offs. Cost-effectiveness curves or tables are studied, and conclusions are made about the possibilities of making trade-offs between desired level of effectiveness and existing budget constraints. The optimal solution depends on many and should include engineering as well as managerial judgement. This judgement is based on the results from the analysis and on considerations of the underlying assumptions.

The cost of using a computerized model depends on (1) the work required to extractthe relevant input data from the producer and from the user; and on (2) the work included in the valuation process of the input data and (3) the amount of (CPU) processing time. Furthermore, the complexity of the equipment under consideration has a major influence on the workload and, as a result, on the cost. However, the larger the system the greater the benefit and the effectiveness that can be achieved by using such models [Ref. 8].

B. THE OPUS PROCEDURE

1. Background

The OPUS procedure was developed as a computer-based aid for certain classes of decisions on spare parts provisioning. The main computer model, OPUS, was initially developed by Systecon AB in 1970, a consultant company to the Swedish Government, as an in-house sponsored project. The further development over the years of that model and other models associated with it have been done under contracts to the Navy and the Air Force Material Departments of the Swedish Defense Material Administration, and the Military Electronics Laboratory. In the Unites States, ITT Gilfillan has utilized the program so far, and it has been recently installed at Northrop (both are in the Los Angeles area), and at the Naval Postgraduate School.

The OPUS procedure has been used in several hundred applications pertaining to more than 100 different systems, among which are electronic equipments for aircrafts, helicopters, naval ships, and ground stations, as well as missiles and aircraft engines. The purposes of these applications have ranged from evaluations of proposals of new equipment to logistic support analysis of systems in the production stage.

2. Introduction

The core of the OPUS procedure is a family of computer models, the development of which started in 1970. Since then, these models have been gradually refined to meet new requirements generated by a growing number of different applications. The phrase "OPUS procedure" has been coined to stress the fact that the actual exercising of a computer model usually incurs the least part of the total cost for performing an analysis.

A major part of the procedure cost will be incurred while preparing the input data for computer models, exercising them, and evaluating their output data. This cost has to be compensated by either actual savings experienced in deciding on the level of investment necessary to achieve a certain predetermined level of readiness for the end item or the assessed savings (through the increased readiness of the end item) for a given investment level with regard to provisioning of spares.

The OPUS procedure was designed to study SYSTEMS (END ITEMS) with two indenture levels [Ref. 8]:

- LINE REPLACEABLE UNITS (LRU)
- SHOP REPLACEABLE UNITS (SRU)

3. Types of Problems

The OPUS procedure has shown itself to be a flexible and useful analysis tool with regard to the following types of problems [Ref. 9]:

- Cost-effectiveness evaluation of alternative maintenance and support concepts and alternative system configurations.
- Initial procurement of LRU's and SRU's, and their allocation within a support organization.
- Reallocation of given assortment of LRU's and SRU's.
- Replenishment procurement of LRU's and SRU's.
- Reallocation of a given assortment of LRU's and SRU's and initial procurement of new types of LRU's and SRU's.

4. Measures of Effectiveness

OPUS VII offers the user the option of selecting one of the following Measures of Effectiveness (MOE), depending upon the specific type of problem being studied [Ref. 9]:

- Probability of successful mission.
- System operational availability.
- Mean waiting time for a spare part.
- Risk of shortage of a spare, when it is demanded.

5. OPUS Characteristics

OPUS VII has the following special characteristics [Ref. 9]:

- It is capable of handling a mixture of different types of LRU and SRU, which may be parts of different kinds of systems, and the associated set of rules on where these spares may be stocked and repaired within a given maintenance and support organization.

- It is capable of handling a complex maintenance and support organization with an arbitrary number of echelons, each consisting of an arbitrary number of repair and/or stock points, and with a complex mixture of support flows.

- It is capable of exploring a wide range of feasible investment levels, in one single run, and also finding the optimal allocations of stocks of LRU's and SRU's to the different stock points of the support organization for every such investment level.

- It allows the user the option of choosing one of four different MOE's, as stated above.

- Finally, it allows different types of systems to be treated simultaneously.

6. Basic Assumptions

The basic assumptions which have been used in the OPUS VII model are as follows [Ref. 9]:

- The demands are Poisson distributed.
- The mean values of the turnaround times are known.
- A failure of one type of item is statistically independent of those that occur for any other type of item.
- Repair times are statistically independent.
- No batching of items before repair.
- In case the system is an electronic equipment, it is assumed that the SRU's in an LRU are in series, and the LRU's in a system are also in series.

7. OPUS Optimization Technique

A central part of the optimization procedure used in the OPUS model is the use of cost-effectiveness (C-E) curves. The measure of effectiveness (MOE) is considered as a function of all the individual stock levels, given all the otherrelevant parameters which describe the activities and the support flow of the maintenance organization. The measure of cost is the total investment in LRU's and SRU's, which are to be distributed in the maintenance organization. Points on a C-E curve are established according to the following optimization criteria:

For a given value of the total investment, determine values on all stock levels such that the measure of effectiveness is minimized or maximized [Ref. 9].

8. Input Data

a. System Data*

The following types of end item data have to be specified [Ref. 9]:

(1) SRU-Data

- Number of different types of SRU
- For each type: replacement rates, and unit price

(2) LRU-Data

- Number of different types of LRU
- For each type: replacement rates, and unit price
- For each type that is modularized into SRU's: identification of those types of SRU it contains, and the number of units of every such type

(3) System-Data

- Number of different types of systems

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*An example of system data (with 3 systems) is included in Appendix B.

- For each type: identification of those types of LRU it contains, and the number of units of every such type

b. Support Organization Data

(1) <u>Demand Generating Stations, DGS</u>

They are shown as DGS-1 through DGS-4 in Figure 6. The following types of input-data must be specified for each Demand Generating Station, DGS [Ref. 9]:

- A reference to the nearest superior Support Station, SS.
- Identification of the different types of systems allocated to the DGS, and the number of each. Each system is also given a specific "utilization rate", as mentioned above.
- Fault location time.
- Time to repair the system by removing and replacing a defective LRU including subsequent check-out time.
- Time to have a spare unit delivered from the superior Support Station, given no shortage exists.

(2) <u>Support Station, SS</u>

They are shown as SS-1 through SS-8 in Figure 6. The following types of input-data must be specified for each Support Station, SS [Ref. 9]:

- A reference to one or several other Support Stations, to which propagated demands are addressed.
- A discrete propagated demand probability distribution, defined on those other Support Stations.

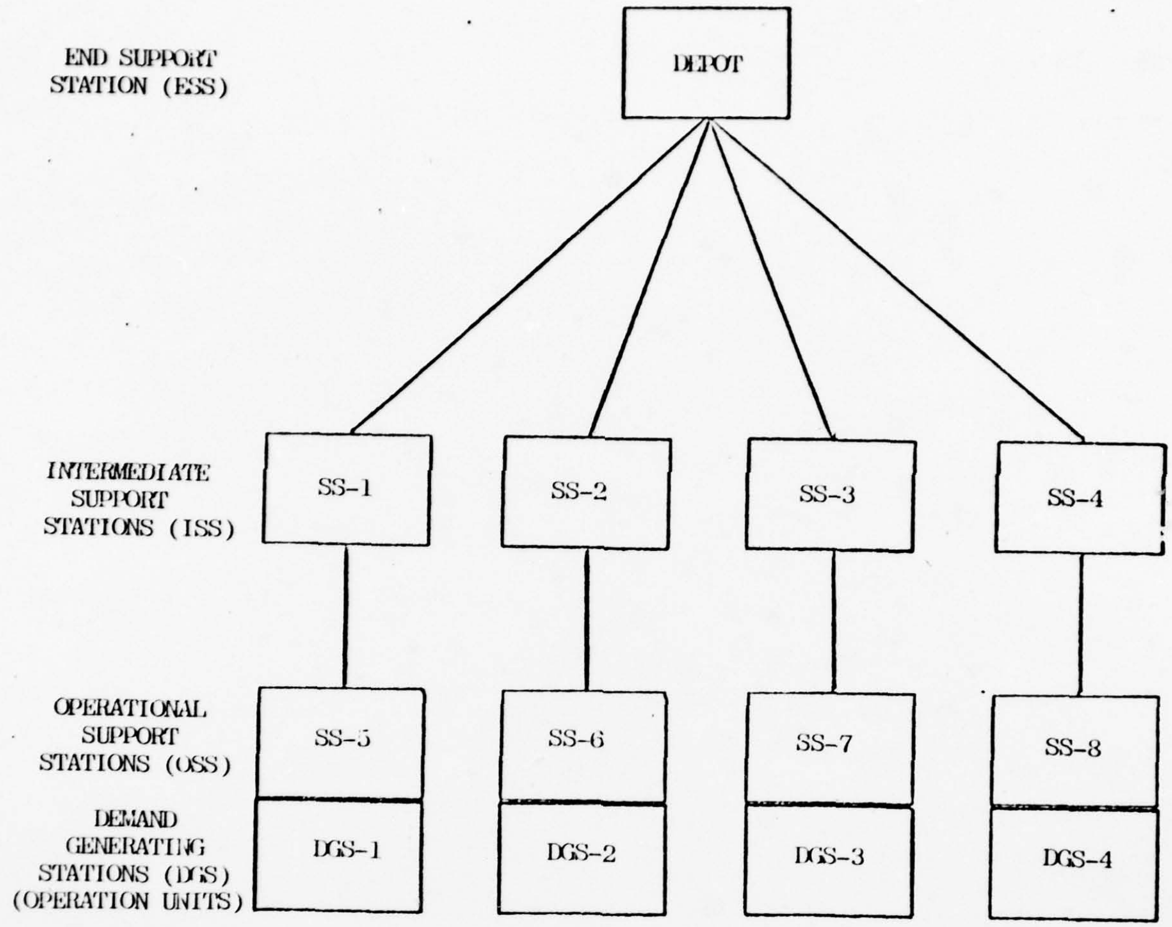

Figure 6. An example of maintenance and supply support organization for OPUS model.

- Identification of the different types of LRU and/or SRU which may be kept in stock. Each of these types has a specific repair-factor, which is the proportion of defective units that are to be repaired at this station.
- Fault isolation time for every type of LRU and SRU.
- Time for removing and replacing a defective unit, including subsequent check-out time.
- Time to repair a LRU or SRU, if repaired at this station.
- Time to have a spare unit delivered from the superior Support Station, given no shortage exists there.

(3) End Support Station, ESS (Depot Level)

It is shown as Depot in Figure 6. An End Support Station is similar to a Support Station, with the exception that demand is not propagated to any other Support Station [Ref. 9].

9. Related Models

For large problems that OPUS VII cannot handle in a single run, the system can be divided to several sub-systems (at the LRU's level). The output for each sub-system from the OPUS VII program is used as an input to a program named OPUS VII-W, which gives the total results for the original problem. (The output from OPUS VII when defined is in the form of punched cards.) [Ref. 8]

C. METRIC—A MULTI-ECHELON TECHNIQUE FOR RECOVERABLE ITEM CONTROL

1. Introduction

The USAF has provided the RAND Corporation with a unique opportunity to study a logistics system in detail and to develop some cost-effectiveness management techniques. It seems that the major factors that have made it possible for the RAND Corporation to develop these models are:

- Air Force funds over a 15-year period; and
- a broad charter from the Air Force to investigate problems that RAND feels are important [Ref. 10].

The family of models appears to be general enough to be applicable to other military services, to contractors who are concerned with ILS, and to medium-sized companies engaged in manufacturing and distribution.

The models are supply related, but in the broadest sense, they include maintenance and operations. They address the problem of what and when to buy, where to place material, and where and when to repair.

Each model is designed to run on a computer. They are analytic and normative in the sense that they can analyze alternative support situations.

The models are based on and developed from the Base Stockage Model (BSM) developed at RAND. The BSM optimizes budget allocation across a group of repairable spare parts used at one base. It was proved that the potential dollar savings possible using the BSM were enormous [Ref. 10].

Several important breakthroughs by the RAND staff enabled the construction of the models. To mention only two of them: (1) a practical formulation of a two-echelon problem where the stock levels at the several bases and the supporting depot are jointly optimized over a group of items; (2) a Bayesian procedure that leads to significantly better decisions for items with low demand (the majority of items) [Ref. 11].

2. The Models

The family of integrated support models developed by RAND is described in the following table [Ref. 10]:

TABLE I. Metric Family Models

MODEL	NAME	SHORT DESCRIPTION
BSM	Base Stockage Model	Budget allocation optimization of repairable spare parts used at one base.
SCAM	Source-Coders Cost Analysis Model	Repair/Discard and Repair level decisions.
METRIC	Multi-Echelon Technique for Recoverable Item Control	Base-Depot supply system: - optimization of stock levels - allocation of fixed stock levels - evaluation (C-E) of given allocation of stock levels.
MINE	Multi-Indenture NORS Evaluator	Evaluation of the expected number of aircraft not operationally ready (NORS) due to supply.
RTM	Real-Time-METRIC	Complements METRIC in a centralized or "push" system for recoverable item distribution.
RPM	Repair-Priorities Model	Buy/Repair decisions. A variant of RTM which computes system "need" for each item over a planning period.

Of this family of models, METRIC is the best known and most applicable for provisioning problems. It is, though, controversial in the sense that it was the first model to consider the problem of multi-echelon, multi-item inventory control, and had some limitations that for some years made it useful only for a specific application (i.e. the USAF support organization) [Ref. 11]. As a result, other models were developed in order to give an answer to these limitations. Still other models were developed using approximations in order to decrease the computation requirements of the model and so to decrease the cost of computer runs with minor decrease in the accuracy. Basically, these models have the same features and assumptions associated with METRIC, but with improved mathematical development [Ref. 12].

These improved models are MOD-METRIC (Multi-Item, Multi-Echelon, Multi-Indenture Inventory System) and the Consolidated Support Model (CSM: A Three Echelon, Multi-Item Model for Recoverable Items) [Refs. 13 and 14].

CSM was developed recently and has not been implemented yet. The computer program for the model is undergoing final testing and validations at the USAF [Ref. 14].

MOD-METRIC, on the other hand, has been implemented by the USAF as the method for computing recoverable spare stock levels for the F-15 weapon system [Ref. 13]. MOD-METRIC is an extension of METRIC, which replaces METRIC and permits the explicit consideration of a mult-indenture structure. (This is, from the application point of view, the major difference between METRIC and MOD-METRIC. Therefore, in the further discussion only the acronym METRIC is used.) Another area in which MOD-METRIC differs from METRIC is in oneof the assumptions made in METRIC, namely that items are normally considered to be equally essential, while in

MOD-METRIC, because of the introduction of indentured parts structure, the essentiality in each level of items (LRU's/SRU's) may be defined differently [Ref. 13].

3. The Description of METRIC [Ref. 15]

METRIC is a model for determing both requirements and distribution of recoverable items in a two-echelon support organization (Fig. 7). The objective of this model is to determine the base and depot stock levels which minimize total expected base level backorders for a specific set of items and bases subject to an investment constraint.

a. Types of Problems

- Optimization of stock levels (depot and bases).
- Evaluation of the expected number of backorders for a fixed/given stock at bases and depot.
- Redistribution/Allocation to bases and depot of a given total stock, such that expected number of backorders is minimized.

These problems are important to solve at different stages of the system life cycle.

b. Measures of Effectiveness

The choices of C-E target is between

- Total dollars of investment, or
- Expected number of backorders per item.

An intermediate target may be one that reduces both backorders and investment. This can be done by changes in the problem structure and comparison between the results.

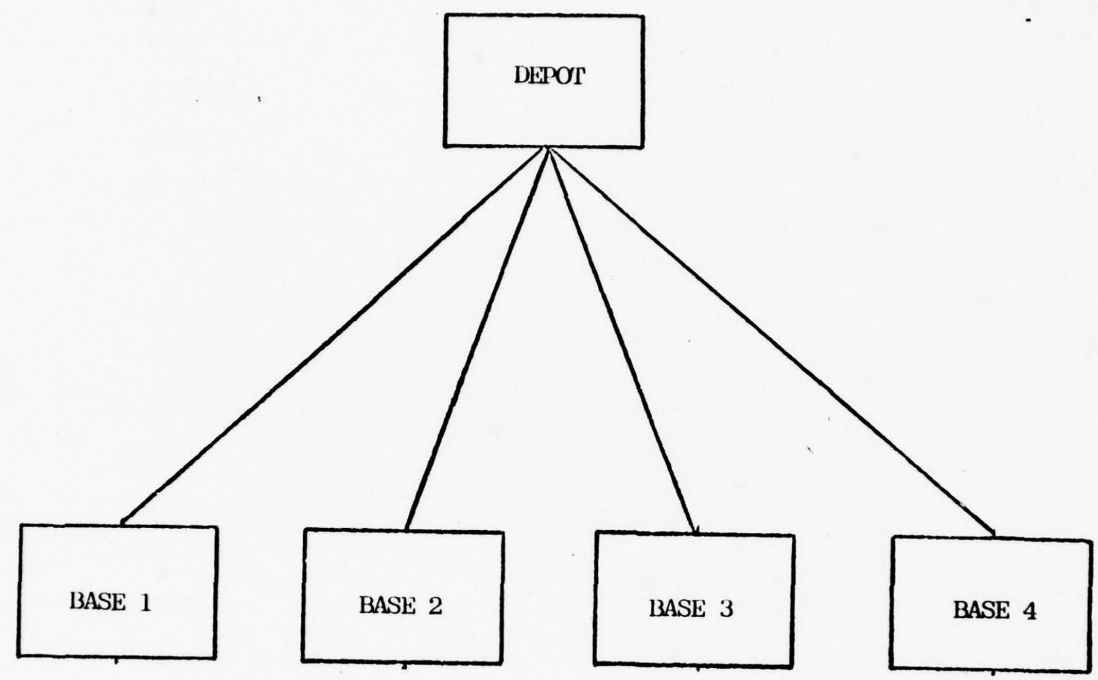

Figure 7. An example of maintenance and supply support organization for METRIC model.

c. Characteristics and Features

The METRIC family of models allows the user the consideration of a Base-Depot supply system for determination of stockage policy of recoverable items which are characterized by high cost/low demand. The model uses past demand data, but combines them with estimates of future program requirements to anticipate buildups or phaseouts. It can also handle, through a Bayesian procedure, initial estimated data with or without past demand. Finally, METRIC provides a device for analysis of alternative support structures, and different levels of support effectiveness depending on the weapon system.

d. Input Parameters

Various data are required as input parameters to the model. These are the average base and depot repair times for each item, unit costs, certain probability distribution parameters, Not-Reparable-This Station (NRTS) rates, and average order and ship times. Minimum and maximum stock levels can be specified. A full description of the input data and their preparation can be found in the documentation published by RAND on the METRIC COMPUTERPROGRAM [Ref. 16].

The input data is determined in three levels:

- By system
- By item
- By item and base.

The computerprogram requirements for the input data format are quite flexible (i.e. the model is not sensitive to input data).

e. Basic Assumptions

The following assumptions are made:

- The demand for each item is Compound Poisson distributed.
- There is no lateral resupply between bases.

- All failed parts(System/LRU's/SRU's) are repaired.
- A failure of one type of item is statistically independent of those that occur for any other type of item.
- Repair times are known and statistically independent.
- There is no batching of items before repair is started.
- The level at which repair is performed depends only on the complexity of the repair (and not on the workload at each level).

D. A COMPARISON BETWEEN OPUS AND MOD-METRIC

Since NPS did not have METRIC and its related computer programs, it was not possible in the time available for this research to prepare a complete comparison between the OPUS procedure and MOD-METRIC, using the same set (or equivalent set) of data. Fortunately, ITT Gilfillan is a user of both OPUS and METRIC. Therefore, their experience is used to summarize the major differences between these two models from an application point of view.

A comparison between the mathematical models and their underlined assumptions may be desirable for an operations research type study. On the other hand, it may be interesting to have an idea about the differences in the results from each model for the same (or equivalent) problem. In general, MOD-METRIC appears to give a solution which is about 20 to 30 percent more "expensive" (total investment) than the OPUS model, for the same situation. The reason is that the assumption about the demand distribution in METRIC is more realistic although it requres more input data.

Basically, the differences between characteristics of these two types of models are summarized in the following table:

TABLE II. Characteristic Comparison between OPUS and METRIC.

SUBJECT	OPUS	METRIC	REMARKS
1. Number of Echelons (Support Organization)	Multi	Two(1)	(1) CSM has 3 echelons
2. Number of Indentures (Items)	Two	Two(2)	(2) Only in CSM and MOD-METRIC
3. Data Preparation	Requires more familiarization for user to control the model	Easier for a beginner	
4. Order of Input	Sensitive(3)	Flexible	(3) The input data drive the program
5. End Item Operation Hours	Included	Included	
6. Total Cost of Operation (LCC)	Not included	Included	
7. Initialization of provisioning	Preferred	--	
8. Evaluation and Redistribution of fixed stock	--	Preferred	
9. Optimal Solution Description	Up to 100 points on each C-E curve	A single point for each set of parameters(4)	(4) The budget or the expected backorders are given

An implementation comparison is as follows:*

1. Data Base Construction

MOD-METRIC data base format is by far the most straightforward and was the easiest to implement at the onset of the study. It became readily obvious that this format would be cumbersome if larger systems were being analyzed where commonality existed between SRU's.

After a short familiarization of the OPUS data base structure, it was found to be more descriptive and flexible in comparison to the MOD-METRIC. For example, changing parameters for an SRU in the OPUS format requires changing one record (an 80 column card) where to make the same change in MOD-METRIC requires changing 2 records. From this small example, it can be seen that large data base management would be simpler and less time consuming task when using OPUS.

2. Analysis Techniques

MOD-METRIC optimizes one LRU/SRU group at a time for a given Maintenance and Support (M&S) organization. The M&S organization may be changes for each LRU/SRU group along with any or all program control parameters. The main disadvantage of this is the non-optimization between LRU/SRU groups and inability to sense this relationship in an overall system measure of effectiveness.

OPUS is a more sophisticated model offering extreme flexibility in M&S organization description and hardware configuration alternatives. OPUS optimizes the entire problem to any of several measures of effectiveness where MOD-METRIC will only optimize one LRU/SRU group. The

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*Implementation comparison was provided by ITT/Gilfillan Logistics Department, which uses both models.

optimization techniques used in OPUS allow for a more rapid and practical analysis versus the "number crunching" techniques used in MOD-METRIC.

In summary, both models have actually been used to solve provisioning problems. METRIC is more theoretically sophisticated than OPUS, while OPUS is more readily applied. The OPUS model seems to be better suited to the logisticians needs. Logistic effects of hardward design and deployment can bereadily quantified in spares investment for a given availability, waiting time, NORS or risk of shortage enabling OPUS to be used not only as a provisioning model but also as a "design tool".

E. RECOMMENDATIONS

It is easy to see that either OPUS or METRIC can provide important advantages to their users. The cost-effectiveness curves would be a great help in defending budget requests for spare parts provisioning. The utilization of parameters such as unit cost and method of demand prediction, together with parameters about maintenance and support organization, would provide better stockage decisions.

The procedure of calculating stock levels at the bases and the depots of a joint organization provides a much better policy than the usual single items, single inventory techniques. The utilization of one standard procedure for both requirements and distribution should help to solve many of the interface problems that exist in the logistics support environment. By using these types of models to make decisions during the system design phase, as an iterative proces between the designers and the logistics people, they should improve some of the design parameters in conjunction with the logistics support requirements and, by so doing, they should improve the total life cycle cost of the weapon system.

VI. UTILIZATION OF OPUS

In this part of the thesis, the OPUS model is utilized to make a sensitivity analysis of the structure of the maintenance and support organization. Because of the difficulty in gathering real world data for computer runs, hypothetical data based on realistic assumptions have been generated. In addition, a few assumptions are made for the analysis.

- Equipment systems are considered to be in existence (they are already manufactured), thus system data is known.
- The inventory deployment policy is considered known (which system, how many, to which DGS).

Thus, the purpose of the analysis is to determine the organizational structure and repair and stockage policy for each station that would result in the highest effectiveness figure to the user. This effectiveness figure is computed for systems at the operational site.

The main idea was to illustrate the analysis results to the reader. However, some difficulties were encountered in the computer outputs when the OPUS was run on the IBM 360 at the Naval Postgraduate School. (The program was orginally programmed for the CDC computer in Sweden.) Thus, what was done, including some computer outputs (in Appendix B), is presented below.

A. SYSTEM DATA

Three systems are used in the analysis. All of them are considered electronic communication systems, are called SYSTEM 1, SYSTEM 2, and

SYSTEM 3 and represent a High Frequency (HF), an Ultra High Frequency (UHF), and a Very High Frequency (VHF) unit respectively.

There are 37 different types of SRU's that constitute 20 different types of LRU's. Table III shows which type of SRU's and quantities of each type are in each LRU. For example, LRU 1 has no SRU's, LRU 2 has two of SRU 1, one of SRU 2, one of SRU 3 and two of SRU 4 in it. Table IV shows the price and the failure of each SRU. For example, SRU 1 costs $100 and its failure rate is 0.2 in a million hours.

In the same manner, Table V shows the LRU's constituting a system and their quantities. For example, SYSTEM 1 consists of one of each LRU's 1 through 10. Table VI(a) shows LRU's and VI(b) shows system price and failure rate data, as in Table IV for SRU's.

B. OPERATIONAL DATA

There are four types of ships; Destroyers (DD), Mine Sweepers (MS), Submarines (SS) and Fast Patrol Boats (FP).

There are 15 of DD, 20 of MS, 10 of SS and 20 of FP. Each ship is considered to have two units, one operation unit (a DGS) and an on-board support station (an OSS). For example, a DD contains a Destroyer Maintenance Unit (DDM) plus a Destroyer Operation Unit (DDO). Although a ship's mission profile is fed to the computer as support station data, it is included here in operational data.

1. Destroyer Operation Unit (DDO)

This unit has three SYSTEM 1, three SYSTEM 2, and one SYSTEM 3 and their utilization rates are 40% of mission time for each SYSTEM 1, 40% of mission time for each SYSTEM 2, and 75% of mission time for SYSTEM 3. Mission time for a DD(DDM + DDO) is 168 hours; this means

TABLE III. SRU Combination for each LRU.

LRU \ SRU	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
1																																					
2	2	1	1	2																																	
3					2	2																															
4						2	3																														
5								1	2	1	2																										
6									4		3	2																									
7												1	1	2																							
8												3			2	1																					
9																	1	2	2																		
10																																					
11																																					
12																				2	2	1															
13												2											2	2													
14																									1	2	2										
15																												2	1								
16																																					
17																						1								2	2						
18												1																				2	2				
19																																		1	2	2	
20																													1								2

One can notice that the program begins to violate stockage policy

TABLE IV. SRU Price and Failure Rate Data

SRU	$/UNIT	FAILURE RATE (Failures/10^6 Hours)
1	100	9.2
2	425	11.5
3	375	6.9
4	25	4.6
5	900	39.2
6	375	16.8
7	250	10.7
8	650	30.0
9	325	4.2
10	450	12.8
11	100	17.1
12	100	5.5
13	150	7.5
14	250	9.9
15	950	50.2
16	800	14.7
17	375	9.2
18	250	11.0
19	500	30.4
20	375	57.8
21	200	71.0
22	50	5.2
23	400	59.0
24	250	96.3
25	75	24.5
26	55	19.1
27	100	36.8
28	250	58.7
29	190	106.6
30	87	26.6
31	63	75.8
32	77	33.8
33	98	79.0
34	20	17.7
35	55	26.6
36	35	13.8
37	45	27.1

TABLE V. LRU Combination for Each System

LRU \ System	1	2	3
1	1		
2	1		
3	1		
4	1		
5	1		
6	1		
7	1		
8	1		
9	1		
10	1		
11		1	1
12		1	
13		1	
14		1	
15		1	
16		1	1
17			1
18			1
19			1
20			1

TABLE VI. LRU and System Price and Failure Rate Data

LRU	$/UNIT	FAILURE RATE (Failures/10^6 Hours)
1	150	6.6
2	1050	46.2
3	2550	112.2
4	1500	66.0
5	1950	85.8
6	1800	79.2
7	750	33.0
8	3000	132.0
9	1875	92.4
10	150	6.6
11	75	19.5
12	1200	263.3
13	1500	321.6
14	385	136.5
15	690	224.3
16	125	9.3
17	350	210.2
18	450	231.4
19	200	98.6
20	280	161.1

(a)

SYSTEM	$/UNIT	FAILURE RATE (Failures/10^6 Hours)
1	15000	695.0
2	4000	1000.0
3	1500	750.0

(b)

during this period of time this ship can not be supported by a higher echelon support station.

2. Mine Sweeper Operation Unit (MSO)

This unit has one of each SYSTEM, and their utilization rates are 100% for SYSTEMs 1 and 2 and 75% for SYSTEM 3. Mission time for a MIS (MS1 + MSO) is 24 hours and again it can not be supported by higher echelon support stations during this period.

3. Submarine Operation Unit (SSO)

The unit has two SYSTEM 1, three SYSTEM 2 and one SYSTEM 3 and their utilization rates are 60% for each SYSTEM 1, 40% for each SYSTEM 2 and 75% for SYSTEM 3. Mission time for a SS is 96 hours and it can not be supported by higher echelon during this period.

4. Fast Patrol Boat Operation Unit (FPO)

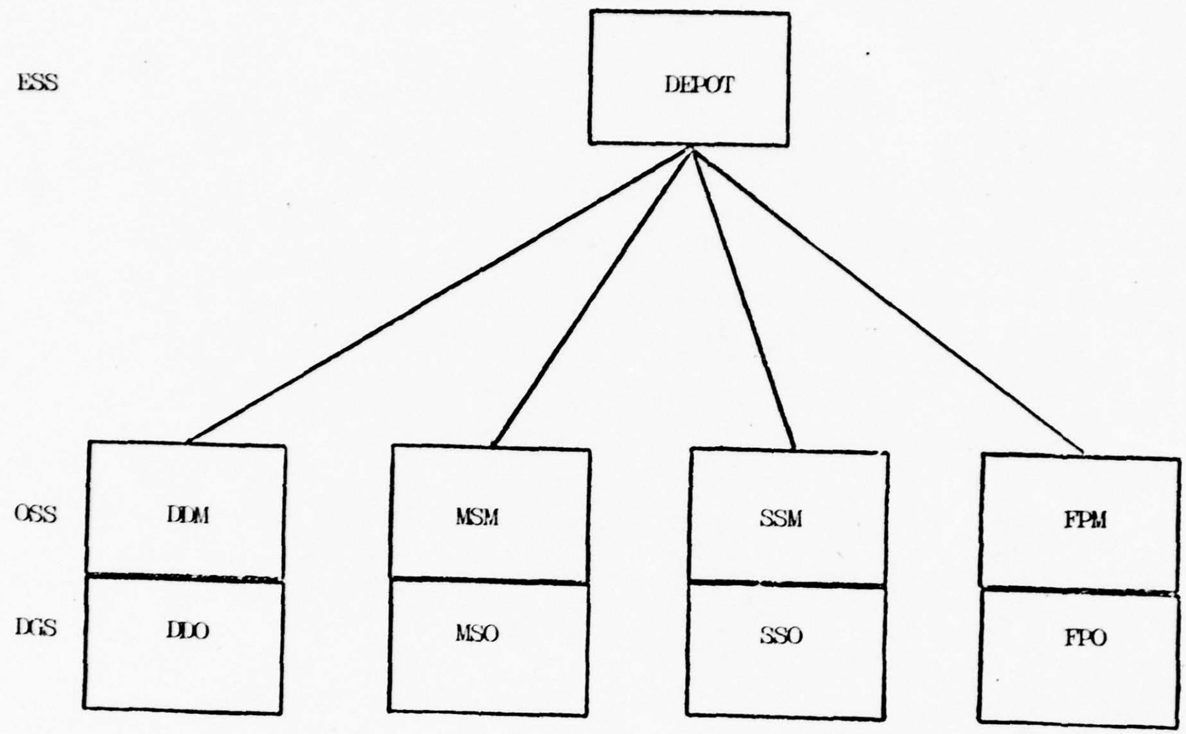
This unit has one SYSTEM 1, two SYSTEM 2 and one SYSTEM 3 and their utilization rates are 100% for SYSTEM 1, 60% for each SYSTEM 2 and 75% for SYSTEM 3. Mission time for a FP (FPM + FPO) is 36 hours and it can not be supported by higher echelon during this period.

C. MAINTENANCE AND SUPPORT ORGANIZATION DATA AND ANALYSIS

Three types of organizational structure are used for analysis. Beginning with Type A organization (which is the basic organizational structure with no intermediate level) the structure was gradually expanded. Each organizational structure is analyzed with several different repair and stockage policies.

1. Type A Organizational Structure

Figure 8 shows the Type A organizational structure. Four types of ships (OSS + DGS) are supported by the depot directly. The ships have no



SYSTEM QTY PER DGS				
SYSTEM 1	3	1	2	1
SYSTEM 2	3	1	3	2
SYSTEM 3	1	1	1	1
QTY OF SHIPS (DSS + DGS)	15	20	10	20

Figure 8. Type A Organizational Structure

maintenance capability, but they have a supply of LRU's. DDM carries 16 different types of LRU's, MSM and FPM 3 different types, and SSM 9 different types of LRU's.

The depot has a repair facility for both LRU's and SRU's, and its stockage policy is changed for analysis. First no stockage is allowed; later all LRU's and SRU's are allowed to be stocked.

2. <u>Type B Organizational Structure</u>

Figure 9 shows the Type B organizational structure. Four types of ships (OSS + DGS) are supported by four Intermediate Support Stations (ISS). Each ISS represents a tendership which supports only one type of ship (i.e. T1A supports only DD's). All tenderships (T1A, T2A, T3A, T4A) are supported by the depot.

Ship maintenance units (OSS) have the same characteristics as explained in organization Type A. For analysis, only ISS and depot (or End Support Station - ESS) stockage and repair policies have been subject to changes. In the first run, the following policy is tried:

o There is no stockage at the ESS but all LRU's and SRU's are repaired there and returned to original stockage stations.

o There is no repair at ISS's, but all LRU's and SRU's are stocked, and they are sent to ESS for repair.

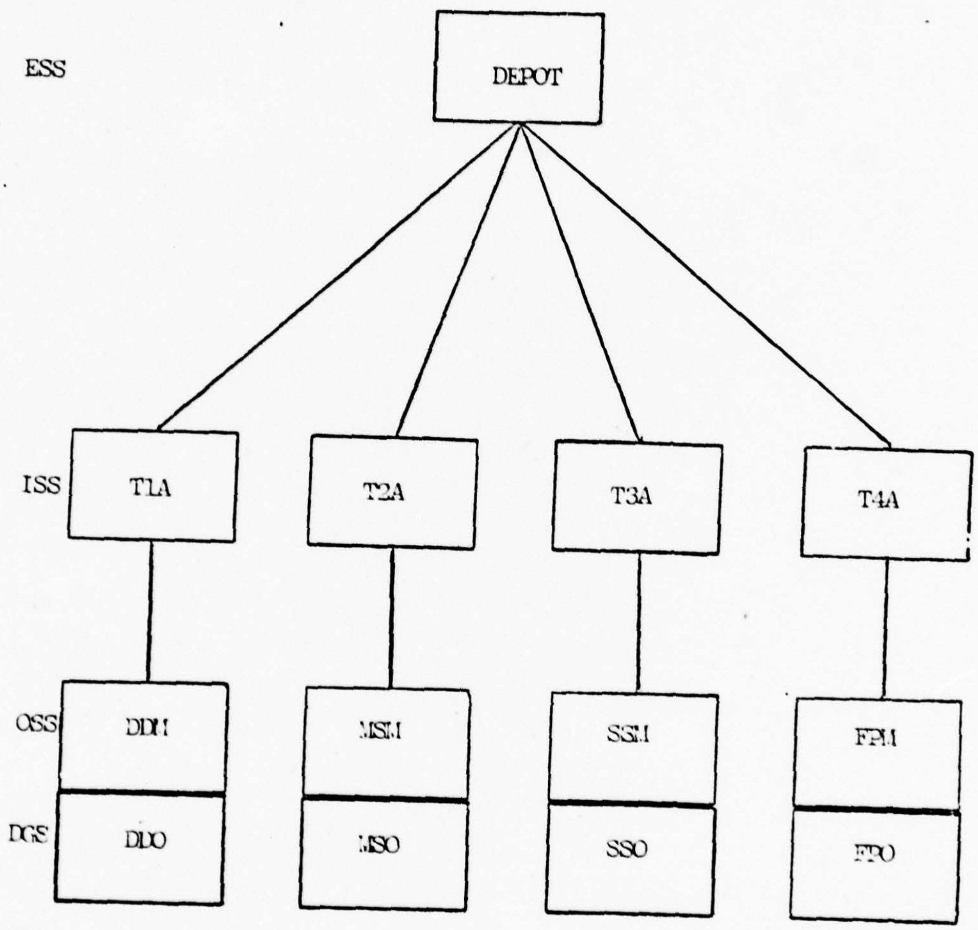
In the second run, some repair actions are added at the ISS level (e.g. 12 LRU's are allowed to be repaired at ISS's but if they can not be repaired at the ISS, then they are sent to ESS.)

In the third run all LRU's and SRU's are allowed to be stocked at ISS as well as some LRU's are allowed to be repaired at ISS's.

3. <u>Type C Organizational Structure</u>

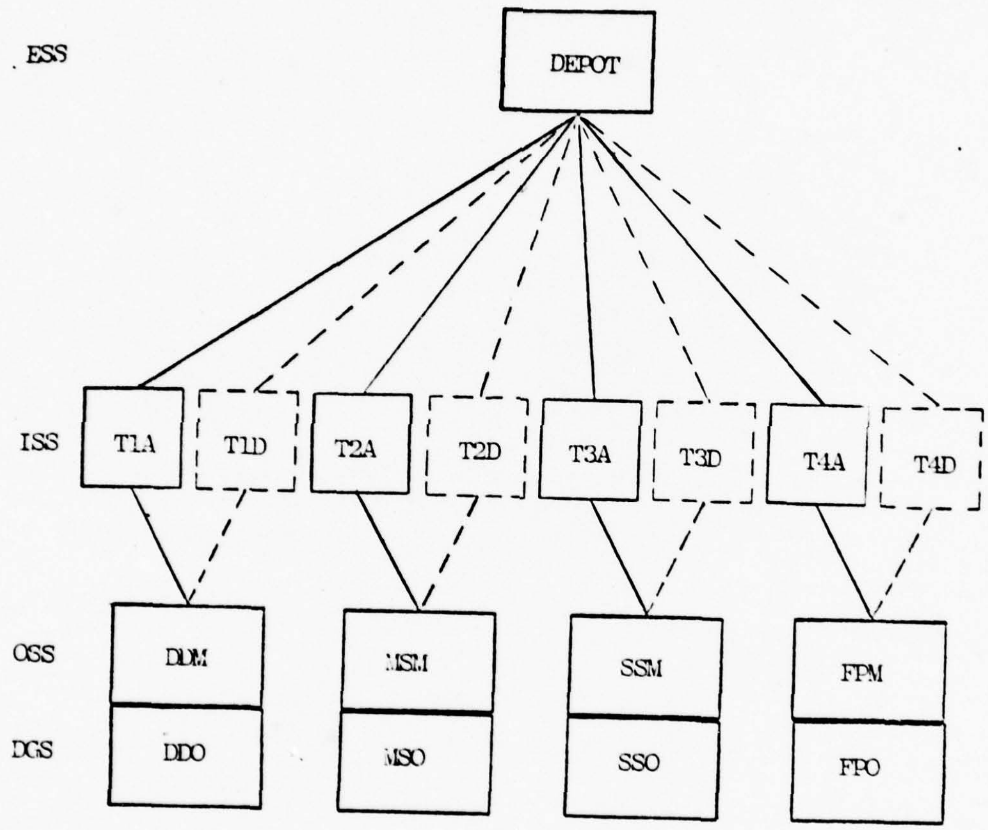
Figure 10 shows the Type C organizational structure. In this type of organization, the ships are allowed to go to ESS directly for

- There is no lateral resupply between bases.



SYSTEM QTY PER DGS				
SYSTEM 1	3	1	2	1
SYSTEM 2	3	1	3	2
SYSTEM 3	1	1	1	1
QTY OF SHIPS (OSS + DGS)	15	20	10	20

Figure 9. Type B Organizational Structure



SYSTEM QTY PER DGS				
SYSTEM 1	3	1	2	1
SYSTEM 2	3	1	3	2
SYSTEM 3	1	1	1	1
QTY OF SHIPS (OSS + DGS)	15	20	10	20

Figure 10. Type C Organizational Structure

support (the real life situation) by using "dummy" tenderships in the model (i.e. T1D, T2D, T3D, T4D). These dummy tenders had to be used because the model does not allow a station to be supported by second higher echelon without going through first higher echelon.

In this case one type of ship is supported by two different stations (e.g. a DD is supported by both T1A and T1D). Table VII gives for each ship the probability of being supported by either real tendership or dummy tendership. For example, a DD is supported by T1A with 0.75 probability or by T1D with 0.25 probability.

The same policies are tried for Type C as are tried for Type B organizational structure. In the first run, spare parts are stocked at ISS's and repaired at ESS. In the second run, repair of some (e.g. 12) LRU's are allowed at ISS's, and in the last run stockage of all LRU's and SRU's are allowed at ESS (Depot).

4. Analysis and Example

Table VIII shows a summary of the organizational structures which were to be analyzed. However, because of problems discovered with the OPUS computer program during the analysis, the work could not be completed. Table IX shows the problems discovered in each run.

Results of Run No. 3 in Table IX are presented in Appendix B. The input data for spare parts (LRU's and SRU's), for systems and for deployment, and organization structure data are presented in the first four pages. The next page shows the repair and stockage policy for each SRU and LRU at a support station. The repair policy figures are given as exponential numbers (0.1000 E 01 is equal to 1), a zero means there is no repair for the SRU or LRU at this station. For the stockage policy, a star (*) or (S) means that the SRU or LRU is allowed to be stocked at that station.

TABLE VII. Probability of Support for Each Ship by ISS's.

	T1A	T1D	T2A	T2D	T3A	T3D	T4A	T4D
DD	0.75	0.25						
MS			0.95	0.05				
SS					0.75	0.25		
FPB							0.99	0.01

TABLE VIII. Organizational Structures to be Analyzed

Run No.	Organization Structure Type	OSS	ISS	ESS
1	A	Some LRU's are stocked	-	No stock, but all LRU's and SRU's are repaired
2	A	"	-	All LRU's and SRU's are stocked and repaired
3	B	"	All LRU's and SRU's are stocked, but no repair	All LRU's and SRU's are repaired, but no stock
4	B	"	All LRU's and SRU's are stocked and 12 LRU's are repaired	"
5	B	"	"	All LRU's and SRU's are repaired, but no stock
6	C	"	All LRU's and SRU's are stocked, but no repair	All LRU's and SRU's are repaired, but no stock
7	C	"	All LRU's and SRU's are stocked and 12 LRU's are repaired	"
8	C	"	"	All LRU's and SRU's are stocked and repaired

TABLE IX. Results of Computer Outputs for Initial Provisioning (PROBLEM TYPE: 0)

Run No.	Organization Structure Type	Run No. at Table VIII	Number of LRU's to be stocked at an OSS	Stockage policy for LRU's at an OSS	COMPUTER OUTPUT RESULT	
					MOE: 0*	MOE: 2**
1	A	-	Exact number to be stocked	All are allowed to be stocked	The program defaulted	The program defaulted
2	A	1	Max. (20)	Some are defined not to be stocked	Defined policy is implemented. Normal Output	The program defaulted
3***	A	2	"	"	Some LRU's are stocked, although they are defined not to be stocked	Defined policy is implemented. Normal Output
4	B	-	Exact number to be stocked	All are allowed to be stocked	The program defaulted	The program defaulted
5	B .	3	Max. (20)	Some are defined not to be stocked	Some LRU's are stocked, although they are defined not to be stocked	Defined policy is implemented. Normal Output
6	B	4	"	"	"	"
7	B	5	"	"	"	"
8	C	-	Exact number to be stocked	All are defined to be stocked	The program defaulted	The program defaulted
9	C	6	Max. (20)	Some are defined not to be stocked	SOME LRU's are stocked, although they are defined not to be stocked. Availability suddenly drops down and later it begins to increase again while investment continues to increase	Defined policy is implemented. Normal Output
10	C	7	"	"	"	"
11	C	8	"	"	"	"

MOE: 0*: Expected Waiting Time (For All Support Stations)
MOE: 2**: Weighted Probability of Mission Failure Due to Shortage (For DGS)
Probability of Shortage Given a Demand (For OSS)
Expected Waiting Time (For ISS and ESS)
3***: Some output data are included in Appendix B for this analysis.

In the remaining pages, computed figures for optimization (Cost-Effectiveness) curves and allocation tables are presented. First the turn around time for SRU and LRU is presented followed by computed demand rates. The next three pages are optimization curves with explanations for them written on each page. Computation of a second optimization curve begins from circled points on the first curve and final allocation tables are for circled points on the third optimization curve. The circled point on upper left corner of each curve (near the top edge of the vertical axis) represents the first point on the table on the same page. Similarly the last circled point on the extreme right of the horizontal axis of each curve represents the last point on the table. The important thing on the curves is that the axes are not always scaled the same; the represent arbitrary values and not dollars for investment. That is why it is hard to determine investment and waiting time (or other effectiveness figures) from the curves by inspection, but the real values are given in the table presented on the same page. The figures in the C-E curves (like 1,2,3—6,7, etc.) show how many points there are in the area which is covered by the number. For example, circled number one (1) represents one point in this area.

The tables which follow these three curves given the allocation of each SRU and LRU to the support stations and the availability for each system at an operation unit (DGS), and other supplemental data. Total number for a SRU or LRU is computed as follows:

TOTAL = [The number at DEP] + 15 [The number at DDM]
+ 20 [The number at MSM] + 10 [The number at SSM]
+ 20 [The number at FPM]

One can notice that the program begins to violate stockage policy at Point No. 16 by stocking LRU 12 at SSM. At Point No. 17, it continues to violate stockage policy by stocking LRU 5 at MSM and FPM and at Point No. 30 (last allocation table), allocation is completely out of policy.

After results for MOE: 0 are presented, the results for MOE: 2 are given. Only the C-E curves and some allocation tables are included for MOE: 2. Stockage policy is implemented as it is defined in the stockage policy table.

5. Summary of Difficulties Encountered with the OPUS Computer Program

- When problem type zero (Initial Procurement) was run with MOE: 0 or MOE: 2 and when "the number of LRU's to be stocked" for an OSS was not defined as either the maximum number of LRU's or zero, the program defaulted and stopped.

- When problem type zero was run with MOE: 0, even though an LRU was defined "not to be stocked" in the stockage policy data for an OSS, the program eventually stocked it at that station.

- When there were 6 support stations in the organization structure, the program defaulted and stopped when it came to print the final (allocation) tables.

- When the "dummy" stations were added to the organization structure, availability suddenly dropped down and later began to increase while investment continued to increase.

- When problem type 10 (Replenishment Procurement of Spares) was run with MOE: 0 or MOE: 2, some LRU's were overstocked (more than 1000) at an OSS.

Since the OPUS program has also been installed at ITT/Gilfillan, they were asked to repeat the same computer runs. They obtained the same results and defaults. After a conference at which we jointly examined the results, we concluded that the OPUS computer program needs revision to overcome the problems noted.

VII. CONCLUSIONS

Since this thesis has considered two related subjects, the conclusions are made in two parts. The first part concerns a second user's position in spare part provisioning and the second part concerns maintenance related provisioning models and their utilization.

A. A SECOND USER AND SPARE PART PROVISIONING

1. Almost all the producer countries for major systems make major system decisions these days based on the total System Life Cycle concept and its associated Life Cycle Cost. But most of the "second user" countries are not aware of these facts and are still making comparisons between systems by considering their acquisition costs rather than their life cycle costs. The fact is that the cost accrued during the use period of a system is generally far greater than its acquisition cost. Thus the evaluation of a system should be made based on the total system life cycle and its associated cost.

2. As a part of the system life cycle, spare part provisioning is an important issue with respect to cost. With the exception of a few non-recurring activities in the system life cycle (e.g. acquisition of the system, building facilities for the system), provisioning is a recurring activity over the useful operational life of the system and naturally its cost is recurring too. Thus the system's requirements with respect to spare parts have to be analyzed, and the type of spare part and required quantity have to be carefully determined to make an efficient provisioning decision. This would keep the provisioning cost down each time spare part provisioning is done.

3. The procedure explained in paragraph (2) has to be considered even more importantly for repair parts because their impact on provisioning cost is more significant than for consumable parts.

4. A second user has to determine his needs for spare parts by considering his environment (Logistics Support Capabilities, Maintenance Policies) rather than to do whatever the first user does.

B. MAINTENANCE-RELATED PROVISIONING MODELS AND THEIR UTILIZATION

1. These models have shown potential for giving more informative results for provisioning decisions. But the assumptions made in these models have to be evaluated very carefully to make them more applicable to the real world.

2. The models should be analyzed by operations researchers working for the user to provie the suitability of their mathematical formulations and assumptions in order to determine their applicability before their utilization.

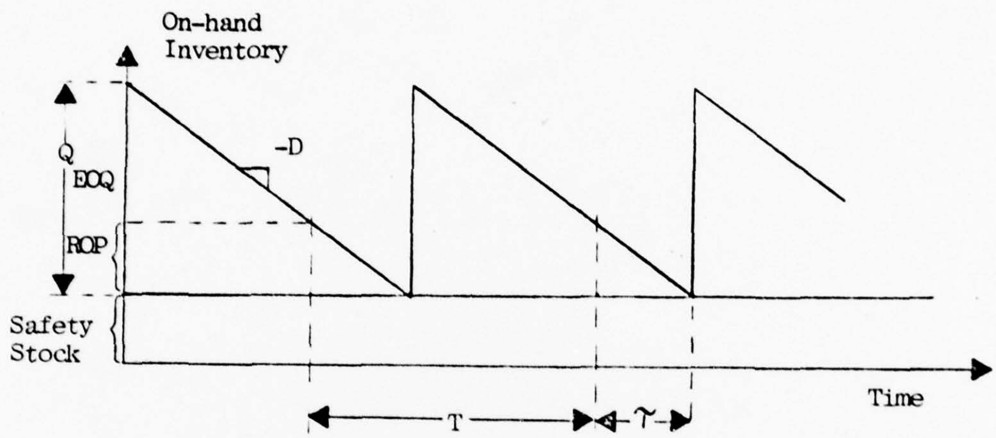
3. The models should be made more versatile and their restrictions should be minimized so that applications in the real world can be expanded.

4. The models should be utilized as a decision-making aid, not as the decision itself.

5. Properly applied, the models can be used as a design aid to optimize the system by the producer as well as to optimize the support organization and its associated policies by the user.

APPENDIX A

A. ECONOMIC ORDER QUANTITY (EOQ) MODEL: [Ref. 17]



Q_{EOQ} = Economic Order Quantity

D = Demand Rate

τ = Procurement Lead Time

T = Cycle Time

ROP = Reorder Point

A = Fixed Cost to Place an Order

C = Item Unit Cost

I = Interest Rate = $I_1 + I_2 + I_3$

I_1 = Opportunity Cost

I_2 = Storage Cost

I_3 = Obsolescence and Shrinkage Cost

K_{EOQ} = Annual Cost

$$Q_{EOQ} = \sqrt{\frac{2(A)(D)}{(I)(C)}}$$

$$K_{EOQ} = \frac{(A)(D)}{Q_{EOQ}} + \frac{(I)(C)(Q_{EOQ})}{2}$$

(a) If $\tau < T$ then $ROP = (D)(\tau)$

(b) If $\tau > T$ then $ROP = [\tau - (N)(T)](D)$

where N = Number of Complete Cycles in τ and is the largest whole number $\leq \frac{\tau}{T}$

B. TIME-WEIGHTED AVERAGE MONTH'S PROGRAMS (TWAMP) [Ref. 18]

The determination of system stock is based upon the time-weighted average month's program (TWAMP) through the program time base (PTB). The PTB is determined by the estimation of the value of annual demand (VAD). If the VAD is greater than $500,000 a PTB of three months is used. For a VAD between $500,000 and $50,000 a PTB of six months is used and for any VAD less than $50,000 a 12 month PTB is used. Deliveries are assumed to occur in mid-month; thus, the cumulative program buildup (Bm) up to and including the last month (m) in PTB is defined as follows:

$$Bm = I_K/2 \quad \text{when } m = 1 \quad \text{and}$$

$$Bm = \left(\sum_{K=1}^{m-1} I_K\right) + Im/2 \quad \text{when } m \geq 2$$

Where: K,m are month indices

I_K = number of specified operational units of program by which the program is incremented during month K in the PTB.

TWAMP is computed by:

$$TWAMP = \frac{\sum_m Bm}{PTB}$$

Given an example of the following operational unit deliveries in a program the TWAMP is computed as follows:

Month	O	N	D	J	F	M	A	M	J	J	A	S
No. of Month	1	2	3	4	5	6	7	8	9	10	11	12
I_K	1	2	2	2	2	3	4	4	4	5	0	0
Bm	.5	2	4	6	8	10.5	14	18	22	26.5	29	29

PTB	TWAMP
3 Month	(.5+2+4)/3 = 2.2
6 Month	(.5+2+4+6+8+10.5)/6 = 5.2
12 Month	(.5+2+4+6+8+10.5+14+18+22+26.5+29+29)/12 = 14.1

In order to derive the quantitative level requirements for an item the TWAMP is multiplied by the number of months for which support is being computed.

PTB	TWAMP	PCLT (12 Mos)
3 Months	2.2	26.4
6 Months	5.2	62.4
12 Months	14.1	169.2

Forecast for demand during Procurement Lead Time (PCLT) on an item with a Best Replacement Factor (BRF) of 1.5 would be determined as follows:

PTB	Item PCLT	times	BRF	times	Factors for Year	Demand Forecast
3 Months	26.4		1.5		4	158.4
6 Months	62.4		1.5		2	187.2
12 Months	169.2		1.5		1	253.8

C. COST DIFFERENCE MODEL (COSDIF) [Ref. 18]

$$COSDIF = (Fo/F_D)[C_p + 2HU\ (R + Q)]$$

$$+ (1 - Fo/F_D)[C_p(D/Q) + HU(S + Q/2) + C_I F_D]$$

$$- (1 - Fo/F_D)[KC_pF_D + PDU + F_DL\ MAX\ ({}^{\lambda E/115}_{or\ HUD}/365F_D)]$$

Where:

Fo/F_D = probability of zero demand in coming two years, given annual frequency of demand F_D

C_p = ICP cost of procure

H = holding cost rate

U = item unit price

R = reorder level

Q = economic order quantity

D = forecast of annual demand

S = Safety level

C_I = cost of issue

F_D = annual frequency of demand

K = conversion factor to adjust procurement cost for non-stocked items

P = increase in item unit price due to spot buy

L = procurement lead time

λ = shortage cost

E = item essentiality

115 is based on average backorder time outstanding in days

The first part of the COSDIF formula is the probability of no demand in two years multiplied by the expected cost to hold that item in inventory for two years. The next part of the formula is the probability of demand in two years multiplied by the holding cost for that item for one year. The third part of the formula is the probability of demand in two years multiplied by the expected cost of not stocking the item and needing it.

APPENDIX B

OPUS7
*****
*****

Selected output data from the computer run.

INPUT DATA
****

***** APPENDIX: B, OPUS MODEL, ORGANIZATION TYPE: A, INIT. PROC., MOE TYPE: 0, ******

PROBLEM TYPE = 0

: INITIAL PROCUREMENT OF SPARES

OPTIMIZATION CRITERIA :

: EXPECTED WAITING TIME (ALL SUPPORT STATIONS).

INVESTMENT INTERVAL

MINIMUM = 0.0
MAXIMUM = 10000000.0

EQUIPMENT DATA
****

SRU DATA

NUMBER DIFFERENT 37

SEC NO.	DENOM	COST	FAILURE RATE E-6	APPLI CATION FACTOR	T A T END SUPP STATION	NUMBER IN INVENTORY
1	SRU 1	100.0	9.20	1.000000	173.0	0
2	SRU 2	425.0	11.50	1.000000	173.0	0
3	SRU 3	375.0	6.90	1.000000	173.0	0
4	SRU 4	25.0	4.60	1.000000	173.0	0
5	SRU 5	900.0	39.20	1.000000	173.0	0
6	SRU 6	375.0	16.80	1.000000	173.0	0
7	SRU 7	250.0	10.70	1.000000	173.0	0
8	SRU 8	650.0	30.00	1.000000	173.0	0
9	SRU 9	325.0	4.20	1.000000	173.0	0
10	SRU 10	450.0	12.80	1.000000	173.0	0
11	SRU 11	100.0	17.10	1.000000	173.0	0
12	SRU 12	100.0	5.50	1.000000	173.0	0
13	SRU 13	150.0	7.50	1.000000	173.0	0
14	SRU 14	250.0	9.90	1.000000	173.0	0
15	SRU 15	950.0	50.20	1.000000	173.0	0
16	SRU 16	800.0	14.70	1.000000	173.0	0
17	SRU 17	375.0	9.20	1.000000	173.0	0
18	SRU 18	250.0	11.00	1.000000	173.0	0
19	SRU 19	500.0	30.40	1.000000	173.0	0
20	SRU 20	375.0	57.80	1.000000	173.0	0
21	SRU 21	200.0	71.00	1.000000	173.0	0
22	SRU 22	50.0	5.20	1.000000	173.0	0
23	SRU 23	400.0	59.00	1.000000	173.0	0
24	SRU 24	250.0	96.30	1.000000	173.0	0
25	SRU 25	75.0	24.50	1.000000	173.0	0
26	SRU 26	55.0	19.10	1.000000	173.0	0
27	SRU 27	100.0	36.80	1.000000	173.0	0
28	SRU 28	250.0	58.70	1.000000	173.0	0
29	SRU 29	190.0	106.60	1.000000	173.0	0
30	SRU 30	87.0	26.60	1.000000	173.0	0
31	SRU 31	63.0	75.80	1.000000	173.0	0
32	SRU 32	77.0	33.80	1.000000	173.0	0
33	SRU 33	98.0	79.00	1.000000	173.0	0
34	SRU 34	20.0	17.70	1.000000	173.0	0
35	SRU 35	55.0	26.60	1.000000	173.0	0
36	SRU 36	35.0	13.80	1.000000	173.0	0
37	SRU 37	45.0	27.10	1.000000	173.0	0

LRU DATA

NUMBER DIFFERENT 20

SEC NO.	DENOM	COST	FAILURE RATE E-6	APPLICATION FACTOR	T A T END SUPP STATION	NUMBER IN INVENTORY	NUMBER DIFFERENT SRU	NUMBER PER SYSTEM SYSTEM 1	SYSTEM 2	SYSTEM 3
1	LRU 1	150.0	6.60	1.000000	172.0	0	0	1	0	0
2	LRU 2	1050.0	46.20	1.000000	172.0	0	4	1	0	0
3	LRU 3	1550.0	112.20	1.000000	172.0	0	2	1	0	0
4	LRU 4	1500.0	66.00	1.000000	172.0	0	2	1	0	0
5	LRU 5	1950.0	85.80	1.000000	172.0	0	4	1	0	0
6	LRU 6	1800.0	79.20	1.000000	172.0	0	3	1	0	0
7	LRU 7	750.0	33.00	1.000000	172.0	0	3	1	0	0
8	LRU 8	3000.0	132.00	1.000000	172.0	0	3	1	0	0
9	LRU 9	1875.0	52.40	1.000000	172.0	0	3	1	0	0
10	LRU 10	150.0	6.60	1.000000	172.0	0	0	1	0	0
11	LRU 11	75.0	19.50	1.000000	172.0	0	0	0	1	1
12	LRU 12	1200.0	263.30	1.000000	172.0	0	3	0	1	0
13	LRU 13	1500.0	321.60	1.000000	172.0	0	3	0	1	0
14	LRU 14	385.0	136.50	1.000000	172.0	0	3	0	1	0
15	LRU 15	690.0	224.30	1.000000	172.0	0	2	0	1	0
16	LRU 16	125.0	9.30	1.000000	172.0	0	0	0	1	1
17	LRU 17	350.0	210.20	1.000000	172.0	0	3	0	0	1
18	LRU 18	450.0	231.40	1.000000	172.0	0	3	0	0	1
19	LRU 19	200.0	98.60	1.000000	172.0	0	3	0	0	1
20	LRU 20	280.0	161.10	1.000000	172.0	0	2	0	0	1

LRU 2 CONSTITUTES
2 OF SRU 1
1 OF SRU 2
1 OF SRU 3
2 OF SRU 4

LRU 3 CONSTITUTES
2 OF SRU 5
2 OF SRU 6

LRU 4 CONSTITUTES
2 OF SRU 6
3 OF SRU 7

LRU 5 CONSTITUTES
1 OF SRU 8
2 OF SRU 9
1 OF SRU 10
2 OF SRU 11

LRU 6 CONSTITUTES
4 OF SRU 9
3 OF SRU 11
2 OF SRU 12

LRU 7 CONSTITUTES
1 OF SRU 12
1 OF SRU 13
2 OF SRU 14

LRU 8 CONSTITUTES
3 OF SRU 12
2 OF SRU 15
1 OF SRU 16

LRU 9 CONSTITUTES
1 OF SRU 17
2 OF SRU 18
2 OF SRU 19

LRU 12 CONSTITUTES
2 OF SRU 20
2 OF SRU 21
1 OF SRU 22

LRU 13 CONSTITUTES
2 OF SRU 12
2 OF SRU 23
2 OF SRU 24

LRU 14 CONSTITUTES
1 OF SRU 25
2 OF SRU 26
2 OF SRU 27

LRU 15 CONSTITUTES
2 OF SRU 28
1 OF SRU 29

LRU 17 CONSTITUTES
1 OF SRU 22
2 OF SRU 30
2 OF SRU 31

LRU 18 CONSTITUTES
1 OF SRU 12
2 OF SRU 32
2 OF SRU 33

LRU 19 CONSTITUTES
1 OF SRU 34
2 OF SRU 35
2 OF SRU 36

LRU 20 CONSTITUTES
1 OF SRU 29
2 OF SRU 37

SYSTEM DATA

NUMBER DIFFERENT 3

SEC NO.	DENOM	COST	FAILURE RATE E-6	APPLICATION FACTOR	NUMBER DIFFERENT LRU
1	SYSTEM 1	15000.0	655.00	1.000000	10
2	SYSTEM 2	4000.0	1000.00	1.000000	6
3	SYSTEM 3	1500.0	750.00	1.000000	6

BREAKDOWN NUMBER	SYSTEM 1 LRU DENOM
1	LRU 1
1	LRU 2
1	LRU 3
1	LRU 4
1	LRU 5
1	LRU 6
1	LRU 7
1	LRU 8
1	LRU 9
1	LRU 10

BREAKDOWN NUMBER	SYSTEM 2 LRU DENOM
1	LRU 11
1	LRU 12
1	LRU 13
1	LRU 14
1	LRU 15
1	LRU 16

BREAKDOWN NUMBER	SYSTEM 3 LRU DENOM
1	LRU 11
1	LRU 16
1	LRU 17
1	LRU 18
1	LRU 19
1	LRU 20

DEPLOYMENT AND ORGANIZATION DATA

SUPPORT STATIONS

SEC NO.	DE-NOM	QUAN-TITY	SUPPOR-TED BY SEQ. NO.	TRANSPOR-TATION TIME - RETURN TRIP	NUMBER LRU TYPES TO BE STOCKED	ADMINI-STRATIVE DELAY TIME	FAULT ISOLATION TIME FOR LRU	TIME TO REPLACE SRU	NUMBER SRU TYPES TO BE STOCKED	ADMINI-STRATIVE DELAY TIME	FAULT ISOLATION TIME FOR SRU	TIME TO REPLACE PART	PROPORTION OF PROPAGATED SUPPORT FLOW
1	CEP	1	0	8760.00	20	168.00	3.00	1.00	37	168.00	2.00	3.00	1.0000
2	DOM	15	1	168.00	20	0.0	0.0	0.0	0	0.0	0.0	0.0	1.0000
3	MSM	20	1	24.00	20	0.0	0.0	0.0	0	0.0	0.0	0.0	1.0000
4	SSM	10	1	96.00	20	0.0	0.0	0.0	0	0.0	0.0	0.0	1.0000
5	FPM	20	1	36.00	20	0.0	0.0	0.0	0	0.0	0.0	0.0	1.0000

DEMAND GENERATING STATIONS

SEC NO.	DE-NOM	QUAN-TITY	SUPPOR-TED BY SEQ.NO.	TRANSPOR-TATION TIME RETURN TRIP	NUMBER OF DIFFE-RENT SYSTEMS	FAULT ISOLATION TIME FOR SYSTEM	TIME TO REPLACE LRU	PROPORTION OF PROPAGATED SUPPORT FLOW
6	DDO	1	2	1.00	3	0.0	0.0	1.0000
7	MSO	1	3	0.50	3	0.0	0.0	1.0000
8	SSO	1	4	1.00	3	0.0	0.0	1.0000
9	FPO	1	5	0.50	3	0.0	0.0	1.0000

D G S	SYSTEM	NUMBER	APPL. FACTOR
DDO	SYSTEM 1	3	0.40000
DDO	SYSTEM 2	3	0.40000
DDO	SYSTEM 3	1	0.75000
MSO	SYSTEM 1	1	1.00000
MSO	SYSTEM 2	1	1.00000
MSO	SYSTEM 3	1	0.75000
SSO	SYSTEM 1	2	0.60000
SSO	SYSTEM 2	3	0.40000
SSO	SYSTEM 3	1	0.75000
FPO	SYSTEM 1	1	1.00000
FPO	SYSTEM 2	2	0.60000
FPO	SYSTEM 3	1	0.75000

REPAIR POLICY

FROPORTION OF DEFECTIVE SPARES TO BE REPAIRED AT THE DIFFERENT SUPPORT STATIONS

		DEP	DDM	MSM	SSM	FPM
LRU	1	0.1000E 01	0.0	0.0	0.0	0.0
LRU	2	0.9957E 00	0.0	0.0	0.0	0.0
LRU	3	0.9992E 00	0.0	0.0	0.0	0.0
LRU	4	0.9955E 00	0.0	0.0	0.0	0.0
LRU	5	0.9953E 00	0.0	0.0	0.0	0.0
LRU	6	0.9937E 00	0.0	0.0	0.0	0.0
LRU	7	0.9935E 00	0.0	0.0	0.0	0.0
LRU	8	0.9970E 00	0.0	0.0	0.0	0.0
LRU	9	0.9957E 00	0.0	0.0	0.0	0.0
LRU	10	0.1000E 01	0.0	0.0	0.0	0.0
LRU	11	0.1000E 01	0.0	0.0	0.0	0.0
LRU	12	0.9981E 00	0.0	0.0	0.0	0.0
LRU	13	0.1000E 01	0.0	0.0	0.0	0.0
LRU	14	0.9995E 00	0.0	0.0	0.0	0.0
LRU	15	0.9987E 00	0.0	0.0	0.0	0.0
LRU	16	0.1000E 01	0.0	0.0	0.0	0.0
LRU	17	0.9990E 00	0.0	0.0	0.0	0.0
LRU	18	0.9987E 00	0.0	0.0	0.0	0.0
LRU	19	0.9990E 00	0.0	0.0	0.0	0.0
LRU	20	0.9981E 00	0.0	0.0	0.0	0.0
SRU	1	0.1000E 01	0.0	0.0	0.0	0.0
SRU	2	0.1000E 01	0.0	0.0	0.0	0.0
SRU	3	0.1000E 01	0.0	0.0	0.0	0.0
SRU	4	0.1000E 01	0.0	0.0	0.0	0.0
SRU	5	0.1000E 01	0.0	0.0	0.0	0.0
SRU	6	0.1000E 01	0.0	0.0	0.0	0.0
SRU	7	0.1000E 01	0.0	0.0	0.0	0.0
SRU	8	0.1000E 01	0.0	0.0	0.0	0.0
SRU	9	0.1000E 01	0.0	0.0	0.0	0.0
SRU	10	0.1000E 01	0.0	0.0	0.0	0.0
SRU	11	0.1000E 01	0.0	0.0	0.0	0.0
SRU	12	0.1000E 01	0.0	0.0	0.0	0.0
SRU	13	0.1000E 01	0.0	0.0	0.0	0.0
SRU	14	0.1000E 01	0.0	0.0	0.0	0.0
SRU	15	0.1000E 01	0.0	0.0	0.0	0.0
SRU	16	0.1000E 01	0.0	0.0	0.0	0.0
SRU	17	0.1000E 01	0.0	0.0	0.0	0.0
SRU	18	0.1000E 01	0.0	0.0	0.0	0.0
SRU	19	0.1000E 01	0.0	0.0	0.0	0.0
SRU	20	0.1000E 01	0.0	0.0	0.0	0.0
SRU	21	0.1000E 01	0.0	0.0	0.0	0.0
SRU	22	0.1000E 01	0.0	0.0	0.0	0.0
SRU	23	0.1000E 01	0.0	0.0	0.0	0.0
SRU	24	0.1000E 01	0.0	0.0	0.0	0.0
SRU	25	0.1000E 01	0.0	0.0	0.0	0.0
SRU	26	0.1000E 01	0.0	0.0	0.0	0.0
SRU	27	0.1000E 01	0.0	0.0	0.0	0.0
SRU	28	0.1000E 01	0.0	0.0	0.0	0.0
SRU	29	0.1000E 01	0.0	0.0	0.0	0.0
SRU	30	0.1000E 01	0.0	0.0	0.0	0.0
SRU	31	0.1000E 01	0.0	0.0	0.0	0.0
SRU	32	0.1000E 01	0.0	0.0	0.0	0.0
SRU	33	0.1000E 01	0.0	0.0	0.0	0.0
SRU	34	0.1000E 01	0.0	0.0	0.0	0.0
SRU	35	0.1000E 01	0.0	0.0	0.0	0.0
SRU	36	0.1000E 01	0.0	0.0	0.0	0.0
SRU	37	0.1000E 01	0.0	0.0	0.0	0.0

STOCKAGE POLICY

S = ALLOWED TO BE STOCKED (NO REDUNDANCY)
* = ALLOWED TO BE STOCKED

		DEP	DDM	MSM	SSM	FPM
LRU	1	*	0	0	0	0
LRU	2	*	S	0	0	0
LRU	3	*	S	0	S	0
LRU	4	*	S	0	0	0
LRU	5	*	S	0	S	0
LRU	6	*	S	0	S	0
LRU	7	*	S	0	0	0
LRU	8	*	S	0	S	0
LRU	9	*	S	0	S	0
LRU	10	*	0	0	0	0
LRU	11	*	0	0	0	0
LRU	12	*	S	S	0	S
LRU	13	*	S	S	0	S
LRU	14	*	S	0	0	0
LRU	15	*	S	0	0	0
LRU	16	*	0	0	0	0
LRU	17	*	S	S	S	S
LRU	18	*	S	0	S	0
LRU	19	*	S	0	S	0
LRU	20	*	S	0	S	0
SRU	1	*				
SRU	2	*				
SRU	3	*				
SRU	4	*				
SRU	5	*				
SRU	6	*				
SRU	7	*				
SRU	8	*				
SRU	9	*				
SRU	10	*				
SRU	11	*				
SRU	12	*				
SRU	13	*				
SRU	14	*				
SRU	15	*				
SRU	16	*				
SRU	17	*				
SRU	18	*				
SRU	19	*				
SRU	20	*				
SRU	21	*				
SRU	22	*				
SRU	23	*				
SRU	24	*				
SRU	25	*				
SRU	26	*				
SRU	27	*				
SRU	28	*				
SRU	29	*				
SRU	30	*				
SRU	31	*				
SRU	32	*				
SRU	33	*				
SRU	34	*				
SRU	35	*				
SRU	36	*				
SRU	37	*				

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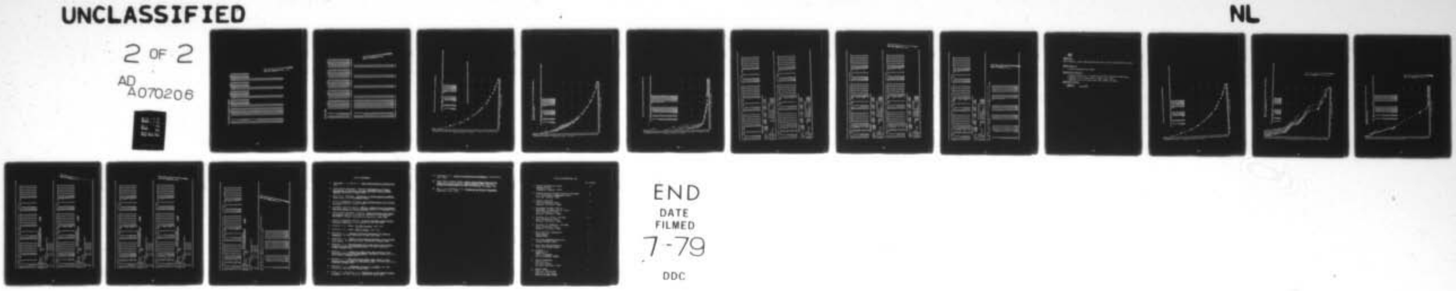

END
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TURN AROUND TIME GIVEN NO SHORTAGE

		DEP	DDM	MSM	SSM	FPM
LRU	1	0.1720E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	2	0.2099E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	3	0.1876E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	4	0.2119E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	5	0.2128E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	6	0.1331E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	7	0.2251E 03	0.1690E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	8	0.1985E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	9	0.2059E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	10	0.1720E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	11	0.1720E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	12	0.1896E 03	0.1690E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	13	0.1720E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	14	0.1849E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	15	0.1937E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	16	0.1720E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	17	0.1903E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	18	0.1934E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	19	0.1809E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
LRU	20	0.1993E 03	0.1680E 03	0.2400E 02	0.9600E 02	0.3600E 02
SRU	1	0.1730E 03	0.0	0.0	0.0	0.0
SRU	2	0.1730E 03	0.0	0.0	0.0	0.0
SRU	3	0.1730E 03	0.0	0.0	0.0	0.0
SRU	4	0.1730E 03	0.0	0.0	0.0	0.0
SRU	5	0.1730E 03	0.0	0.0	0.0	0.0
SRU	6	0.1730E 03	0.0	0.0	0.0	0.0
SRU	7	0.1730E 03	0.0	0.0	0.0	0.0
SRU	8	0.1730E 03	0.0	0.0	0.0	0.0
SRU	9	0.1730E 03	0.0	0.0	0.0	0.0
SRU	10	0.1730E 03	0.0	0.0	0.0	0.0
SRU	11	0.1730E 03	0.0	0.0	0.0	0.0
SRU	12	0.1730E 03	0.0	0.0	0.0	0.0
SRU	13	0.1730E 03	0.0	0.0	0.0	0.0
SRU	14	0.1730E 03	0.0	0.0	0.0	0.0
SRU	15	0.1730E 03	0.0	0.0	0.0	0.0
SRU	16	0.1730E 03	0.0	0.0	0.0	0.0
SRU	17	0.1730E 03	0.0	0.0	0.0	0.0
SRU	18	0.1730E 03	0.0	0.0	0.0	0.0
SRU	19	0.1730E 03	0.0	0.0	0.0	0.0
SRU	20	0.1730E 03	0.0	0.0	0.0	0.0
SRU	21	0.1730E 03	0.0	0.0	0.0	0.0
SRU	22	0.1730E 03	0.0	0.0	0.0	0.0
SRU	23	0.1730E 03	0.0	0.0	0.0	0.0
SRU	24	0.1730E 03	0.0	0.0	0.0	0.0
SRU	25	0.1730E 03	0.0	0.0	0.0	0.0
SRU	26	0.1730E 03	0.0	0.0	0.0	0.0
SRU	27	0.1730E 03	0.0	0.0	0.0	0.0
SRU	28	0.1730E 03	0.0	0.0	0.0	0.0
SRU	29	0.1730E 03	0.0	0.0	0.0	0.0
SRU	30	0.1730E 03	0.0	0.0	0.0	0.0
SRU	31	0.1730E 03	0.0	0.0	0.0	0.0
SRU	32	0.1730E 03	0.0	0.0	0.0	0.0
SRU	33	0.1730E 03	0.0	0.0	0.0	0.0
SRU	34	0.1730E 03	0.0	0.0	0.0	0.0
SRU	35	0.1730E 03	0.0	0.0	0.0	0.0
SRU	36	0.1730E 03	0.0	0.0	0.0	0.0
SRU	37	0.1730E 03	0.0	0.0	0.0	0.0

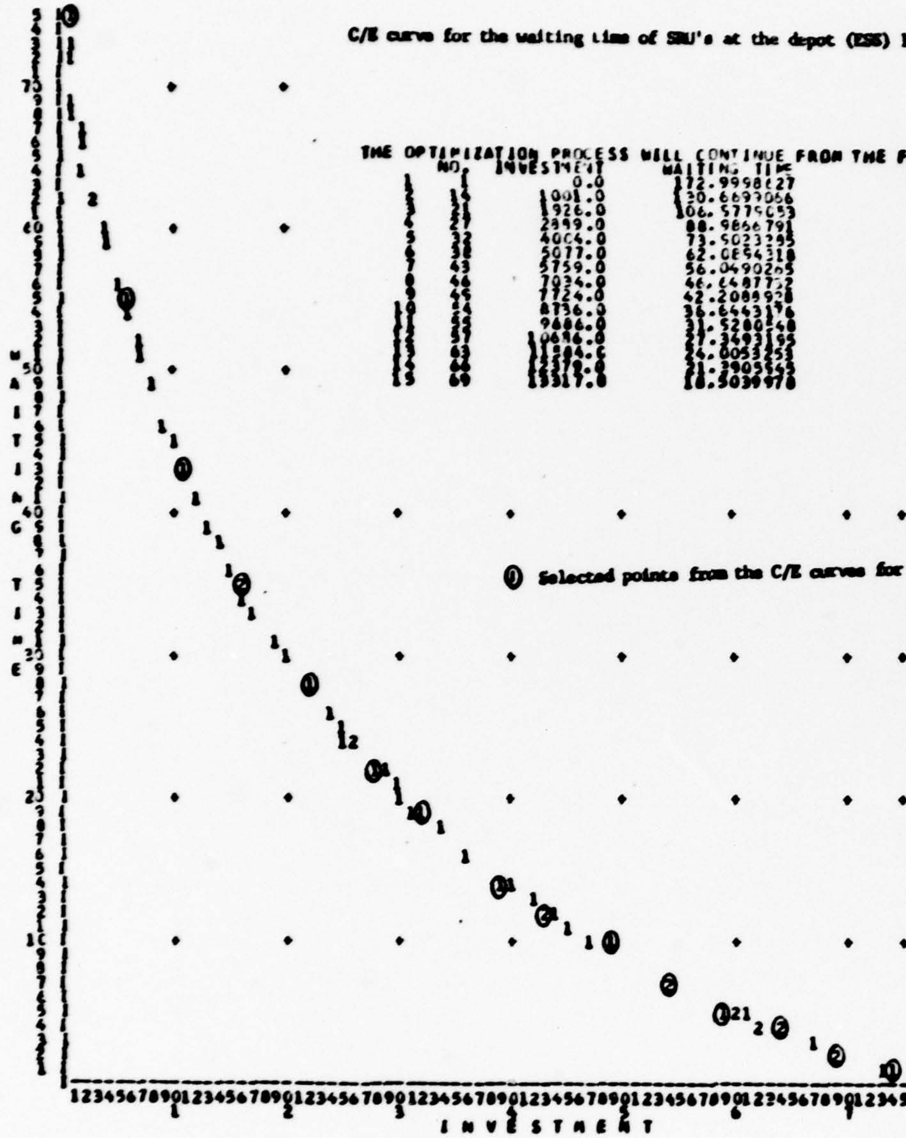
DEMAND RATES

	DEP	DDM	MSM	SSM	FPM
LRU 1	0.4620E-03	0.7920E-05	0.6600E-05	0.7920E-05	0.6600E-05
LRU 2	0.3234E-02	0.5544E-04	0.4620E-04	0.5544E-04	0.4620E-04
LRU 3	0.7854E-02	0.1346E-03	0.1122E-03	0.1346E-03	0.1122E-03
LRU 4	0.4620E-02	0.7920E-04	0.6600E-04	0.7920E-04	0.6600E-04
LRU 5	0.6006E-02	0.1030E-03	0.8580E-04	0.1030E-03	0.8580E-04
LRU 6	0.5544E-02	0.9504E-04	0.7920E-04	0.9504E-04	0.7920E-04
LRU 7	0.2310E-02	0.3960E-04	0.3300E-04	0.3960E-04	0.3300E-04
LRU 8	0.9240E-02	0.1584E-03	0.1320E-03	0.1584E-03	0.1320E-03
LRU 9	0.6468E-02	0.1109E-03	0.9240E-04	0.1109E-03	0.9240E-04
LRU 10	0.4620E-03	0.7920E-05	0.6600E-05	0.7920E-05	0.6600E-05
LRU 11	0.2394E-02	0.3802E-04	0.3412E-04	0.3302E-04	0.3802E-04
LRU 12	0.1948E-01	0.3160E-03	0.2633E-03	0.3160E-03	0.3160E-03
LRU 13	0.2380E-01	0.3859E-03	0.3216E-03	0.3859E-03	0.3859E-03
LRU 14	0.1010E-01	0.1638E-03	0.1365E-03	0.1638E-03	0.1638E-03
LRU 15	0.1660E-01	0.2692E-03	0.2243E-03	0.2692E-03	0.2692E-03
LRU 16	0.1142E-02	0.1813E-04	0.1627E-04	0.1813E-04	0.1813E-04
LRU 17	0.1025E-01	0.1576E-03	0.1576E-03	0.1576E-03	0.1576E-03
LRU 18	0.1128E-01	0.1735E-03	0.1735E-03	0.1735E-03	0.1735E-03
LRU 19	0.4807E-02	0.7395E-04	0.7395E-04	0.7395E-04	0.7395E-04
LRU 20	0.7854E-02	0.1208E-03	0.1208E-03	0.1208E-03	0.1208E-03
****SUM***	0.7695E 00	0.1254E-01	0.1091E-01	0.1254E-01	0.1188E-01
SRU 1	0.1299E-02	0.0	0.0	0.0	0.0
SRU 2	0.5050E-03	0.0	0.0	0.0	0.0
SRU 3	0.4830E-03	0.0	0.0	0.0	0.0
SRU 4	0.6440E-03	0.0	0.0	0.0	0.0
SRU 5	0.5488E-02	0.0	0.0	0.0	0.0
SRU 6	0.4704E-02	0.0	0.0	0.0	0.0
SRU 7	0.2247E-02	0.0	0.0	0.0	0.0
SRU 8	0.2100E-02	0.0	0.0	0.0	0.0
SRU 9	0.1764E-02	0.0	0.0	0.0	0.0
SRU 10	0.8960E-03	0.0	0.0	0.0	0.0
SRU 11	0.5985E-02	0.0	0.0	0.0	0.0
SRU 12	0.3292E-02	0.0	0.0	0.0	0.0
SRU 13	0.5250E-03	0.0	0.0	0.0	0.0
SRU 14	0.1386E-02	0.0	0.0	0.0	0.0
SRU 15	0.7028E-02	0.0	0.0	0.0	0.0
SRU 16	0.1029E-02	0.0	0.0	0.0	0.0
SRU 17	0.6440E-03	0.0	0.0	0.0	0.0
SRU 18	0.1540E-02	0.0	0.0	0.0	0.0
SRU 19	0.4256E-02	0.0	0.0	0.0	0.0
SRU 20	0.8554E-02	0.0	0.0	0.0	0.0
SRU 21	0.1051E-01	0.0	0.0	0.0	0.0
SRU 22	0.6383E-03	0.0	0.0	0.0	0.0
SRU 23	0.8732E-02	0.0	0.0	0.0	0.0
SRU 24	0.1425E-01	0.0	0.0	0.0	0.0
SRU 25	0.1813E-02	0.0	0.0	0.0	0.0
SRU 26	0.2927E-02	0.0	0.0	0.0	0.0
SRU 27	0.5446E-02	0.0	0.0	0.0	0.0
SRU 28	0.8699E-02	0.0	0.0	0.0	0.0
SRU 29	0.1309E-01	0.0	0.0	0.0	0.0
SRU 30	0.2593E-02	0.0	0.0	0.0	0.0
SRU 31	0.7390E-02	0.0	0.0	0.0	0.0
SRU 32	0.3295E-02	0.0	0.0	0.0	0.0
SRU 33	0.7702E-02	0.0	0.0	0.0	0.0
SRU 34	0.8629E-03	0.0	0.0	0.0	0.0
SRU 35	0.2593E-02	0.0	0.0	0.0	0.0
SRU 36	0.1345E-02	0.0	0.0	0.0	0.0
SRU 37	0.2642E-02	0.0	0.0	0.0	0.0
****SUM***	0.7459E 00	0.0	0.0	0.0	0.0

C/E curve for the waiting time of SRU's at the depot (ESS) level.

THE OPTIMIZATION PROCESS WILL CONTINUE FROM THE FOLLOWING SELECTED POINTS OF THE C/E-CURVE

	NO.	INVESTMENT	WAITING TIME
1	1	0.0	172.9998627
2	15	1001.0	130.6697066
3	21	1926.0	106.5779053
4	27	2999.0	88.9866791
5	32	4004.0	73.5023295
6	38	5077.0	62.0854318
7	43	5759.0	56.0490265
8	46	7034.0	46.6487752
9	49	7724.0	42.2089928
10	54	8736.0	36.6443176
11	55	9686.0	[illegible]
12	57	10696.0	27.3493195
13	63	[illegible]	24.0053251
14	66	12379.0	21.3905545
15	69	13317.0	18.5039978

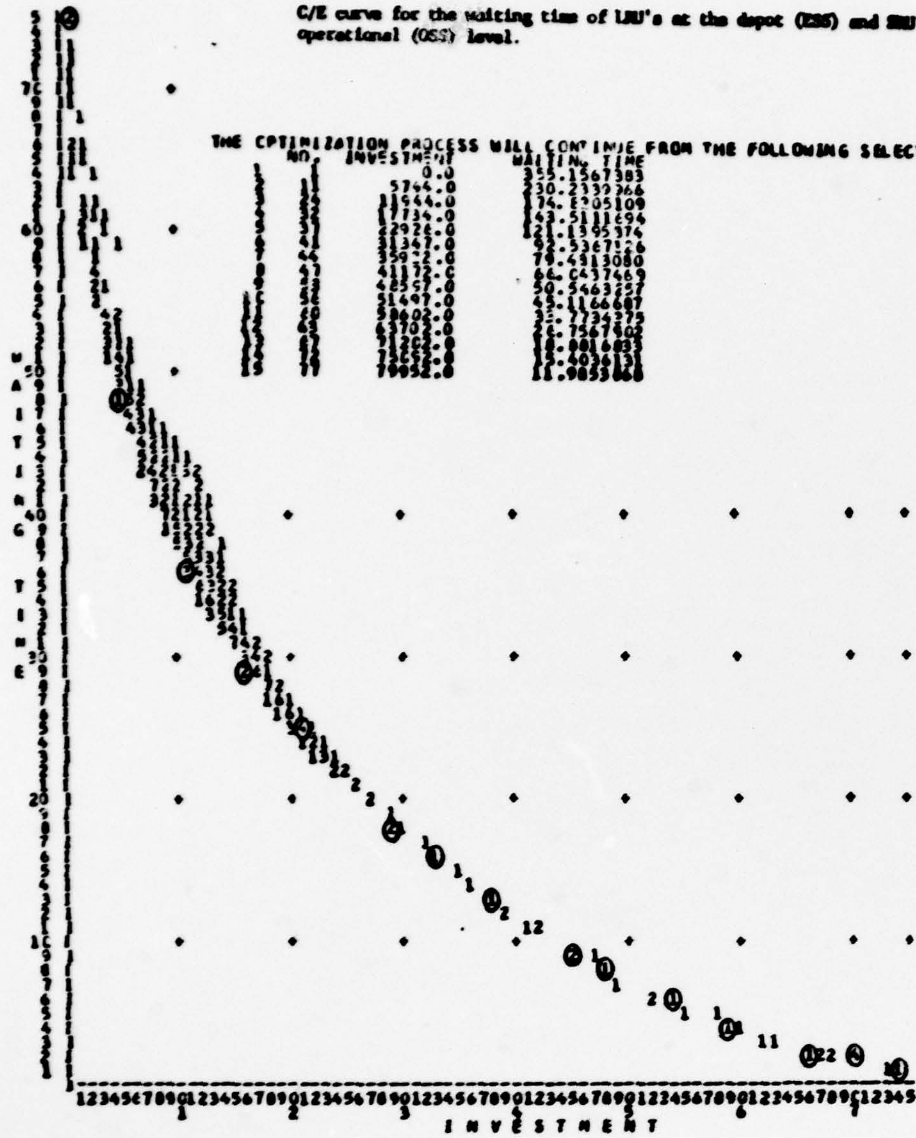


⓪ Selected points from the C/E curves for continuation or final results.

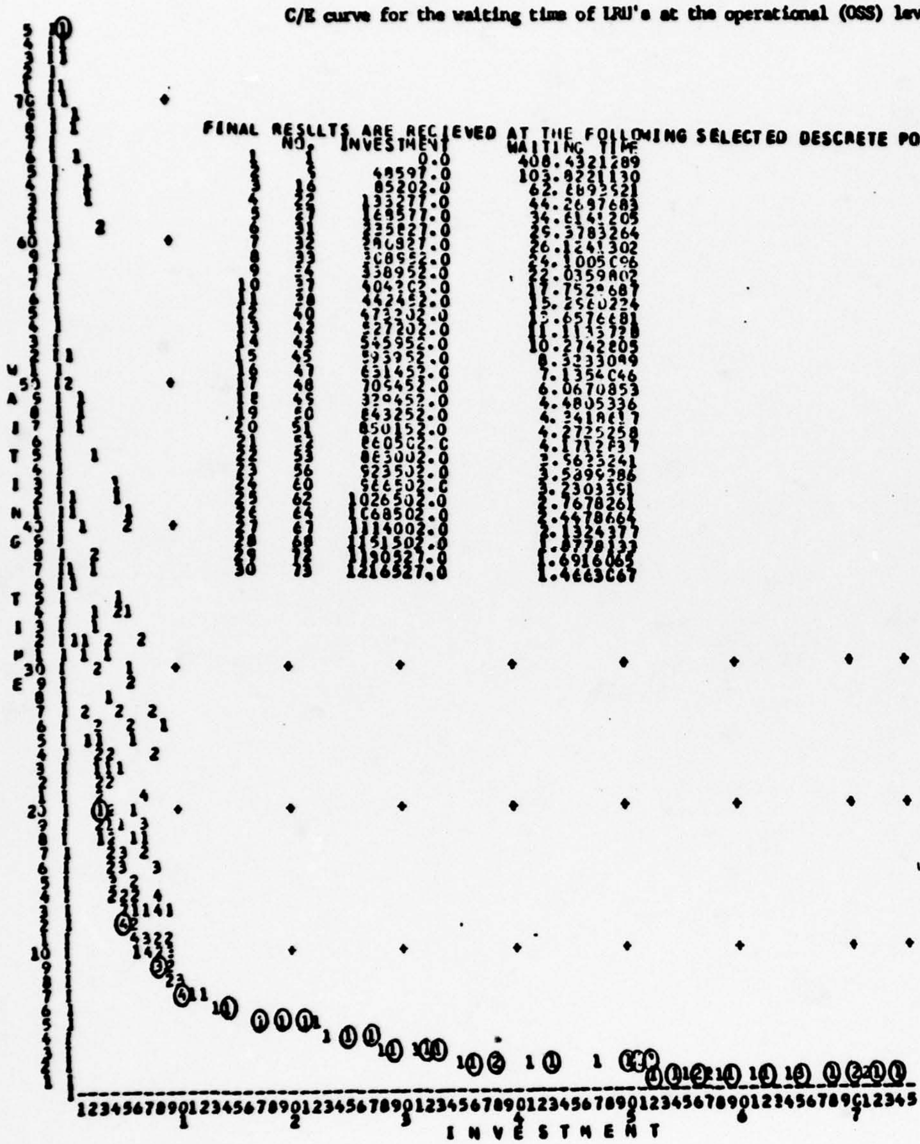
C/E curve for the waiting time of LRU's at the depot (ESS) and SRU's at operational (OSS) level.

THE OPTIMIZATION PROCESS WILL CONTINUE FROM THE FOLLOWING SELECTED POINTS OF THE C/E-CURVE

	NO.	INVESTMENT	WAITING TIME
1	1	0.0	355.1567383
2	11	5744.0	230.2332266
3	[illegible]	11944.0	174.8205109
4	32	17734.0	143.5111694
5	37	22926.0	121.1395374
6	41	31347.0	98.5367126
7	44	35972.0	79.4313080
8	47	41172.0	66.0437469
9	53	46557.0	50.5463257
10	56	51497.0	45.1166687
11	60	58602.0	33.7734375
12	65	63702.0	26.7567902
13	[illegible]	71202.0	18.8816833
14	[illegible]	75652.0	15.4036131
15	[illegible]	79952.0	11.9853668



C/E curve for the waiting time of LRU's at the operational (OSS) level.



FINAL RESLLTS ARE RECIEVED AT THE FOLLOWING SELECTED DESCRETE POINTS

	NO.	INVESTMENT	WAITING TIME
1	1	0.0	408.4321289
2	5	48597.0	103.8221130
3	16	85202.0	62.6693521
4	22	133277.0	44.2697683
5	27	169577.0	34.6141205
6	31	235827.0	29.5783264
7	32	290927.0	26.1241302
8	33	308952.0	24.1005096
9	34	338952.0	22.0359802
10	37	404202.0	17.7529687
11	38	442452.0	15.2560224
12	40	473202.0	13.6576681
13	42	527202.0	11.1135728
14	43	545952.0	10.2742805
15	45	593952.0	8.3233099
16	47	631452.0	7.1354046
17	48	705452.0	6.0670853
18	49	729452.0	4.4805336
19	50	843252.0	4.3418617
20	51	850152.0	4.2725258
21	52	860502.0	4.1712837
22	53	863002.0	3.5635241
23	56	923502.0	3.5899286
24	60	966502.0	3.2303391
25	62	1026502.0	2.7678261
26	64	1068502.0	2.4478664
27	67	1114002.0	2.1324377
28	68	1151502.0	1.8778137
29	72	1190527.0	1.6916065
30	73	1216527.0	1.4663067

***** APPENDIX: B.OPUS MODEL.ORGANIZATION TYPE: A.INIT. PROC.,MOE TYPE: 0.******   POINT NO. 1

DEMDN		TOTAL	INVEST.	DEPOOMSMSSSMFPM					DEMDN		TOTAL	INVEST.	DEPOOMSMSSSMFPM					DEMDN		TOTAL	INVEST.	DEPOOMSMSSSMFPM				
LRU	1	0	0.0	0	0	0	0	0	LRU	20	0	0.0	0	0	0	0	0	SRU	19	0	0.0	0	0	0	0	0
LRU	2	0	0.0	0	0	0	0	0	SRU	1	0	0.0	0	0	0	0	0	SRU	20	0	0.0	0	0	0	0	0
LRU	3	0	0.0	0	0	0	0	0	SRU	2	0	0.0	0	0	0	0	0	SRU	21	0	0.0	0	0	0	0	0
LRU	4	0	0.0	0	0	0	0	0	SRU	3	0	0.0	0	0	0	0	0	SRU	22	0	0.0	0	0	0	0	0
LRU	5	0	0.0	0	0	0	0	0	SRU	4	0	0.0	0	0	0	0	0	SRU	23	0	0.0	0	0	0	0	0
LRU	6	0	0.0	0	0	0	0	0	SRU	5	0	0.0	0	0	0	0	0	SRU	24	0	0.0	0	0	0	0	0
LRU	7	0	0.0	0	0	0	0	0	SRU	6	0	0.0	0	0	0	0	0	SRU	25	0	0.0	0	0	0	0	0
LRU	8	0	0.0	0	0	0	0	0	SRU	7	0	0.0	0	0	0	0	0	SRU	26	0	0.0	0	0	0	0	0
LRU	9	0	0.0	0	0	0	0	0	SRU	8	0	0.0	0	0	0	0	0	SRU	27	0	0.0	0	0	0	0	0
LRU	10	0	0.0	0	0	0	0	0	SRU	9	0	0.0	0	0	0	0	0	SRU	28	0	0.0	0	0	0	0	0
LRU	11	0	0.0	0	0	0	0	0	SRU	10	0	0.0	0	0	0	0	0	SRU	29	0	0.0	0	0	0	0	0
LRU	12	0	0.0	0	0	0	0	0	SRU	11	0	0.0	0	0	0	0	0	SRU	30	0	0.0	0	0	0	0	0
LRU	13	0	0.0	0	0	0	0	0	SRU	12	0	0.0	0	0	0	0	0	SRU	31	0	0.0	0	0	0	0	0
LRU	14	0	0.0	0	0	0	0	0	SRU	13	0	0.0	0	0	0	0	0	SRU	32	0	0.0	0	0	0	0	0
LRU	15	0	0.0	0	0	0	0	0	SRU	14	0	0.0	0	0	0	0	0	SRU	33	0	0.0	0	0	0	0	0
LRU	16	0	0.0	0	0	0	0	0	SRU	15	0	0.0	0	0	0	0	0	SRU	34	0	0.0	0	0	0	0	0
LRU	17	0	0.0	0	0	0	0	0	SRU	16	0	0.0	0	0	0	0	0	SRU	35	0	0.0	0	0	0	0	0
LRU	18	0	0.0	0	0	0	0	0	SRU	17	0	0.0	0	0	0	0	0	SRU	36	0	0.0	0	0	0	0	0
LRU	19	0	0.0	0	0	0	0	0	SRU	18	0	0.0	0	0	0	0	0	SRU	37	0	0.0	0	0	0	0	0

	AVAILABILITY PER SYSTEM:	PER SYSTEM AND DEMAND GENERATING STATION OOO	MSO	SSO	FMO
SYSTEM 1	0.78664	0.84295	0.74875	0.77183	0.72510
SYSTEM 2	0.78262	0.70991	0.71817	0.75333	0.79526
SYSTEM 3	0.76561	0.69527	0.60916	0.74300	0.79337
TOTAL :	0.78110				

INVESTMENT		MEASURE OF EFFECTIVENESS	
TOT INVEST. :	0.0	AVAILIABILITY :	0.78110
PERC E S S :	0.0	N O R S :	66.74515
PERC FIRST LEVEL:	0.0	WAITING TIME :	400.43213
PERC LRU :	0.0	RISK OF SHORTAGE :	1.000000
PERC SRU :	0.0	RSK SHRTGE(1ST LVL):	1.000000

***** APPENDIX: B.OPUS MODEL.ORGANIZATION TYPE: A.INIT. PROC.,MOE TYPE: 0.******   POINT NO. 10

DEMDN		TOTAL	INVEST.	DEPOOMSMSSSMFPM					DEMDN		TOTAL	INVEST.	DEPOOMSMSSSMFPM					DEMDN		TOTAL	INVEST.	DEPOOMSMSSSMFPM				
LRU	1	1	150.0	1	0	0	0	0	LRU	20	29	8120.0	4	1	0	1	0	SRU	19	1	500.0	1	0	0	0	0
LRU	2	13	17650.0	2	1	0	0	0	SRU	1	1	100.0	1	1	0	0	0	SRU	20	3	1125.0	3	0	0	0	0
LRU	3	3	7650.0	3	0	0	0	0	SRU	2	0	0.0	0	1	0	0	0	SRU	21	4	800.0	4	0	0	0	0
LRU	4	17	25500.0	2	1	0	0	0	SRU	3	0	0.0	0	0	0	0	0	SRU	22	1	10.0	1	0	0	0	0
LRU	5	17	33150.0	2	1	0	0	0	SRU	4	1	25.0	1	0	0	0	0	SRU	23	3	1200.0	3	0	0	0	0
LRU	6	17	30500.0	2	1	0	0	0	SRU	5	1	900.0	1	0	0	0	0	SRU	24	5	1000.0	5	0	0	0	0
LRU	7	2	1500.0	2	0	0	0	0	SRU	6	2	750.0	2	0	0	0	0	SRU	25	2	150.0	2	0	0	0	0
LRU	8	18	54300.0	3	1	0	0	0	SRU	7	1	250.0	1	0	0	0	0	SRU	26	2	110.0	2	0	0	0	0
LRU	9	18	33750.0	3	1	0	0	0	SRU	8	1	650.0	1	0	0	0	0	SRU	27	3	300.0	3	0	0	0	0
LRU	10	3	150.0	3	0	0	0	0	SRU	9	1	325.0	1	0	0	0	0	SRU	28	3	750.0	3	0	0	0	0
LRU	11	3	225.0	3	0	0	0	0	SRU	10	0	0.0	0	0	0	0	0	SRU	29	3	450.0	3	0	0	0	0
LRU	12	41	49200.0	6	1	0	0	1	SRU	11	3	300.0	3	0	0	0	0	SRU	30	2	174.0	2	0	0	0	0
LRU	13	42	63000.0	7	1	0	0	1	SRU	12	2	200.0	2	0	0	0	0	SRU	31	4	252.0	4	0	0	0	0
LRU	14	25	7700.0	5	1	0	0	0	SRU	13	1	150.0	1	0	0	0	0	SRU	32	2	144.0	2	0	0	0	0
LRU	15	21	14450.0	6	1	0	0	0	SRU	14	1	150.0	1	0	0	0	0	SRU	33	4	362.0	4	0	0	0	0
LRU	16	2	250.0	2	0	0	0	0	SRU	15	1	950.0	1	0	0	0	0	SRU	34	2	40.0	2	0	0	0	0
LRU	17	36	24500.0	5	1	1	1	1	SRU	16	0	0.0	0	0	0	0	0	SRU	35	2	310.0	2	0	0	0	0
LRU	18	32	13500.0	5	1	0	1	0	SRU	17	0	0.0	0	0	0	0	0	SRU	36	2	70.0	2	0	0	0	0
LRU	19	28	5600.0	3	1	0	1	0	SRU	18	1	250.0	1	0	0	0	0	SRU	37	2	90.0	2	0	0	0	0

	AVAILABILITY PER SYSTEM:	PER SYSTEM AND DEMAND GENERATING STATION OOO	MSO	SSO	FMO
SYSTEM 1	0.50591	0.54661	0.90007	0.88140	0.85469
SYSTEM 2	0.53553	0.93613	0.94546	0.88762	0.95583
SYSTEM 3	0.31907	0.84519	0.95813	0.90526	0.93907
TOTAL :	0.52161				

INVESTMENT		MEASURE OF EFFECTIVENESS	
TOT INVEST. :	464292.0	AVAILIABILITY :	0.52161
PERC E S S :	19.8	N O R S :	23.90845
PERC FIRST LEVEL:	80.2	WAITING TIME :	17.75287
PERC LRU :	96.7	RISK OF SHORTAGE :	0.623410
PERC SRU :	3.3	RSK SHRTGE(1ST LVL):	0.623410

***** APPENDIX: B, OPUS MODEL, ORGANIZATION TYPE: A, INIT. PROC., MOE TYPE: 0, ******   POINT NO. 16

DENOM	TOTAL	INVESTM.	DEP	DOM	MSM	SSM	FPM
LRU 1	1	150.0	1	0	0	0	0
LRU 2	17	17850.0	2	1	0	0	0
LRU 3	15	71500.0	2	1	0	1	0
LRU 4	17	25500.0	2	1	0	0	0
LRU 5	67	132650.0	3	1	0	1	0
LRU 6	27	48600.0	2	1	0	1	0
LRU 7	17	12750.0	2	1	0	0	0
LRU 8	58	95000.0	3	1	0	1	0
LRU 9	20	32500.0	3	1	0	1	0
LRU 10	1	150.0	1	0	0	0	0
LRU 11	3	225.0	1	0	0	0	0
LRU 12	71	85200.0	6	1	1	1	1
LRU 13	62	53000.0	7	1	1	0	0
LRU 14	20	7700.0	5	1	0	0	0
LRU 15	41	14450.0	6	1	0	0	0
LRU 16	2	250.0	2	0	0	0	0
LRU 17	70	24500.0	5	1	1	1	1
LRU 18	30	13500.0	5	1	0	1	0
LRU 19	20	5600.0	3	1	0	1	0

DENOM	TOTAL	INVESTM.	DEP	DOM	MSM	SSM	FPM
LRU 20	29	8120.0	4	1	0	1	0
SRU 1	1	100.0	1	0	0	0	0
SRU 2	0	0.0	0	0	0	0	0
SRU 3	0	0.0	0	0	0	0	0
SRU 4	1	25.0	1	0	0	0	0
SRU 5	1	900.0	1	0	0	0	0
SRU 6	1	750.0	1	0	0	0	0
SRU 7	1	250.0	1	0	0	0	0
SRU 8	1	650.0	1	0	0	0	0
SRU 9	1	325.0	1	0	0	0	0
SRU 10	0	0.0	0	0	0	0	0
SRU 11	3	300.0	3	0	0	0	0
SRU 12	2	200.0	2	0	0	0	0
SRU 13	1	150.0	1	0	0	0	0
SRU 14	1	250.0	1	0	0	0	0
SRU 15	1	950.0	1	0	0	0	0
SRU 16	0	0.0	0	0	0	0	0
SRU 17	0	0.0	0	0	0	0	0
SRU 18	1	250.0	1	0	0	0	0

DENOM	TOTAL	INVESTM.	DEP	DOM	MSM	SSM	FPM
SRU 19	1	500.0	1	0	0	0	0
SRU 20	3	1125.0	3	0	0	0	0
SRU 21	4	400.0	4	0	0	0	0
SRU 22	1	50.0	1	0	0	0	0
SRU 23	3	1200.0	3	0	0	0	0
SRU 24	4	1000.0	4	0	0	0	0
SRU 25	2	150.0	2	0	0	0	0
SRU 26	2	110.0	2	0	0	0	0
SRU 27	3	300.0	3	0	0	0	0
SRU 28	3	750.0	3	0	0	0	0
SRU 29	5	450.0	5	0	0	0	0
SRU 30	2	174.0	2	0	0	0	0
SRU 31	4	252.0	4	0	0	0	0
SRU 32	2	154.0	2	0	0	0	0
SRU 33	2	392.0	2	0	0	0	0
SRU 34	2	40.0	2	0	0	0	0
SRU 35	2	110.0	2	0	0	0	0
SRU 36	2	70.0	2	0	0	0	0
SRU 37	2	90.0	2	0	0	0	0

	AVAILABILITY PER SYSTEM:	PER SYSTEM AND DEMAND GENERATING STATION ODO	MSO	SSO	FPO
SYSTEM 1	0.51569	0.55633	0.90007	0.89086	0.86469
SYSTEM 2	0.93339	0.93613	0.96171	0.88830	0.96583
SYSTEM 3	0.54807	0.84519	0.95813	0.90526	0.93907
TOTAL :	0.92611				

INVESTMENT		MEASURE OF EFFECTIVENESS	
TOT INVESTM. :	631452.0	AVAILIABILITY :	0.92611
PERC E S S :	12.7	N O R S :	22.53652
PERC FIRST LEVEL :	87.3	WAITING TIME :	7.13560
PERC LRU :	97.9	RISK OF SHORTAGE :	0.472458
PERC SRU :	2.1	RSK SHRTGE(1ST LVL) :	0.472458

***** APPENDIX: B, OPUS MODEL, ORGANIZATION TYPE: A, INIT. PROC., MOE TYPE: 0, ******   POINT NO. 17

DENOM	TOTAL	INVESTM.	DEP	DOM	MSM	SSM	FPM
LRU 1	1	150.0	1	0	0	0	0
LRU 2	17	17850.0	2	1	0	0	0
LRU 3	28	71400.0	3	1	0	1	0
LRU 4	17	25500.0	2	1	0	0	0
LRU 5	67	130550.0	3	1	1	1	1
LRU 6	27	48600.0	2	1	0	1	0
LRU 7	17	12750.0	2	1	0	0	0
LRU 8	53	95000.0	3	1	0	1	0
LRU 9	20	32500.0	3	1	0	1	0
LRU 10	1	150.0	1	0	0	0	0
LRU 11	3	325.0	3	0	0	0	0
LRU 12	71	85200.0	6	1	1	1	1
LRU 13	62	93000.0	7	1	1	0	0
LRU 14	20	7700.0	5	1	0	0	0
LRU 15	41	14450.0	6	1	0	0	0
LRU 16	2	250.0	2	0	0	0	0
LRU 17	73	24500.0	5	1	1	1	1
LRU 18	32	13500.0	5	1	0	1	0
LRU 19	26	5600.0	3	1	0	1	0

DENOM	TOTAL	INVESTM.	DEP	DOM	MSM	SSM	FPM
LRU 20	29	8120.0	4	1	0	1	0
SRU 1	1	100.0	1	0	0	0	0
SRU 2	0	0.0	0	0	0	0	0
SRU 3	0	0.0	0	0	0	0	0
SRU 4	1	25.0	1	0	0	0	0
SRU 5	1	900.0	1	0	0	0	0
SRU 6	1	750.0	1	0	0	0	0
SRU 7	1	250.0	1	0	0	0	0
SRU 8	1	650.0	1	0	0	0	0
SRU 9	1	325.0	1	0	0	0	0
SRU 10	0	0.0	0	0	0	0	0
SRU 11	3	300.0	3	0	0	0	0
SRU 12	2	200.0	2	0	0	0	0
SRU 13	1	150.0	1	0	0	0	0
SRU 14	1	250.0	1	0	0	0	0
SRU 15	1	950.0	1	0	0	0	0
SRU 16	0	0.0	0	0	0	0	0
SRU 17	0	0.0	0	0	0	0	0
SRU 18	1	250.0	1	0	0	0	0

DENOM	TOTAL	INVESTM.	DEP	DOM	MSM	SSM	FPM
SRU 19	1	500.0	1	0	0	0	0
SRU 20	3	1125.0	3	0	0	0	0
SRU 21	4	800.0	4	0	0	0	0
SRU 22	1	50.0	1	0	0	0	0
SRU 23	3	1200.0	3	0	0	0	0
SRU 24	4	1000.0	4	0	0	0	0
SRU 25	2	150.0	2	0	0	0	0
SRU 26	2	110.0	2	0	0	0	0
SRU 27	3	300.0	3	0	0	0	0
SRU 28	3	750.0	3	0	0	0	0
SRU 29	5	550.0	5	0	0	0	0
SRU 30	2	174.0	2	0	0	0	0
SRU 31	4	252.0	4	0	0	0	0
SRU 32	2	154.0	2	0	0	0	0
SRU 33	2	362.0	2	0	0	0	0
SRU 34	2	40.0	2	0	0	0	0
SRU 35	2	310.0	2	0	0	0	0
SRU 36	2	70.0	2	0	0	0	0
SRU 37	2	90.0	2	0	0	0	0

	AVAILABILITY PER SYSTEM:	PER SYSTEM AND DEMAND GENERATING STATION ODO	MSO	SSO	FPO
SYSTEM 1	0.91651	0.95633	0.90341	0.85086	0.86777
SYSTEM 2	0.93839	0.93613	0.96171	0.88830	0.96583
SYSTEM 3	0.51807	0.84519	0.95813	0.90526	0.93907
TOTAL :	0.92653				

INVESTMENT		MEASURE OF EFFECTIVENESS	
TOT INVESTM. :	709452.0	AVAILIABILITY :	0.92653
PERC E S S :	11.3	N O R S :	22.40820
PERC FIRST LEVEL :	88.7	WAITING TIME :	6.06769
PERC LRU :	98.1	RISK OF SHORTAGE :	0.456290
PERC SRU :	1.9	RSK SHRTGE(1ST LVL) :	0.456290

••••• APPENDIX: B.OPUS MODEL,ORGANIZATION TYPE: A,INIT. PROC.,MOE TYPE: 0,•••••• POINT NO. 30

DENOM		TOTAL	INVESTM.	DEPOCMMSMSSMFPM					DENOM		TOTAL	INVESTM.	DEPOCMMSMSSMFPM					DENOM		TOTAL	INVESTM.	DEPOCMMSMSSMFPM				
LRU	1	1	150.0	1	0	0	0	0	LRU	20	69	19320.0	4	1	1	1	1	SRU	19	1	500.0	1	0	0	0	0
LRU	2	61	70350.0	2	1	1	1	1	SRU	1	1	100.0	1	0	0	0	0	SRU	20	3	1125.0	3	0	0	0	0
LRU	3	53	71400.0	3	1	0	1	0	SRU	2	0	0.0	0	0	0	0	0	SRU	21	4	800.0	4	0	0	0	0
LRU	4	67	100500.0	2	1	1	1	1	SRU	3	0	0.0	0	0	0	0	0	SRU	22	1	50.0	1	0	0	0	0
LRU	5	67	133650.0	2	1	1	1	1	SRU	4	1	25.0	1	0	0	0	0	SRU	23	3	1200.0	3	0	0	0	0
LRU	6	47	94600.0	2	1	0	1	1	SRU	5	1	900.0	1	0	0	0	0	SRU	24	4	1600.0	4	0	0	0	0
LRU	7	17	12750.0	2	1	0	0	0	SRU	6	1	750.0	2	0	0	0	0	SRU	25	2	150.0	2	0	0	0	0
LRU	8	63	204330.0	3	1	1	1	1	SRU	7	1	250.0	1	0	0	0	0	SRU	26	5	110.0	5	0	0	0	0
LRU	9	68	127500.0	3	1	1	1	1	SRU	8	1	650.0	1	0	0	0	0	SRU	27	3	300.0	3	0	0	0	0
LRU	10	1	150.0	1	0	0	0	0	SRU	9	1	325.0	1	0	0	0	0	SRU	28	3	750.0	3	0	0	0	0
LRU	11	3	225.0	3	0	0	0	0	SRU	10	0	0.0	0	0	0	0	0	SRU	29	5	650.0	5	0	0	0	0
LRU	12	88	103200.0	4	2	1	1	1	SRU	11	3	300.0	3	0	0	0	0	SRU	30	2	176.0	2	0	0	0	0
LRU	13	87	131550.0	7	2	1	1	1	SRU	12	2	200.0	2	0	0	0	0	SRU	31	4	252.0	4	0	0	0	0
LRU	14	35	13475.0	5	2	0	0	0	SRU	13	1	150.0	1	0	0	0	0	SRU	32	2	154.0	2	0	0	0	0
LRU	15	86	37340.0	6	2	1	1	1	SRU	14	1	250.0	1	0	0	0	0	SRU	33	2	392.0	2	0	0	0	0
LRU	16	2	250.0	2	0	0	0	0	SRU	15	1	950.0	1	0	0	0	0	SRU	34	2	40.0	2	0	0	0	0
LRU	17	65	29750.0	5	2	1	1	1	SRU	16	0	0.0	0	0	0	0	0	SRU	35	2	110.0	2	0	0	0	0
LRU	18	70	31500.0	5	1	1	1	1	SRU	17	0	0.0	0	0	0	0	0	SRU	36	2	70.0	2	0	0	0	0
LRU	19	68	13600.0	3	1	1	1	1	SRU	18	1	250.0	1	0	0	0	0	SRU	37	2	90.0	2	0	0	0	0

	AVAILABILITY PER SYSTEM:	PER SYSTEM AND DEMAND GENERATING STATION DDO	PSO	SSO	FPC
SYSTEM 1	0.52078	0.95633	0.91256	0.85230	0.87753
SYSTEM 2	0.93304	0.93761	0.96253	0.88914	0.96632
SYSTEM 3	0.51871	0.84544	0.95910	0.90526	0.94001
TOTAL 1	0.92842				

INVESTMENT			MEASURE OF EFFECTIVENESS		
TOT INVESTM.	:	1216527.0	AVAILIABILITY	:	0.52842
PERC E.S.S	:	6.6	N O R S	:	21.83179
PERC FIRST LEVEL	:	53.4	WAITING TIME	:	1.46631
PERC LRU	:	98.9	RISK OF SHORTAGE	:	0.135887
PERC SRU	:	1.1	RSK SHRTGE(1ST LVL)	:	0.135887

••••• APPENDIX: B.OPUS MODEL,ORGANIZATION TYPE: A,INIT. PROC.,MOE TYPE: 0,••••••

POINT NO.	INVESTMENT	AVAILIABILITY	N O R S	WAITING TIME	RISK OF SHORTAGE
1	0.0	0.78110	66.76515	408.432	1.00000000
2	48557.00	0.89595	34.48120	103.922	1.00000000
3	85232.00	0.90255	29.59965	62.695	0.98504031
4	123377.00	0.91009	27.42505	44.269	0.88026541
5	166377.00	0.91414	26.18799	34.614	0.81139796
6	235827.00	0.91645	25.48145	29.378	0.72031293
7	253327.00	0.91735	25.05493	26.124	0.70558938
8	309952.00	0.91874	24.78516	24.101	0.69480761
9	331552.00	0.91970	24.49097	22.036	0.64545233
10	404202.00	0.92161	23.90845	17.753	0.62340551
11	442452.00	0.92273	23.56593	15.256	0.61061746
12	473202.00	0.92341	23.36133	13.658	0.60015332
13	527202.00	0.92445	23.04036	11.113	0.55620277
14	545552.00	0.92478	22.94057	10.274	0.54509106
15	553552.00	0.92566	22.68066	8.323	0.50158632
16	631452.00	0.92611	22.53653	7.136	0.47249945
17	[illegible]	0.92653	22.40920	6.067	0.45029002
18	[illegible]	0.92716	22.21558	4.481	0.41615198
19	843252.00	0.92723	22.19556	4.342	0.38125157
20	851152.00	0.92725	22.18726	4.273	0.36378145
21	866502.00	0.92730	22.17358	4.171	0.36262208
22	883002.00	0.92739	22.14526	3.963	0.36026630
23	923502.00	0.92754	22.09985	3.550	0.32651258
24	[illegible]	0.92770	22.05035	3.230	0.26437855
25	1025502.00	0.92789	21.99341	2.768	0.24725550
26	1065502.00	0.92802	21.95410	2.448	0.23526281
27	1114002.00	0.92814	21.91577	2.132	0.20406353
28	1151502.00	0.92825	21.88306	1.878	0.15207554
29	1160527.00	0.92833	21.85840	1.632	0.14616162
30	1216527.00	0.92842	21.83179	1.466	0.13588732

OPUS7
*****
*****

INPUT DATA
****

***** APPENDIX: B.OPUS MODEL.ORGANIZATION TYPE: A.INIT. PROC..MOE TYPE: 2. ******

PROBLEM TYPE = 0

: INITIAL PROCUREMENT OF SPARES

OPTIMIZATION CRITERIA :

: WEIGHTED PROBABILITY OF MISSION FAILURE DUE TO SHORTAGE (OPERATIONAL).
: PROBABILITY OF SHORTAGE GIVEN A DEMAND (FIRST LEVEL).
: EXPECTED WAITING TIME (NON FIRST LEVEL SUPPORT STATIONS).

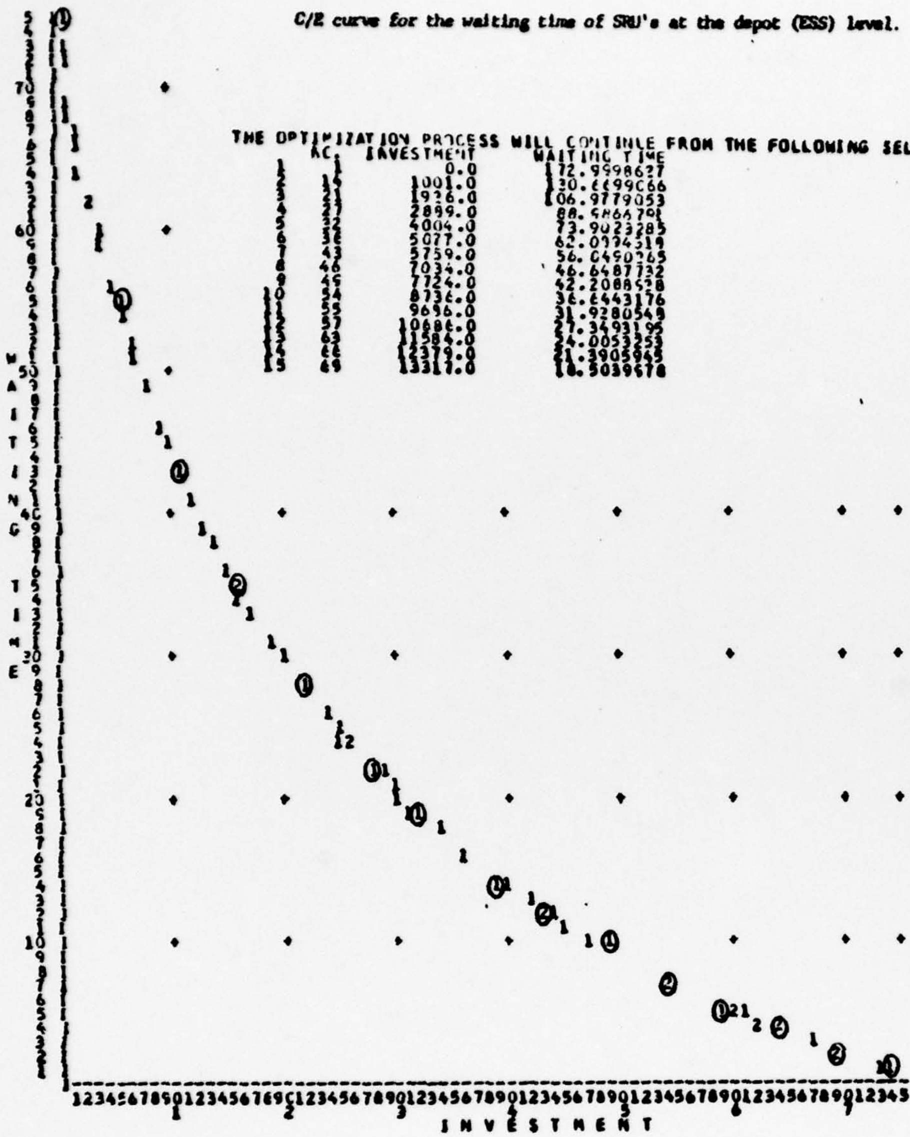
INVESTMENT INTERVAL

MINIMUM = 0.0
MAXIMUM = 10000000.0

C/E curve for the waiting time of SRU's at the depot (ESS) level.

THE OPTIMIZATION PROCESS WILL CONTINUE FROM THE FOLLOWING SELECTED POINTS OF THE C/E-CURVE

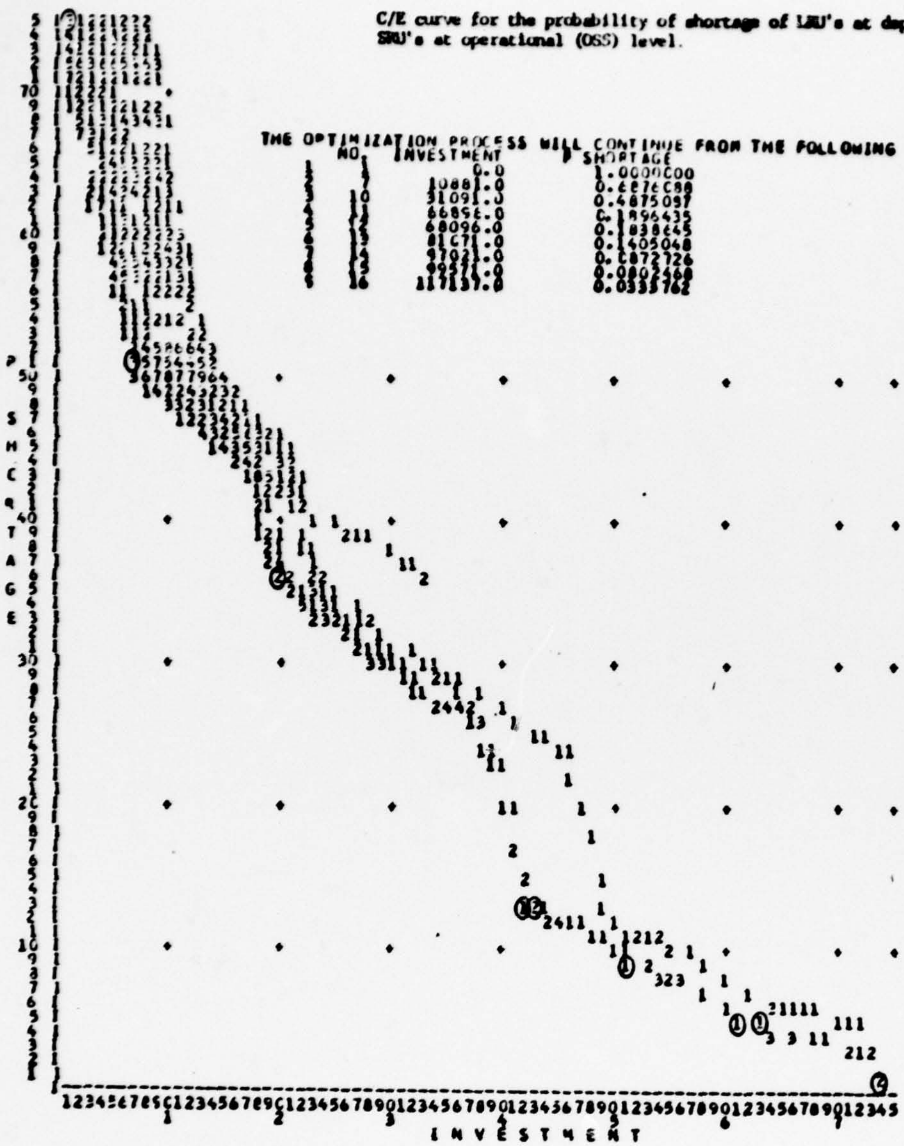
	NC.	INVESTMENT	WAITING TIME
1	1	0.0	172.9998627
2	15	1001.0	130.6699066
3	21	1936.0	106.9779053
4	27	2899.0	88.5866791
5	32	4004.0	73.9023285
6	38	5077.0	62.0374519
7	43	5759.0	56.0490765
8	46	7034.0	46.6487732
9	49	7724.0	42.2088578
10	54	8736.0	36.6443176
11	55	9696.0	31.9280549
12	57	10686.0	27.3493195
13	63	11584.0	24.0053253
14	66	12379.0	21.3905945
15	69	13317.0	18.5039578

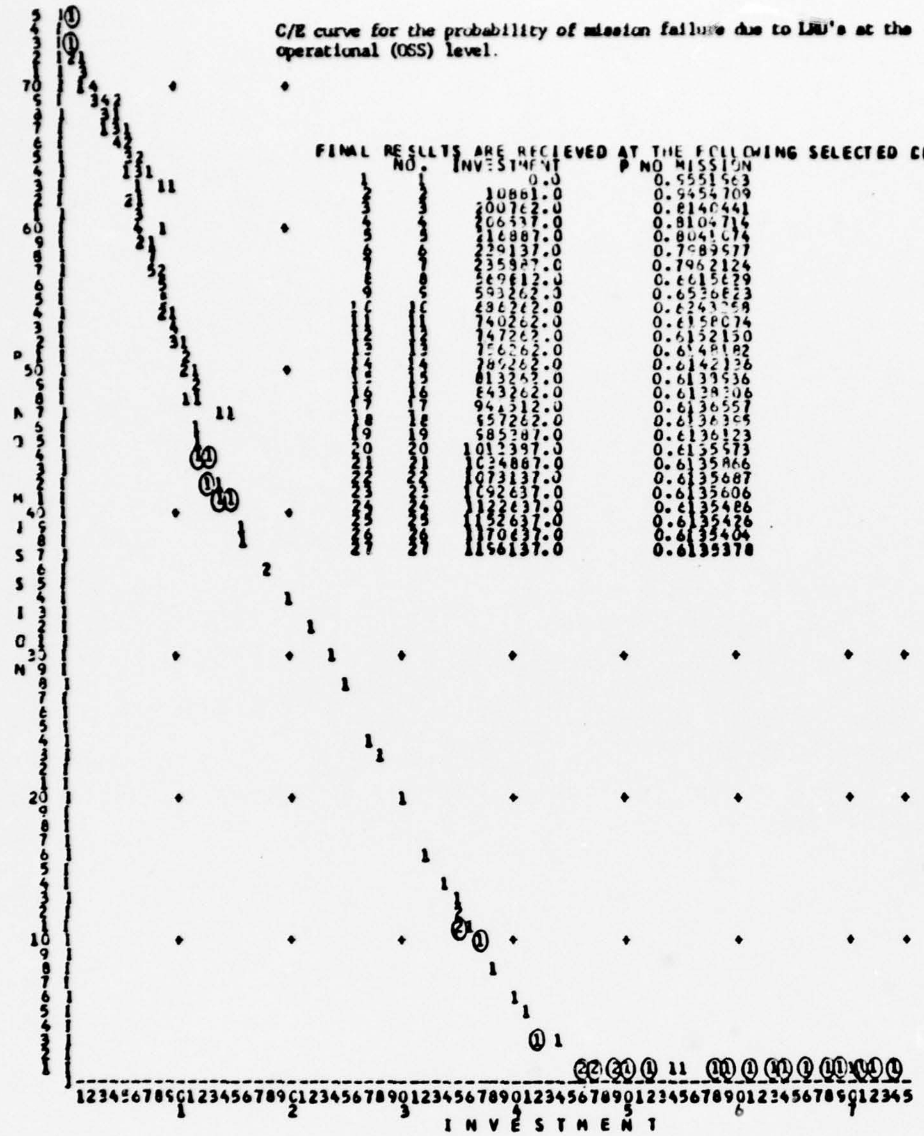


C/E curve for the probability of shortage of LRU's at depot (DSS) and SRU's at operational (OSS) level.

THE OPTIMIZATION PROCESS WILL CONTINUE FROM THE FOLLOWING SELECTED POINTS OF THE C/E-CURVE

	NO.	INVESTMENT	P SHORTAGE
1	1	0.0	1.0000000
2	7	10881.0	0.6676080
3	10	31091.0	0.4875097
4	11	66856.0	0.1896435
5	12	68096.0	0.1838645
6	13	81671.0	0.1405048
7	14	97021.0	0.0872726
8	15	99571.0	0.0802460
9	16	117137.0	0.0335762





C/E curve for the probability of mission failure due to LRU's at the operational (OSS) level.

FINAL RESULTS ARE RECIEVED AT THE FOLLOWING SELECTED DESCRETE POINTS

	NO.	INVESTMENT	P NO MISSION
1	1	0.0	0.9551963
2	2	10861.0	0.9454709
3	3	200762.0	0.8140441
4	4	206337.0	0.8104714
5	5	216887.0	0.8041074
6	6	229137.0	0.7989577
7	7	235987.0	0.7962124
8	8	569812.0	0.6615629
9	9	593262.0	0.6536823
10	10	686262.0	0.6243258
11	11	740262.0	0.6158074
12	12	747262.0	0.6152150
13	13	756262.0	0.6148182
14	14	789262.0	0.6142136
15	15	813262.0	0.6139536
16	16	843262.0	0.6138306
17	17	944312.0	0.6136557
18	18	957262.0	0.6136395
19	19	985387.0	0.6136123
20	20	1012397.0	0.6135573
21	21	1034887.0	0.6135866
22	22	1073137.0	0.6135687
23	23	1092637.0	0.6135606
24	24	1122637.0	0.6135486
25	25	1152637.0	0.6135426
26	26	1170637.0	0.6135404
27	27	1156137.0	0.6135378

***** APPENDIX: B,OPUS MODEL,ORGANIZATION TYPE: A,INIT. PROC.,MOE TYPE: 2,****** POINT NO. 1

DENOM	TOTAL	INVESTM.	DEPD	DMM	SMS	SSM	FPM
LRU 1	0	0.0	0	0	0	0	0
LRU 2	0	0.0	0	0	0	0	0
LRU 3	0	0.0	0	0	0	0	0
LRU 4	0	0.0	0	0	0	0	0
LRU 5	0	0.0	0	0	0	0	0
LRU 6	0	0.0	0	0	0	0	0
LRU 7	0	0.0	0	0	0	0	0
LRU 8	0	0.0	0	0	0	0	0
LRU 9	0	0.0	0	0	0	0	0
LRU 10	0	0.0	0	0	0	0	0
LRU 11	0	0.0	0	0	0	0	0
LRU 12	0	0.0	0	0	0	0	0
LRU 13	0	0.0	0	0	0	0	0
LRU 14	0	0.0	0	0	0	0	0
LRU 15	0	0.0	0	0	0	0	0
LRU 16	0	0.0	0	0	0	0	0
LRU 17	0	0.0	0	0	0	0	0
LRU 18	0	0.0	0	0	0	0	0
LRU 19	0	0.0	0	0	0	0	0
LRU 20	0	0.0	0	0	0	0	0
SRU 1	0	0.0	0	0	0	0	0
SRU 2	0	0.0	0	0	0	0	0
SRU 3	0	0.0	0	0	0	0	0
SRU 4	0	0.0	0	0	0	0	0
SRU 5	0	0.0	0	0	0	0	0
SRU 6	0	0.0	0	0	0	0	0
SRU 7	0	0.0	0	0	0	0	0
SRU 8	0	0.0	0	0	0	0	0
SRU 9	0	0.0	0	0	0	0	0
SRU 10	0	0.0	0	0	0	0	0
SRU 11	0	0.0	0	0	0	0	0
SRU 12	0	0.0	0	0	0	0	0
SRU 13	0	0.0	0	0	0	0	0
SRU 14	0	0.0	0	0	0	0	0
SRU 15	0	0.0	0	0	0	0	0
SRU 16	0	0.0	0	0	0	0	0
SRU 17	0	0.0	0	0	0	0	0
SRU 18	0	0.0	0	0	0	0	0
SRU 19	0	0.0	0	0	0	0	0
SRU 20	0	0.0	0	0	0	0	0
SRU 21	0	0.0	0	0	0	0	0
SRU 22	0	0.0	0	0	0	0	0
SRU 23	0	0.0	0	0	0	0	0
SRU 24	0	0.0	0	0	0	0	0
SRU 25	0	0.0	0	0	0	0	0
SRU 26	0	0.0	0	0	0	0	0
SRU 27	0	0.0	0	0	0	0	0
SRU 28	0	0.0	0	0	0	0	0
SRU 29	0	0.0	0	0	0	0	0
SRU 30	0	0.0	0	0	0	0	0
SRU 31	0	0.0	0	0	0	0	0
SRU 32	0	0.0	0	0	0	0	0
SRU 33	0	0.0	0	0	0	0	0
SRU 34	0	0.0	0	0	0	0	0
SRU 35	0	0.0	0	0	0	0	0
SRU 36	0	0.0	0	0	0	0	0
SRU 37	0	0.0	0	0	0	0	0

INVESTMENT		MEASURE OF EFFECTIVENESS	
TOTAL INVESTMENT =	0.0	WEIGHTED PROB MISSION SUCCESS =	0.04480
PERC E S S =	0.0	RISK OF SHORTAGE(BASE LEVEL) =	1.00000
PERC FIRST LEVEL =	0.0		
PERC LRU =	0.0		
PERC SRU =	0.0		

PROB MISSION SUCCESS

STATION	MISSION TIME	PROB MISSION SUCCESS
DOM	168.0	0.1619564295
MSM	24.0	0.8929311633
SSM	96.0	0.3934223652
FPM	36.0	0.7874745727

***** APPENDIX: B,OPUS MODEL,ORGANIZATION TYPE: A,INIT. PROC.,MOE TYPE: 2,****** POINT NO. 6

DENOM	TOTAL	INVESTM.	DEPD	DMM	SMS	SSM	FPM
LRU 1	2	300.0	2	0	0	0	0
LRU 2	3	3150.0	3	0	0	0	0
LRU 3	5	12750.0	5	0	0	0	0
LRU 4	4	6000.0	4	0	0	0	0
LRU 5	4	7800.0	4	0	0	0	0
LRU 6	4	7200.0	4	0	0	0	0
LRU 7	3	2250.0	3	0	0	0	0
LRU 8	6	18000.0	6	0	0	0	0
LRU 9	5	9375.0	5	0	0	0	0
LRU 10	2	300.0	2	0	0	0	0
LRU 11	4	300.0	4	0	0	0	0
LRU 12	25	30000.0	10	1	0	0	0
LRU 13	19	28500.0	4	1	0	0	0
LRU 14	36	13360.0	6	2	0	0	0
LRU 15	37	25530.0	7	2	0	0	0
LRU 16	2	250.0	2	0	0	0	0
LRU 17	66	23100.0	6	2	0	1	1
LRU 18	32	14400.0	7	1	0	1	0
LRU 19	4	800.0	4	0	0	0	0
LRU 20	30	8400.0	5	1	0	1	0
SRU 1	1	100.0	1	0	0	0	0
SRU 2	0	0.0	0	0	0	0	0
SRU 3	0	0.0	0	0	0	0	0
SRU 4	1	25.0	1	0	0	0	0
SRU 5	1	900.0	1	0	0	0	0
SRU 6	2	750.0	2	0	0	0	0
SRU 7	1	250.0	1	0	0	0	0
SRU 8	1	650.0	1	0	0	0	0
SRU 9	1	325.0	1	0	0	0	0
SRU 10	0	0.0	0	0	0	0	0
SRU 11	3	300.0	3	0	0	0	0
SRU 12	2	200.0	2	0	0	0	0
SRU 13	1	150.0	1	0	0	0	0
SRU 14	1	250.0	1	0	0	0	0
SRU 15	1	950.0	1	0	0	0	0
SRU 16	0	0.0	0	0	0	0	0
SRU 17	0	0.0	0	0	0	0	0
SRU 18	1	250.0	1	0	0	0	0
SRU 19	1	500.0	1	0	0	0	0
SRU 20	3	1125.0	3	0	0	0	0
SRU 21	4	800.0	4	0	0	0	0
SRU 22	1	50.0	1	0	0	0	0
SRU 23	3	1200.0	3	0	0	0	0
SRU 24	4	1000.0	4	0	0	0	0
SRU 25	2	150.0	2	0	0	0	0
SRU 26	2	150.0	2	0	0	0	0
SRU 27	3	300.0	3	0	0	0	0
SRU 28	3	750.0	3	0	0	0	0
SRU 29	5	950.0	5	0	0	0	0
SRU 30	2	174.0	2	0	0	0	0
SRU 31	4	252.0	4	0	0	0	0
SRU 32	2	154.0	2	0	0	0	0
SRU 33	4	392.0	4	0	0	0	0
SRU 34	2	40.0	2	0	0	0	0
SRU 35	2	110.0	2	0	0	0	0
SRU 36	2	70.0	2	0	0	0	0
SRU 37	2	90.0	2	0	0	0	0

INVESTMENT		MEASURE OF EFFECTIVENESS	
TOTAL INVESTMENT =	225582.0	WEIGHTED PROB MISSION SUCCESS =	0.20100
PERC E S S =	53.4	RISK OF SHORTAGE(BASE LEVEL) =	0.55559
PERC FIRST LEVEL =	45.6		
PERC LRU =	94.1		
PERC SRU =	5.9		

PROB MISSION SUCCESS

STATION	MISSION TIME	PROB MISSION SUCCESS
DOM	168.0	0.5066440701
MSM	24.0	0.9140949249
SSM	96.0	0.5202305913
FPM	36.0	0.8342756033

***** APPENDIX: B.OPUS MODEL,ORGANIZATION TYPE: A,INIT. PROC.,MOE TYPE: 2,****** POINT NO. 11

DENOM	TOTAL	INVESTM.	DEP	DDM	MSM	SSM	FPM
LRU 1	2	300.0	2	0	0	0	0
LRU 2	18	18900.0	3	1	0	0	0
LRU 3	30	75500.0	5	1	0	1	0
LRU 4	15	23500.0	4	1	0	0	0
LRU 5	29	56550.0	4	1	0	1	0
LRU 6	29	52200.0	4	1	0	1	0
LRU 7	18	13500.0	3	1	0	0	0
LRU 8	31	53000.0	6	1	0	1	0
LRU 9	30	56250.0	5	1	0	1	0
LRU 10	2	300.0	2	0	0	0	0
LRU 11	4	300.0	4	0	0	0	0
LRU 12	60	96000.0	10	2	1	0	1
LRU 13	74	111000.0	4	2	1	0	1
LRU 14	36	13860.0	6	2	0	0	0
LRU 15	37	25530.0	7	2	0	0	0
LRU 16	2	250.0	2	0	0	0	0
LRU 17	56	33600.0	6	2	1	2	1
LRU 18	57	25650.0	7	2	0	2	0
LRU 19	29	5800.0	4	1	0	1	0

DENOM	TOTAL	INVESTM.	DEP	DDM	MSM	SSM	FPM
LRU 20	55	15400.0	5	2	0	2	0
SRU 1	1	100.0	1	0	0	0	0
SRU 2	0	0.0	0	0	0	0	0
SRU 3	0	0.0	0	0	0	0	0
SRU 4	1	25.0	1	0	0	0	0
SRU 5	1	900.0	1	0	0	0	0
SRU 6	2	750.0	2	0	0	0	0
SRU 7	1	250.0	1	0	0	0	0
SRU 8	1	650.0	1	0	0	0	0
SRU 9	1	325.0	1	0	0	0	0
SRU 10	0	0.0	0	0	0	0	0
SRU 11	3	300.0	3	0	0	0	0
SRU 12	2	200.0	2	0	0	0	0
SRU 13	1	150.0	1	0	0	0	0
SRU 14	1	250.0	1	0	0	0	0
SRU 15	1	950.0	1	0	0	0	0
SRU 16	0	0.0	0	0	0	0	0
SRU 17	0	0.0	0	0	0	0	0
SRU 18	1	250.0	1	0	0	0	0

DENOM	TOTAL	INVESTM.	DEP	DDM	MSM	SSM	FPM
SRU 19	1	500.0	1	0	0	0	0
SRU 20	3	1125.0	3	0	0	0	0
SRU 21	4	800.0	4	0	0	0	0
SRU 22	1	50.0	1	0	0	0	0
SRU 23	3	1200.0	3	0	0	0	0
SRU 24	4	1000.0	4	0	0	0	0
SRU 25	2	150.0	2	0	0	0	0
SRU 26	2	110.0	2	0	0	0	0
SRU 27	3	300.0	3	0	0	0	0
SRU 28	3	750.0	3	0	0	0	0
SRU 29	5	550.0	5	0	0	0	0
SRU 30	2	174.0	2	0	0	0	0
SRU 31	4	252.0	4	0	0	0	0
SRU 32	2	154.0	2	0	0	0	0
SRU 33	4	392.0	4	0	0	0	0
SRU 34	2	40.0	2	0	0	0	0
SRU 35	2	110.0	2	0	0	0	0
SRU 36	2	70.0	2	0	0	0	0
SRU 37	2	90.0	2	0	0	0	0

INVESTMENT

TOTAL INVESTMENT	=	736707.0
PERC E S S	=	15.4
PERC FIRST LEVEL	=	84.6
PERC LRU	=	98.2
PERC SRU	=	1.8

MEASURE OF EFFECTIVENESS

WEIGHTED PROB MISSION SUCCESS	=	0.38419
RISK OF SHORTAGE(BASE LEVEL)	=	0.55559

PROB MISSION SUCCESS

STATION	MISSION TIME	PROB MISSION SUCCESS
DDM	168.0	0.7787403464
MSM	24.0	0.5432517290
SSM	96.0	0.5872046351
FPM	36.0	0.8507138705

***** APPENDIX: B.OPUS MODEL,ORGANIZATION TYPE: A,INIT. PROC.,MOE TYPE: 2,****** POINT NO. 20

DENOM	TOTAL	INVESTM.	DEP	DDM	MSM	SSM	FPM
LRU 1	2	300.0	2	0	0	0	0
LRU 2	33	34650.0	3	2	0	0	0
LRU 3	30	75500.0	5	1	0	1	0
LRU 4	17	28500.0	4	1	0	0	0
LRU 5	44	65300.0	4	2	0	1	0
LRU 6	44	75200.0	4	2	0	1	0
LRU 7	18	13500.0	3	1	0	0	0
LRU 8	46	139000.0	6	2	0	1	0
LRU 9	45	84375.0	5	2	0	1	0
LRU 10	2	300.0	2	0	0	0	0
LRU 11	4	300.0	4	0	0	0	0
LRU 12	120	144000.0	10	2	2	0	2
LRU 13	114	171000.0	4	2	2	0	2
LRU 14	36	13960.0	6	2	0	0	0
LRU 15	37	25530.0	7	2	0	0	0
LRU 16	2	250.0	2	0	0	0	0
LRU 17	136	47600.0	6	2	2	2	2
LRU 18	57	25650.0	7	2	0	2	0
LRU 19	54	10900.0	4	2	0	2	0

DENOM	TOTAL	INVESTM.	DEP	DDM	MSM	SSM	FPM
LRU 20	55	15400.0	5	2	0	2	0
SRU 1	1	100.0	1	0	0	0	0
SRU 2	0	0.0	0	0	0	0	0
SRU 3	0	0.0	0	0	0	0	0
SRU 4	1	25.0	1	0	0	0	0
SRU 5	1	900.0	1	0	0	0	0
SRU 6	2	750.0	2	0	0	0	0
SRU 7	1	250.0	1	0	0	0	0
SRU 8	1	650.0	1	0	0	0	0
SRU 9	1	325.0	1	0	0	0	0
SRU 10	0	0.0	0	0	0	0	0
SRU 11	3	300.0	3	0	0	0	0
SRU 12	2	200.0	2	0	0	0	0
SRU 13	1	150.0	1	0	0	0	0
SRU 14	1	250.0	1	0	0	0	0
SRU 15	1	950.0	1	0	0	0	0
SRU 16	0	0.0	0	0	0	0	0
SRU 17	0	0.0	0	0	0	0	0
SRU 18	1	250.0	1	0	0	0	0

DENOM	TOTAL	INVESTM.	DEP	DDM	MSM	SSM	FPM
SRU 19	1	500.0	1	0	0	0	0
SRU 20	3	1125.0	3	0	0	0	0
SRU 21	4	800.0	4	0	0	0	0
SRU 22	1	50.0	1	0	0	0	0
SRU 23	3	1200.0	3	0	0	0	0
SRU 24	4	1000.0	4	0	0	0	0
SRU 25	2	150.0	2	0	0	0	0
SRU 26	2	110.0	2	0	0	0	0
SRU 27	3	300.0	3	0	0	0	0
SRU 28	3	750.0	3	0	0	0	0
SRU 29	5	550.0	5	0	0	0	0
SRU 30	2	174.0	2	0	0	0	0
SRU 31	4	252.0	4	0	0	0	0
SRU 32	2	154.0	2	0	0	0	0
SRU 33	4	392.0	4	0	0	0	0
SRU 34	2	40.0	2	0	0	0	0
SRU 35	2	110.0	2	0	0	0	0
SRU 36	2	70.0	2	0	0	0	0
SRU 37	2	90.0	2	0	0	0	0

INVESTMENT

TOTAL INVESTMENT	=	1068832.0
PERC E S S	=	11.3
PERC FIRST LEVEL	=	83.7
PERC LRU	=	98.7
PERC SRU	=	1.3

MEASURE OF EFFECTIVENESS

WEIGHTED PROB MISSION SUCCESS	=	0.38640
RISK OF SHORTAGE(BASE LEVEL)	=	0.55559

PROB MISSION SUCCESS

STATION	MISSION TIME	PROB MISSION SUCCESS
DDM	168.0	0.7792751789
MSM	24.0	0.5442048665
SSM	96.0	0.5873692036
FPM	36.0	0.8940686584

***** APPENDIX: B.OPUS MODEL,ORGANIZATION TYPE: A,INIT. PROC.,MOE TYPE: 2,******   POINT NO. 27

DENOM		TOTAL	INVESTM.	DEPO	OOM	PSM	SSM	FPM
LRU	1	2	300.0	2	0	0	0	0
LRU	2	33	34650.0	3	2	0	0	0
LRU	3	85	140250.0	5	2	0	2	0
LRU	4	26	51000.0	4	2	0	0	0
LRU	5	84	105300.0	4	2	0	2	0
LRU	6	86	57200.0	4	2	0	2	0
LRU	7	33	24750.0	3	2	0	0	0
LRU	8	56	168000.0	6	2	0	2	0
LRU	9	55	133125.0	5	2	0	2	0
LRU	10	2	300.0	2	0	0	0	0
LRU	11	4	300.0	4	0	0	0	0
LRU	12	120	144000.0	10	2	2	0	2
LRU	13	114	171000.0	4	2	2	0	2
LRU	14	36	13500.0	4	2	0	0	0
LRU	15	37	25530.0	7	2	0	0	0
LRU	16	2	250.0	2	0	0	0	0
LRU	17	136	47600.0	6	2	2	2	2
LRU	18	87	25650.0	7	2	0	2	0
LRU	19	54	10800.0	4	2	0	2	0
LRU	20	55	15400.0	5	2	0	2	0
SRU	1	1	100.0	1	0	0	0	0
SRU	2	0	0.0	0	0	0	0	0
SRU	3	0	0.0	0	0	0	0	0
SRU	4	1	25.0	1	0	0	0	0
SRU	5	1	500.0	1	0	0	0	0
SRU	6	2	750.0	2	0	0	0	0
SRU	7	1	250.0	1	0	0	0	0
SRU	8	1	650.0	1	0	0	0	0
SRU	9	1	325.0	1	0	0	0	0
SRU	10	0	0.0	0	0	0	0	0
SRU	11	2	300.0	2	0	0	0	0
SRU	12	2	200.0	2	0	0	0	0
SRU	13	1	150.0	1	0	0	0	0
SRU	14	1	250.0	1	0	0	0	0
SRU	15	1	950.0	1	0	0	0	0
SRU	16	0	0.0	0	0	0	0	0
SRU	17	0	0.0	0	0	0	0	0
SRU	18	1	250.0	1	0	0	0	0
SRU	19	1	500.0	1	0	0	0	0
SRU	20	3	1125.0	3	0	0	0	0
SRU	21	4	850.0	4	0	0	0	0
SRU	22	1	50.0	1	0	0	0	0
SRU	23	3	1200.0	3	0	0	0	0
SRU	24	4	1000.0	4	0	0	0	0
SRU	25	2	[illegible]	2	0	0	0	0
SRU	26	2	[illegible]	2	0	0	0	0
SRU	27	3	300.0	3	0	0	0	0
SRU	28	3	[illegible]	3	0	0	0	0
SRU	29	4	650.0	4	0	0	0	0
SRU	30	2	174.0	2	0	0	0	0
SRU	31	4	252.0	4	0	0	0	0
SRU	32	2	[illegible]	2	0	0	0	0
SRU	33	4	342.0	4	0	0	0	0
SRU	34	2	40.0	2	0	0	0	0
SRU	35	2	110.0	2	0	0	0	0
SRU	36	2	70.0	2	0	0	0	0
SRU	37	2	96.0	2	0	0	0	0

INVESTMENT

TOTAL INVESTMENT =	1192582.0
PERC E S S =	9.5
PERC FIRST LEVEL =	90.5
PERC LRU =	98.9
PERC SRU =	1.1

MEASURE OF EFFECTIVENESS

WEIGHTED PROB MISSION SUCCESS =	0.38644
RISK OF SHORTAGE(BASE LEVEL) =	0.55559

PROB MISSION SUCCESS

STATION	MISSION TIME	PROB MISSION SUCCESS
OOM	168.0	0.7793371081
PSM	24.0	0.5442048665
SSM	96.0	0.5874130130
FPM	36.0	0.8940696584

***** APPENDIX: B.OPUS MODEL,ORGANIZATION TYPE: A,INIT. PROC.,MOE TYPE: 2,******

POINT NO.	INVESTMENT	PROB MISSION SUCCESS	RISK OF SHORTAGE
1	0.0	0.0448037386	1.0000000000
2	10145.00	0.0545231305	0.8115215365
3	157207.00	0.1855558821	0.5555927753
4	202582.00	0.1855286441	0.5555927753
5	[illegible]	0.1955025726	0.5555927753
6	[illegible]	0.2010022558	0.5555927753
7	[illegible]	0.2337075652	0.5555927753
8	[illegible]	0.3394337400	0.5555927753
9	539707.00	0.3463177065	0.5555927753
10	652707.00	0.3756751891	0.5555927753
11	736707.00	0.3841526455	0.5555927753
12	763707.00	0.3847845565	0.5555927753
13	782707.00	0.3851519442	0.5555927753
14	785707.00	0.3857863548	0.5555927753
15	835707.00	0.3861062719	0.5555927753
16	839707.00	0.3861694236	0.5555927753
17	537957.00	0.3862443136	0.5555927753
18	557707.00	0.3863605261	0.5555927753
19	581832.00	0.3863877058	0.5555927753
20	[illegible]	0.3864026666	0.5555927753
21	[illegible]	[illegible]	0.5555927753
22	[illegible]	0.3864313264	0.5555927753
23	[illegible]	0.3864393830	0.5555927753
24	1119082.00	0.3864512636	0.5555927753
25	1145082.00	0.3864573836	0.5555927753
26	1167082.00	0.3864595890	0.5555927753
27	1192582.00	0.3864422116	0.5555927753

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