

THE PETROLEUM DISRUPTION RESPONSE SYSTEM

by

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## THE PETROLEUM DISRUPTION RESPONSE SYSTEM

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(ABSTRACT)

The petroleum disruptions experienced in 1973 and 1979 demonstrated to the Department of Defense (DoD) that, for numerous reasons, the normal support for DoD requirements could rapidly deteriorate. Crude oil shortages caused DoD's historical supplier to prorate or completely cease deliveries under existing contracts, and it became difficult for the Defense Fuel Supply Center (DFSC) to secure replacement or follow-on contracts for fuels. In order to sustain necessary peacetime activities, the services were forced to dip into the war reserves. The effect was a decrease in the wartime sustainability of our forces until the war reserves were reconstituted.

As a result of DoD "Supply Assurance" initiatives prompted by the 1979 disruption, numerous policy options have been developed to help the Office of the Secretary of Defense (OSD) more effectively deal with future shortage situations.

The key to avoiding the problems of 1973 and 1979 is early identification of shortage situations and selection of appropriate policy options designed to ensure a steady supply of military fuels during energy emergencies.

The Petroleum Disruption Response System (PDRS) is a decision support system designed to assist DFSC energy analysts and planners in preparing recommendations for the Office of the Assistant Secretary of Defense (OASD) energy policy staff on appropriate policy options to ensure adequate petroleum supplies for the national defense.

This paper contains a conceptual model of PDRS that is based on a network optimization distribution model. The model would optimize the resupply distribution network in terms of minimum cost solution.

## ACKNOWLEDGEMENTS

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## TABLE OF CONTENTS

1.	INTRODUCTION	1
	1.1 Defining the Problem	2
	1.2 Project Objectives	5
2.	LITERATURE REVIEW	6
3.	METHODS	8
	3.1 Network Model Approach	8
	3.2 General Solution Strategy	15
4.	RESULTS	18
	4.1 PDRS Model Formulation	18
	4.2 Cost Determinant Structure	22
	4.3 Network Optimization	24
	4.4 Model Input	26
	4.5 Model Outputs	29
	4.6 Solution Methodology	30
5.	DISCUSSION	33
	5.1 Inventory Accuracy	33
	5.2 Capability to Produce Feasible Optimum Solutions	36
	5.3 Hardware	37
	5.4 Software	39
6.	CONCLUSIONS	42
7.	SUMMARY	46
8.	LITERATURE CITED	48
9.	APPENDIX A. PDRS Modeling Alternatives	50

## 1. INTRODUCTION

The petroleum disruptions experienced in 1973 and 1979 demonstrated to the Department of Defense (DoD) that, for numerous reasons, the normal support for DoD requirements could rapidly deteriorate. Crude oil shortages caused DoD's historical supplier to prorate or completely cease deliveries under existing contracts, and it became difficult for the Defense Fuel Supply Center (DFSC) to secure replacement or follow-on contracts for fuels. In order to sustain necessary peacetime activities, the services were forced to dip into the war reserves. The effect was a decrease in the wartime sustainability of our forces until the war reserves were reconstituted.

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The Petroleum Disruption Response System (PDRS) is a decision support system designed to assist DFSC energy analysts and planners in preparing recommendations for the Office of the Assistant Secretary of Defense (OASD) energy policy staff on appropriate policy options to ensure adequate petroleum supplies for the national defense.

### **1.1 Defining the Problem**

The issues uncovered in an analysis, which was done earlier by a PRC study team of which I was a member, indicate that improvements can be made at the tactical planning level. This level in planning is of major significance in the development of automated support, whether it is in the form of management information systems, decision support systems, or computer models. This is because the basic nature of the management issues to be considered and the information needed to make quick decisions is different from other planning levels - operational and strategic. The scope of the distribution system must therefore encompass the requirements for the tactical planning level and the decision processes at this level of DFSC to be supported.

Physical distribution at a tactical level is the determination of how to use existing resources. Tactical

planning is basically short-range planning or contingency planning for an emergency energy situation. The main concern in this area of planning is that the resources used in the distribution process are being used as effectively and efficiently as possible. Careful planning of distribution alternatives allows management to achieve high utilization of resources involved in the distribution process. Tactical planning is concerned with the question, "How can the distribution system best be utilized?"

The strategic level of planning is used to decide, in a broad sense, what the overall system configuration should be for distribution. It is concerned with the facility location, the selection of transportation modes, and the determination of policy input to tactical planning. Strategic planning develops the broad guidelines under which the organization will operate.

Operational planning involves the daily tasks that a manager and workers must perform to ensure the smooth flow of products through the distribution network. The focus of this aspect is mainly supervision and task accomplishment.

The analysis has also indicated that many current distribution decisions, because of time constraints, must be made on the basis of incomplete or inadequate data. Further,

a considerable amount of time is spent by decision-makers on manual gathering of data rather than the analysis of it. Therefore, tools capable of analyzing the current distribution network or proposed alternative schemes are needed to help making quick decisions at the tactical planning level. Tools that will provide the decision-maker with current and correct data upon which to make distribution decisions would be of great benefit.

A major part of developing the conceptual model is reviewing the data requirements in terms of their availability, timeliness, and accuracy. Alternative interfaces between current systems and the distribution model are reviewed using these guidelines.

After the direction for model development is provided by DFSC, a review of applicable software packages is conducted along with an analysis of current ADP limitations. Alternative interfaces with current systems are analyzed.

The PDRS modeling alternatives and recommendations that described in Appendix A are then developed, at the request of DFSC, through working sessions with DFSC, Defense Logistics Agency (DLA), and Defense Fuel Region (DFR) personnel.

## 1.2 Project Objectives

The objective of this project is to:

- Provide a conceptual model of a system which could be used by DFSC personnel at both Cameron Station and the Defense Fuel Regions (DFRs) to aid in making distribution decisions and related policy decisions.
  - The model should include procedures, methods, and algorithms that effectively and efficiently react to the effects of transportation and scheduling activity on inventory.
  - The model should also include procedures, methods, and algorithms that permit DFSC personnel to evaluate storage and distribution alternatives in a user-friendly, real-time mode, as a function of cost.
  - The model concept should address the feasibility of interfacing these procedures with the inventory computation system to permit DFSC to evaluate the reciprocal effects of storage, transportation, distribution scheduling, and inventory upon each other.
  - The conceptual model should be capable of analyzing the fuel distribution network as a whole. It must be capable of evaluating the cost-effectiveness of any current or proposed wholesale terminals and be able to provide revised distribution plans when changes, actual or proposed, are made to basic distribution factors.

## 2. LITERATURE REVIEW

Buffa and Dyer [6] state that network models are an important special case of linear optimization models for three reasons. First, many real-world can be modeled by using networks. Problems related to the determination of transportation and distribution systems are routinely solved in many organizations by this method. A special form of a network, known as the transportation model, takes its name from this use. A generalization of the transportation model is the transshipment model, that allows greater flexibility in the nature of the distribution system being analyzed. These models can also be used as aids in assigning workers to jobs. Other network models can be used to determine the longest or shortest path through a network. These models can be applied to determining equipment replacement policies and in scheduling activities in large-scale projects. The latter models include the network scheduling techniques PERT and CPM.

A second important feature of the network is that the model has a visual interpretation in addition to the mathematical formulation. The ability to visualize a network, much like a decision tree, significantly reduces problems of communication between managers and technical analysts and

among managers. Since one of the most important factors limiting the use of management science models by managers is their confidence in the model, this feature cannot be overemphasized.

Finally, the third advantage of the network is that the corresponding mathematical formulation has a special structure that allows extremely large problems to be solved very quickly by using specialized versions of the simplex algorithm for solving linear programming problems. The resulting low cost encourages the user to run the model many times to gain full advantage of it. An additional bonus is that integer-valued optimal solutions are obtained automatically. When a problem cannot be formulated as a network problem and an integer-valued solution is required, the additional computational effort can become quite burdensome.

The three advantages of network models - the large number of potential real-world applications, the visual interpretation, and an efficient solution strategy - are so important that the modern manager should be familiar with problems that can be analyzed with networks.

### **3. METHODS**

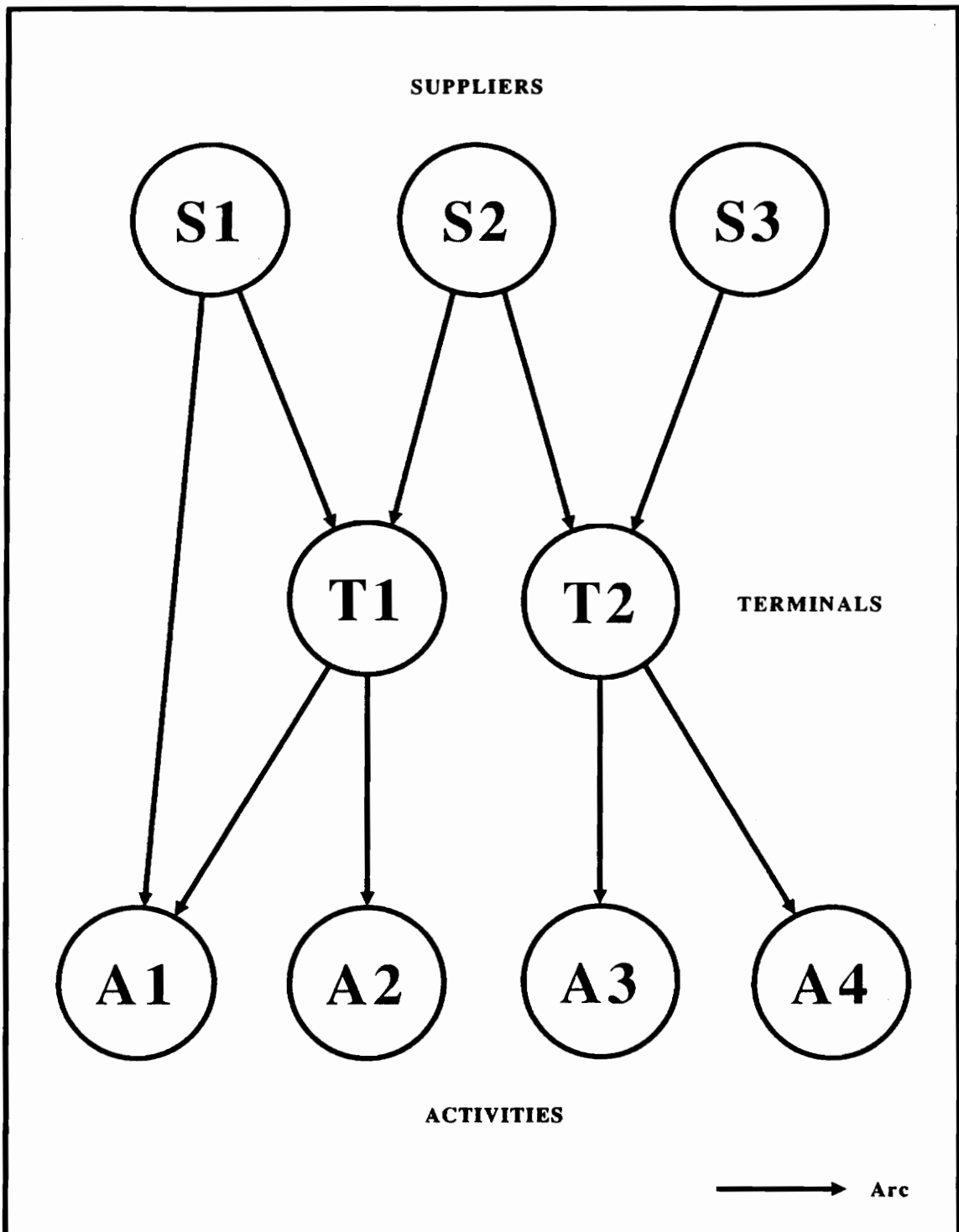
This section presents the actual use of a network model to aid in solving a real-world problem. The problem is the assignment of suppliers to activities via terminals during the normal operation. The supplier/activity distribution problem is complicated by the lack of a clearly defined objective to serve as the evaluative model that guides a solution process. The capacities of the suppliers must be balanced against the demands of the activities, while energy policies and resource constraints must also be considered. Even these constraints are "loose," and some may be recognized only as the solution evolves.

#### **3.1 Network Model Approach**

How can one go about formulating an optimizing model for aiding a decision maker in analyzing a complex problem such as this one? First, the model builder may look for analogies with more familiar models. The distribution model suggests that the problem might be modeled as a transportation problem, with each supplier being represented as a supply point that supplies petroleum products into the system, and with each

activity viewed as a demand point that takes petroleum products out of the system. An arc from a particular supplier to a particular activity would indicate that it could deliver a petroleum product. Otherwise, the arc would be omitted.

In addition, the activities are receiving petroleum products from terminals, and the distribution network must incorporate terminals. Thus, the analogy went further. The terminals could be viewed as transshipment points, with the products of the supplier "shipped" through particular terminals to corresponding terminal transshipment points for the activities. The network model that resulted from this analogy is shown in Figure 3-1 on the following page.



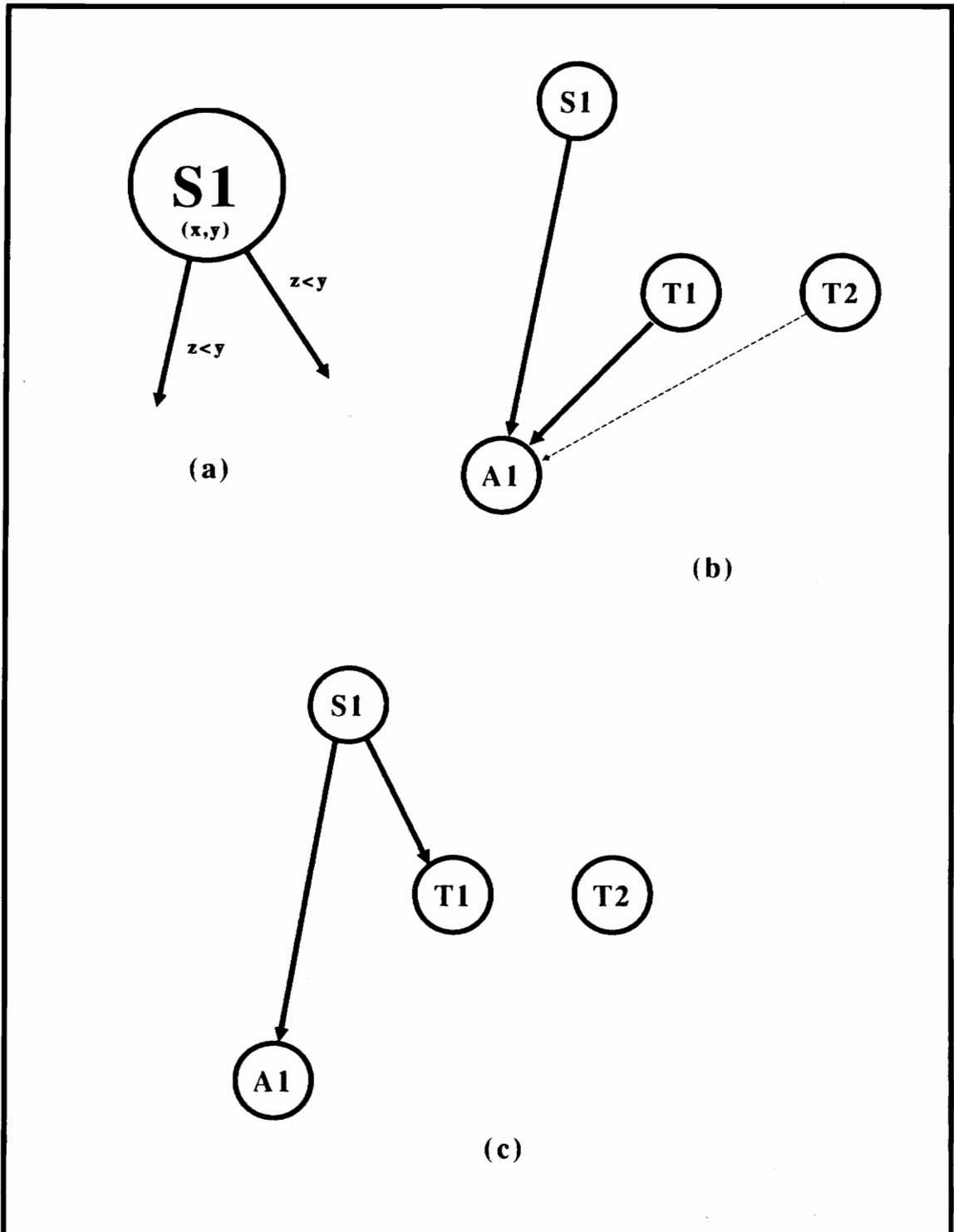
**Figure 3-1. Network Representation of the Supplier/Activity Distribution Problem**

The flow on the arcs of the network is petroleum products. The nodes in the network are either supplier or activity related. For each supplier, there are up to  $n$  nodes corresponding to  $n$  terminals. However, if a supplier is not delivering petroleum products during a disruption, the corresponding node is deleted. There are similar set of nodes for the activities. Figure 3-2 portrays several examples of how lower and upper bounds of the flows on the arcs can be useful in achieving various objectives. As illustrated in Figure 3-2(a), the total capacity to be delivered by the supplier during the normal operation is restricted to between  $x$  and  $y$  barrels. However, any one terminal or activity cannot have more than  $z$  barrels ( $z < y$ ) delivered by the supplier because of the capacity restrictions of the other arcs.

Similar restrictions determine the demands of the activities. For example, A1 will be receiving petroleum products from two sources during the normal operation as shown in Figure 3-2(b). The supplier S1 and the terminal T1 will deliver their petroleum products as indicated by the corresponding minimum and maximum flow restrictions. The terminal T2 may be delivered its petroleum products during either the supplier S1 or the terminal T1 is disrupted. The determination of whether this terminal will actually be delivering petroleum during the disruption, will be made by the model, based on the availability of supplier resources.

Thus, the user is able to incorporate many options within the context of a simple network model. Further, this visual interpretation makes it easy to convey the logic of the model to actual users.

The availabilities of the suppliers receive consideration in the model in the following way. Subject to energy policies, the user may determine the number of activities to which a supplier will deliver its petroleum products by manipulating the lower and upper bounds of the flow restrictions as illustrated in Figure 3-2(c). The supplier S1 will deliver all of its petroleum products to the terminal T1 and the activity A1 and be free from delivering products to the terminal T2.



**Figure 3-2. Individual Supplier/Activity Nodes and Associated Arcs**

Although a number of considerations relevant to the supplier/activity distribution problem can be incorporated in this network model, this formulation is only a crude approximation to the "ideal" model that would actually solve the distribution problem in a single run. Therefore, the actual solution strategy for the problem is iterative, with the model providing a "first cut," and approximate solution that must be modified by the decision maker to include more subtle issues not considered in the model.

The decision analyst must determine first if the solution is feasible, given the supplier resources and the projected demand for activities. If not, he must consider whether to obtain additional resources, if possible, or to reduce the demands of activities. Once the appropriate balance is achieved between supplier resources and activity demands, he must decide whether a solution is "acceptable." In making this decision, he must consider all of the criteria relevant for evaluating this distribution, as well as his implicit estimate of the probability that he could improve the distribution, and of the time and trouble such an attempt would require. If he does not accept the distribution, he must attempt to modify it.

The user may wish to attempt to improve the solution by modifying it by hand. If he feels that the solution

determined by the approximate model is "close" to an acceptable distribution, he may persist with these hand assignments until an acceptable solution is obtained, or until he wishes to be aided by the approximate model.

The user may wish to modify the network formulation by defining new arcs from some suppliers to certain activities and by deleting other arcs. He may also modify the lower and upper bounds on the supplier/terminal arcs that determine the number of activities a supplier delivers petroleum products to each terminal. In such a manner, he can generate new candidate distributions for his evaluation.

### **3.2 General Solution Strategy**

The general solution strategy is summarized in Figure 3-3, and described step-by-step as follows:

- Step 1. Generate the data required for the approximate model. These data include supplier information and activity information, both modified to reflect the energy policies.
- Step 2. (Approximation) Generate the network model, and solve.
- Step 3. (Evaluation) Determine whether the distribution is a feasible alternative. If not, return to step 1.
- Step 4. (Evaluation) Determine whether the distribution is acceptable. If not, go to step 6.

- Step 5. Report the distribution for review.
- Step 6. Decide whether to persist in attempting to improve the distribution by hand. If not, go to step 8.
- Step 7. (Modification) Make manual changes in the distribution. Go to step 3.
- Step 8. (Modification) Make changes in the network formulation. Go to step 3.

The purpose of this presentation of the solution strategy is to emphasize again that a model need not be sufficiently detailed to "solve" a problem in a single computer run in order to be useful. Rather, the decision maker should view it as a decision-making aid that efficiently does much of the required computational work for him, but that must be used intelligently in order to actually provide some benefit.

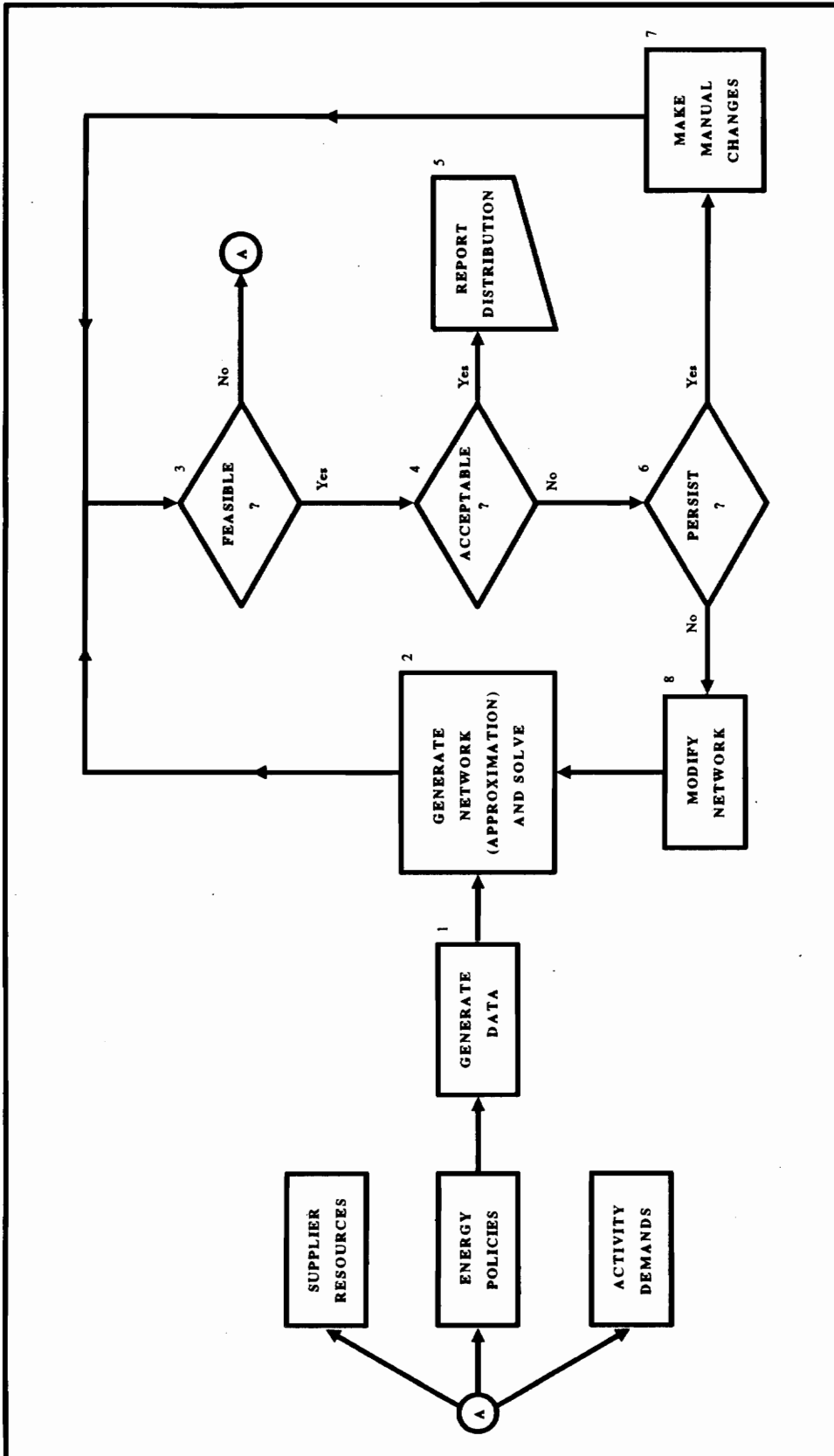


Figure 3-3. The Solution Strategy for the Supplier/Activity Distribution Model

## **4. RESULTS**

### **4.1 PDRS Model Formulation**

Planning for the fuels distribution network involves combining the suppliers, terminals and military service activities into an efficient channel of resupply for the delivery of fuel. At the tactical level, the distribution network planning must support planning for any disruptions to the fuel network that might affect the resupply of fuel. Planning at this level involves finding the most cost effective routes using various optimization techniques. The flow rate of fuel through the network must be considered along with constraints placed upon the network by suppliers, carriers, and facilities involved in the resupply of fuel. These are extremely important considerations when developing feasible optimal networks for resupply.

Currently the terminals are planned for resupply using the Source Identification and Ordering Authorization (SIOATH) as the ordering and routing guideline. Based on award patterns and the SIOATH, a one-to-one ordering relationship is established between the supplier and the terminal. There are no provisions on the SIOATH for identifying an alternate

supplier should the supply of fuel be disrupted. The Inventory Managers order fuel from the suppliers based on their requirements and the amounts specified on the SIOATH. This is a "push" type planning system and usually results in inventories being managed to "top of the tank" levels.

At the terminal level, SIOATHs are developed manually specifying where and in what amounts activities can order fuel. Once again there is no identification of alternative sources of resupply. Terminal SIOATHs, like supplier SIOATHs, identify only one avenue of resupply for an activity. Contingency planning is not supported.

The current fuel distribution network is a "push" system that forces requirements down from the supplier through the system. The current distribution network is developed from the top down paying little or no attention to alternative networks of resupply and fuel requirements at the activities level. Consequently there is no formal method for performing any contingency planning or identifying and developing cost-effective alternatives and optimization of resupply networks.

The distribution model approaches the fuel distribution networks from a total system perspective. Figure 4-1 is an example of how the distribution model views the network. All suppliers relevant to an area are identified along with the

terminals and activities, then distribution networks are developed for the resupply of fuel. As Figure 4-1 shows the network identifies all relevant networks of resupply including: supplier to terminal to activity, supplier to activity (Direct Delivery), and Terminal Release Orders (TRO). As can be seen in Figure 4-1 the distribution model identifies not only planned networks, but also identifies contingency networks for resupply.

Once networks are developed for fuel resupply, these networks can be used for optimization at the tactical level of planning. By determining flow rates through the system based on supplier, transportation, terminal and activity constraints, the most cost effective and efficient methods of resupply can be established for planning purposes.

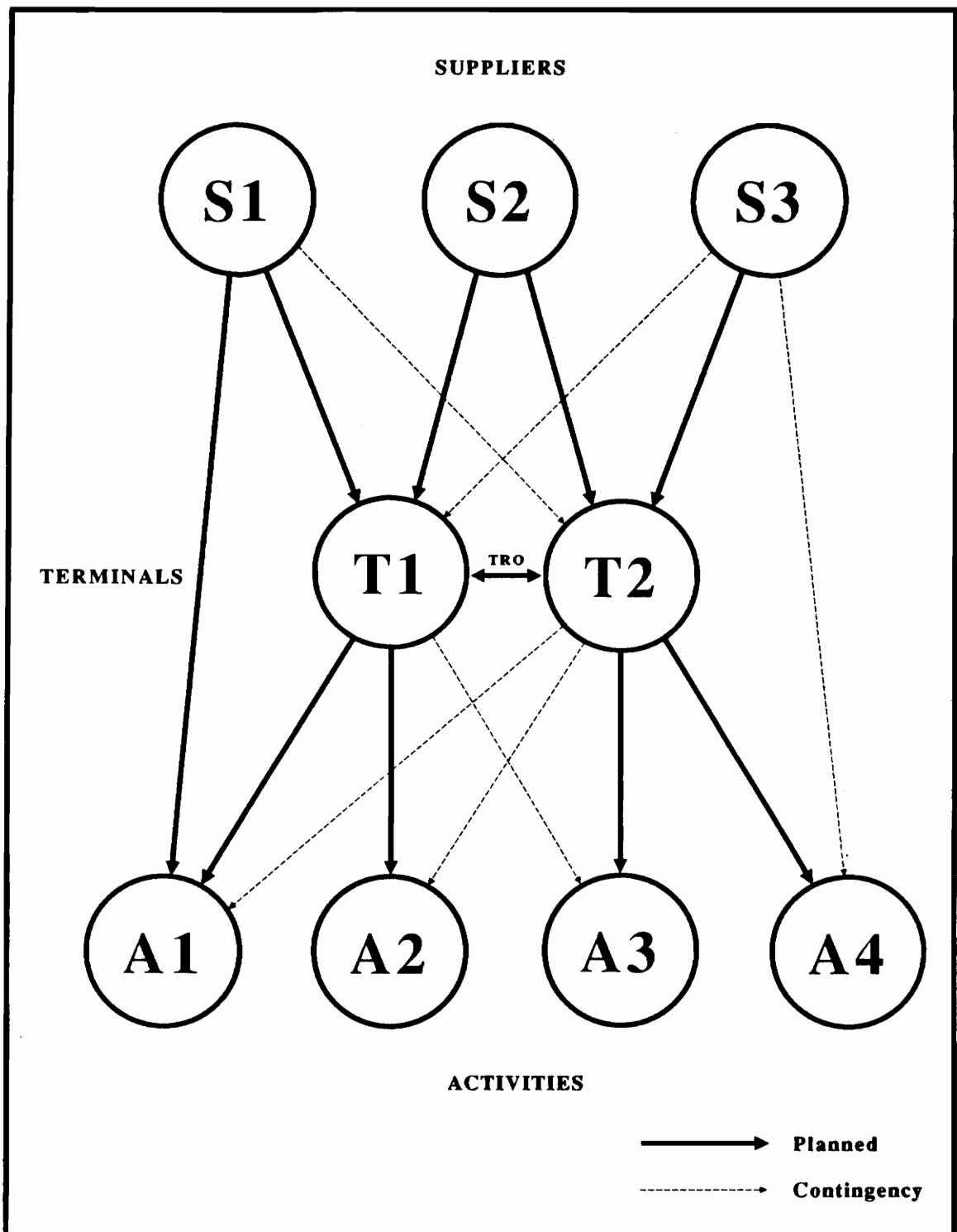


Figure 4-1. DFSC Fuels Distribution Network

#### 4.2 Cost Determinant Structure

A menu-driven cost determinant structure will be used to enter costs into the distribution system. A uniform determinant structure will be provided with which to enter cost information in each cost category. This determinant structure will provide the ability to enter costs in whatever manner they are incurred. Costs will be entered on line into a central database. This will allow costs to be entered as closely to their source as possible which reduces the chances of errors. It will also provide the uniformity of data required when evaluating alternative resupply networks. Menu-driven input screens will be used when entering costs. These screens will prompt the user for inputs based on the selected cost category. Within each category there will be appropriate screens further identifying the types of costs to be entered.

Costs will fall under four general categories: product, facility, transportation, and contingency. Product, facility and transportation costs are the costs normally associated with the distribution resupply network. Contingency costs are used when the other costs are not available. Within each of these categories, there will be established units of measure with which to enter costs. Preliminary units of measures would be costs per time period, costs per volume, and costs per distance traveled. This uniform structure will allow for

editing of input data. If a user tries to enter costs in a form other than the established units of measure, the data will be rejected, and the user will be prompted again.

The costs entered within the framework provided will be used to support the evaluation of alternative resupply networks. At the tactical planning level, costs will be provided to support the optimization of the network costs which in turn, will be provided to support contingency planning. The system will provide the ability to aggregate costs upward for tactical planning purpose. For instance, it may be necessary to aggregate costs from a lower planning level to a higher planning level such as aggregate daily costs to arrive at monthly costs for tactical planning. However, the system will not artificially break costs down into smaller timeframes. If costs are incurred on a yearly basis they will not be converted to a monthly or daily basis. This follows the general rule of entering costs as they are incurred.

The system will also provide conversion tables, factors, and rates that can be used when converting cost elements from one unit of measure to another before they are entered into the central database. This will normally occur when converting \$/BBL to \$/GAL or when converting long tons to gallons. This feature will make it easier for the staff to enter costs. It will also reduce the chances of human error

when performing the conversions.

### **4.3 Network Optimization**

This section describes the techniques that will be used to optimize the resupply networks. Optimization techniques based on linear programming will be used in the evaluation of resupply networks to determine the lowest cost distribution pattern. The optimizer will handle multiple products (JP4, JP5, etc.) The distribution system optimizer will support the tactical planning. The tactical solution set will focus on how best to distribute fuel given the available network of suppliers, carriers, activities, and facilities. The optimizer will obtain a solution by time period. The time periods could be by month, quarter, or year. The resupply network will be modeled as a flow model for the tactical planning purpose. This will require the operating constraints - supplier, carrier and facility capability as well as terminal and activity fuel requirements - to be expressed as flow rates or as availability/ requirements by time period.

The model will initially be set up to obtain optimal feasible solutions at the tactical level by using the general solution strategy described in section 3.2. This is the same level that is currently being used to run the Bid Evaluation

Model (BEM). The BEM is a linear programming model used to evaluate bids from suppliers. The objective is to determine the quantity of fuel to purchase and the company and shipping point from which to purchase the fuel so as to minimize the cost to the government. The BEM attempts to determine the optimal supply award pattern. The distribution system optimizer will be used to optimize the distribution network. It will determine how to distribute the fuel from the suppliers to the terminals and activities so as to minimize the costs to the government.

Sensitivity analysis and parametric analysis will be performed by operations research personnel on the tactical feasible solution set. The mathematical algorithm used to obtain the tactical solution will then be rerun to obtain the optimum solution. This is an iterative process (using one solution to obtain another solution).

The PDRS optimizer will use a commercial software package. In-house custom programming will be provided for the interfaces between the optimizer and other systems.

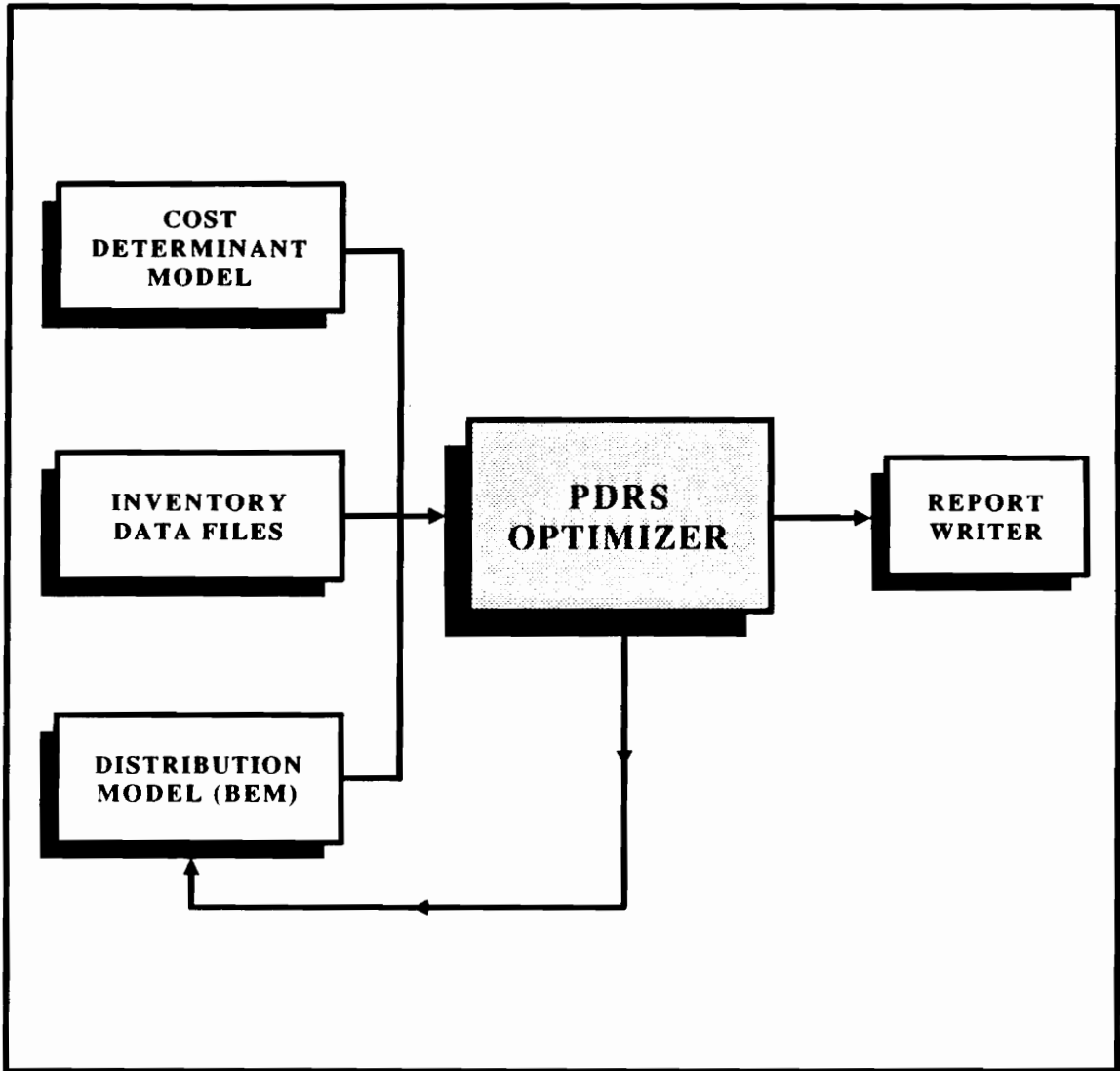
#### 4.4 Model Input

The inputs that will be needed to perform the optimization include cost determinants, operating constraints, fuel requirements and terminal inventory. These inputs will be considered on an aggregate level for the tactical planning purpose. The cost determinants used will include: fuel product costs, facility costs and transportation costs by mode - barge, tanker, rail car, truck and pipeline. The operating constraints will be for the current or planned resupply networks. They will consist of supplier constraints, carrier constraints and facility constraints. Supplier constraints identify supply availability by time period. Carrier constraints identify carrying capabilities by mode and time period. Facility constraints identify facility throughput capacity by time period and mode. Some of these constraints may be available as outputs of the network cost optimization - especially when performing tactical optimization. Taken together these constraints identify the total feasible set of resupply options.

Fuel requirements will be obtained for the activities and for the terminals. The activity fuel requirements by time period will be obtained from the demand forecaster. Terminal fuel requirements will be obtained by aggregating the requirements of the activities supplied by the terminal.

Inventory levels of the terminals will also be obtained and used for optimization. In the resupply network, terminals can be thought of as inventory queues. They will serve as transshipment points since they can both receive (demand) and ship (supply) fuel.

An overview of the recommended PDRS optimizer interface is shown in Figure 4-2 on the following page.



**Figure 4-2. The Recommended PDRS Optimizer Interface**

#### **4.5 Model Outputs**

The outputs that will be provided from the solution algorithm include a recommended resupply network and sensitivity tables. The recommended minimum cost resupply network will contain a recommended percentage participation for each route and mode in the resupply network. It will also identify the minimum total cost solution as well as laid-down costs per gallon for the resupply network. The sensitivity tables identify the ranges over which given input factors may vary without affecting the optimum solution. These tables will be used in the sensitivity and parametric programming analysis required to perform tactical level optimization.

The outputs will be provided as files for the report writer identifying the recommended network. There will be output files from the tactical solution set. The tactical files will be made available to support the bid evaluation process. In this way the bids could be evaluated using the same network data used in the distribution network optimizer.

#### **4.6 Solution Methodology**

A mathematical algorithm will be used to obtain the recommended minimum cost resupply network. This algorithm

will be based on linear programming techniques. It will apply the cost determinants, fuel requirements and terminal inventory levels to the operating constraints to identify the minimum cost solution. The resupply network will be modeled using a transshipment formulation. The transshipment formulation is an extension of the transportation problem which itself is a special type of linear programming problem. In it, the terminals are transshipment points in the network since they can serve as both sources and destinations of fuel. The transshipment algorithm will solve simultaneously for the amounts of fuel to ship from each source (fuel supplier or terminal) to each destination (terminal or activity) so as to minimize total distribution costs. The recommended network will contain a recommended percentage participation for each route and mode in the resupply network based on the minimum cost solution.

The solution will be obtained in a series of stages. Each stage will be seeking a solution to a slightly different problem but they will use the same mathematical algorithm. The first stage will optimize the resupply network within a particular region. This stage will optimize the barge, pipeline, rail, and truck deliveries within a region since most regions have control and responsibility for routing and scheduling these modes. The cost determinants, fuel requirements and operating constraints will be those

identified for each region. The fuel supply available to the region will be identified from the DPA/SIOATH. Note that this fuel supply may be available to other regions as well.

The second stage will seek a global optimum for all regions (i.e., the total fuel network) combined. It will optimize tanker deliveries, supplies that are available to more than one region (interregional supplies) and shared transportation resources between regions (where they share barges, pipelines, rail cars and trucks). The solution that results from this stage (including supply and transportation constraints on resources available to more than one region) will be forced down to the region level.

The third stage will be performed at the region level using the forced constraints from the second stage. This may result in a different solution than that obtained in the first stage due to the forced constraints, particularly the fuel supply constraints. For instance, the first stage may have assumed that all of the fuel from a particular supplier could be used within one region. But when the global optimum was obtained, that supply may have been allocated to a different region. Therefore, when the third stage is run the fuel that may have been available to supply a region's needs in the first stage is no longer available to supply that region's needs. This will probably change the transportation routing

decisions within a region. The same logic on forced supply constraints applies to shared transportation resources between regions.

The process of obtaining a region, global, region solution (stage 1, 2, and 3) is an iterative one. It will be performed as many times as necessary until the solution set at the two levels (region and global) agree with each other - i.e., all the supply available for the global solution equals the sum of the supplies available for all the regional solutions.

## **5. DISCUSSION**

### **5.1 Inventory Accuracy**

Inventory accuracy is an important issue and a critical element in the current distribution model. Implementing effective planning for fuel distribution at the tactical level requires an accurate figure from which to project fuel inventory and fuel available for resupply. It is important that inventory accuracy figures have the capability to be measured to determine and establish appropriate levels of performance.

The analysis of the current system has shown that the capability is there to determine inventory accuracy at the Defense Fuel Supply Point (DFSP) level. This ability to measure inventory accuracy allows DFSC to pinpoint and measure good performance and risk areas.

In order to develop successful inventory accuracy, Class A inventory should be achieved. Class A inventory is classified as 95% inventory accuracy or better. A sample of 16 terminals demonstrated that the current system is capable of Class A inventory accuracy. Using data from Defense Fuel

Automated Management System (DFAMS) it is determined inventory accuracy based on the reporting and timeliness of shipments and receipts of fuel at various DFSPs. Six of the sixteen terminals were well within Class A inventory standards of 95% accuracy within a 4-day time period. Of the remaining 10 terminals, 5 were within 95% accuracy for a 6-day time period. Very little effort would be needed to draw these terminals into acceptable Class A inventory levels. It is important to note that the sample was developed from a wide variety of terminals involving both tanker and non-tanker modes of resupply. The results of this example clearly show that Class A inventory accuracy can be achieved and maintained at the DFSP level.

It is important to realize that the main requirement of providing inventory accuracy is the ability to measure performance. In areas where performance does not meet DFSC standards, management can override the system with the current manual methods for the DFSP involved. It is important to monitor individual DFSPs in order to identify performance.

Insuring inventory accuracy is a significant and crucial step in developing effective requirements and distribution planning. DFSC cannot continue to be able to support planning effectively until reasonable and accurate inventory figures can be consistently maintained. In determining the

feasibility of implementing Class A inventory accuracy for DFSC terminals four major points were established:

- The current DFAMS inventory transaction processing system has the capability to provide excellent accuracy (less than 5% error within 4 days),
- Accuracy of individual DFSPs should be monitored,
- Manual overrides should be implemented for DFSP with poor accuracy, and
- Projecting available inventory based on the current transaction system is feasible.

Currently the DFAMS inventory transaction processing system has the capability to provide excellent inventory accuracy. In order to develop performance criteria for inventory accuracy, individual terminals must be monitored to determine and pinpoint risk areas. For DFSPs with poor accuracy, manual management overrides should be implemented until accuracy improves. Finally, based on a solid approach to inventory control, projecting available inventory based on the current transaction system is feasible. In order for planners to develop and project fuel availability, inventory accuracy must be established so that there is confidence in the numbers and figures used in the transaction data base.

## 5.2 Capability to Produce Feasible Optimum Solutions

The capability to produce feasible optimum solutions at the tactical planning level will be examined based on the analysis of the current distribution system as well as the direction of private industry. The ability of the system to produce optimal solutions at this level is related to the accuracy, timeliness, and availability of input data. The accuracy of the data should improve at this level with the use of the on-line integrated database. The timeliness of the data is an issue only at the operational level. Tactical and strategic data must only be timely by the month whereas operational data must be timely by the day. The availability of the data required to obtain optimal solutions is an issue at the tactical planning level.

Based on the analysis of the current system, optimal solutions can be obtained at the tactical level. Optimal feasible solutions at this level would be obtained and used as the baseline for developing strategic solutions. Sensitivity and parametric programming analysis, using the sensitivity tables from the tactical solution, would be used by operation research personnel to form the basis of generating strategic solutions. The types of data required to obtain a tactical optimum solution are currently available or will be made available when the distribution model is implemented.

The fact that the Bid Evaluation Model (BEM) is currently being used to produce tactical optimum solutions lends support to the availability of the distribution model to produce tactical optimum solutions. The same types of input data that are currently available to support the BEM would be required to support the distribution model optimizer. However, it must be emphasized that the BEM is used to generate the optimal supply award pattern whereas the distribution system optimizer would generate an optimal distribution pattern given the supply award pattern.

### **5.3 Hardware**

The distribution model will be developed within the current hardware environment of DFSC. Currently the majority of production processing is done on an IBM 4341 mainframe computer. It is also anticipated in the near future that many of the sites associated with the distribution model will have access to a microcomputer (IBM PC or compatibles). Software should conform with the current DFSC ADP environment.

DFSC handles much of its data processing on the mainframe. There are certain advantages to developing the distribution model using the current hardware environment. The major advantage is compatibility with DFAMS. Interfacing

DFAMS with the distribution model will be much easier using the present system.

Since the data base will be maintained entirely on the existing system it will provide for visibility of the total network data base. Better planning will be available at all levels due to the accessibility of the data base.

Finally the system is currently used to support DFAMS for transaction processing. Disruptions would not be beneficial to the current DFSC approach in implementing DFAMS.

As mentioned previously, many sites involved with the distribution model have or are acquiring microcomputers for use for different areas of planning. This will provide options in the development of the distribution model. The microcomputer approach will allow data to be downloaded from the mainframe to allow for the use of relevant data at the particular function level. Much of the tactical planning could be developed on the microcomputer.

Development of the distribution model can take place on the current existing hardware of DFSC. Developing the model on the current system should provide significant costs and time benefits to DFSC in implementation.

#### 5.4 Software

There are three general areas involved in determining and developing the software needed to support the distribution model: custom programming, available commercial software, and in-house software developed by DFSC personnel. Developing the distribution model will involve combining these three areas into a functional software architecture.

Because of the risk and cost associated with custom programming, a life-cycle management approach would be used in developing software. There are certain drawbacks associated with custom programming that should be identified before it is undertaken.

Custom programming involves a long lead time for implementation. All requirements and interfaces involving the software must be carefully thought-out and considered before any coding is undertaken. There is also a certain amount of risk and cost uncertainty associated with developing custom software. Requirements are subject to change over the implementation period causing custom programs to become obsolete.

Cost is uncertain in custom programming due to the nature of estimating costs and man-hours associated with development.

Custom programming should only be developed in areas where it is the only method available.

Application of commercial software could play a large role in development of the distribution model. There are many advantages associated with the use of commercial software that should be attractive to DFSC.

The implementation time associated with commercial software is relatively short compared to the long implementation associated with custom programming. The risk associated with commercial software is also very low, as the software has already been tested and implemented. Another advantage of using commercial software is the cost. Software is usually offered at a firm fixed price covering installation and initial tailoring. The major advantage of commercial software is that it is usually modular in nature. This allows the customer to choose modules relevant to his system. It is important when selecting software to insure that the terminology used in the software is tailored to the terminology used in developing the system requirements.

An important area of concern will be modifying commercial software modules to fit into the structured framework of the distribution system. Modification of the modular programs will be difficult to predict until the system starts to take

shape and the appropriate modifications are identified. The interfaces between the various modules will be of particular importance as they will encompass a large part of the modifications.

Finally, some of the software used in the distribution model will be developed in-house by DFSC personnel. There are some areas involved with the model that are unique that can best be implemented by DFSC for security and cost reasons.

## 6. CONCLUSIONS

The basis of the conceptual distribution model lies in the capture of timely and accurate inventory transaction data from the distributed work centers that are responsible for the actual distribution process, and the sharing of this data between work centers and levels of DFSC to obtain an integrated information support system. The distribution theory that most closely fits the DFSC process is known as the transshipment problem. This is a generalized theory that fits the DFSC tactical level requirements, and provides a framework for capturing the essential data elements for integration into a total fuels management system.

The potential benefits of implementing the PDRS result from improved supply and transportation planning and scheduling. The current informal manual systems would be replaced with formal uniform decision logic. Minimum cost tactical plan can be developed and input to operational and strategic planning for execution. A central data base is essential to unite all phases of planning and execution.

The results achieved by private industry in implementing similar distribution models are translated in one word -

productivity. Some results that industry has achieved are:

- Improved customer service (supply assurance),
- Reduced inventory levels and inventory obsolescence,
- Reduced operating costs
  - Direct labor and overtime
  - Purchasing
  - Transportation
- Improved accountability throughout the organization,
- Obtained information to react quickly, and
- Ability to anticipate and plan.

These results will now be related to the DoD organization like DFSC.

The tactical functions in PDRS will provide the DFSC not only with short term planning during disruptions but also with improved long term distribution network planning. The major emphasis of this area of planning is providing visibility to the laid-down cost of fuel. Network costs will be optimized and alternative scenario facilities, modes, terminals, and fuel suppliers will be evaluated. Further, minimum cost solutions for the complete distribution network will be provided in the tactical planning. Facility cost justification and planning contingency routes will be supported in a more timely and formal manner. This improved decision support capability will provide a formal

organizational "game plan" that would guide tactical planning and execution. This "game plan" would be used to monitor performance to improve accountability throughout DFSC.

The basis for implementing and controlling the "game plan" at the tactical planning level is the network cost optimization. One of the major benefits of this optimization is reduced operating cost through improved supply and transportation planning. Transportation costs at DFSC are approximately \$500 million per year. A one percent improvement in transportation costs would mean a \$5 million per year savings. Therefore, the potential savings for DFSC are enormous.

Specific benefits that DFSC could realize by using PDRS at the tactical planning level include:

- Better facility planning and utilization,
- Reduced safety stocks,
- Larger lift sizes, and
- Reduced expediting.

Improvement in these areas would result in reduced operating costs. The improved contingency planning capabilities in a more timely manner from the model will require the automation of several manual forms. This will

provide the information to react quickly. In order to capture timely information for fuel supply and transportation, both the fuel order and route order should be automated. It is also important that as many manual reports as possible be eliminated to reduce the workload on current personnel to facilitate better contingency planning.

In addition to providing substantial cost benefits, the PDRS should provide better inventory control for supply assurance. Private industry claims for improved customer service at reduced inventory levels seems contradictory. However, with PDRS computer support, managers have much greater visibility of projected available inventory levels. The improved information identifies high risk locations and locations with excessive safety stock. The net result would be improved supply assurance at reduced overall inventory levels.

Improved visibility of projected inventories and inventory turnover rates aids private industry in reducing inventory obsolescence. DFSC is concerned with stock rotation based on shelf life. Phasing in and out of fuel types, JP5 to JP4, based on military service requirement is very important. Improved inventory projections should aid in this area of concern.

## 7. SUMMARY

The Defense Fuel Supply Center (DFSC), under the direction of the Defense Logistics Agency (DLA), has the mission to provide effective and economical support of petroleum products and petroleum services to the military departments and other Department of Defense (DoD) components during a petroleum disruption. In its capacity as wholesale fuels distributor for the DoD, DFSC annually procures and distributes over 130 million barrels of fuel through terminals with an average inventory of about 88 million barrels.

To support its mission, DFSC is seeking to make major improvements in the current methods of determining how much fuel to stock, and the current methods of distribution planning and transportation scheduling during a disruption. The effort is the development of a system that can determine, predict, and consider the affects of distribution planning and transportation scheduling options on inventory as a function of least distribution cost. The DFSC has very little computer support in this aspect.

The analysis of the current fuel supply system clearly shows that there is very little timely computer support

provided for making distribution decisions in an energy emergency situation. Currently, informal manual information would be used if distribution decisions are needed. As a result many decisions would be made with dated information and poor visibility of other organizations' cost and supply requirements. This results in higher operating costs at reduced supply assurance. The DoD needs improved computer systems to better support its mission.

The DFSC supply network is extremely dynamic. Planning at the tactical level can be influenced by such factors as facility, carrier, or supplier interruptions as well as changes in fuel demand at the activities. Planners must develop alternative methods of resupply at a complex level when faced with a distribution system interruption.

The recommended PDRS will be developed based on supply and transportation planning system requirements identified in the current system analysis, the feasibility of model implementation, and related private industry direction. The model function is an essential building block and will provide the capability to evaluate alternative resupply networks and to recommend the optimum cost solution for the distribution network.

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## APPENDIX A - PDRS MODELING ALTERNATIVES

The alternatives and recommendations presented here were developed with a large degree of input from DFSC personnel. The alternatives evolved from the understanding of the current fuels management systems, the PDRS functional requirements, and the development of the evaluation criteria.

The major distinction between the PDRS modeling alternatives is in the modeling approach used to implement the model functions. These alternatives are then evaluated based on their ability to address the key management and technical issues. The alternatives also differ in the level of effort for implementation, complexity, and accuracy.

There are three possible alternative modeling forms that are developed and analyzed for use as a distribution model:

- Spreadsheet
- Mathematical Programming, and
- Simulation.

The spreadsheet is a relatively simple technique that would be executed in a matrix format. It involves simplified

calculations on the input data to produce the PDRS tactical plan. The results would be based on assumptions about the distributions of the variables and the categorization of terminals to which they apply. These assumptions, as well as other simplifying assumptions made in the model, adversely affect the quality of the output generated. The spreadsheet produces the least amount of output of the three modeling techniques and similarly requires the least development effort.

Since the model should be used as an evaluation tool using different input combinations, the spreadsheet should be automated. This would be accomplished on a microcomputer using commercially available electronic spreadsheet packages. A minimal data analyzer would be required to support application of the model.

The second model alternative, mathematical programming (or math programming), is an optimization model. Specific techniques within the math programming family include linear programming, non-linear programming, dynamic programming, goal programming, and integer programming. This approach involves the use of constraints to optimize an objective function. A mathematical algorithm must be derived or assumed for each terminal or terminal grouping. Input data would be fed into this algorithm to calculate the PDRS tactical plan. The

output generated from this model would be more accurate and more elaborate than the output from the spreadsheet.

The math programming alternative requires substantially more effort to develop than the spreadsheet model. This is because of the more detailed understanding of the terminals that is required to build the mathematical algorithms. This alternative also requires a more developed data analyzer.

Because of the complex calculations involved in producing the PDRS plan, the math programming model would be implemented on a mainframe, a minicomputer, or a microcomputer. The software would probably be a commercially available software package or FORTRAN-based to provide compatibility with most computer systems.

The third model alternative, simulation, is a method of modeling a probabilistic system without developing the mathematical algorithm. Discrete events would be represented by random variables and performance indices would be accumulated through the cyclical model "runs." The expected behavior of the system would then be reviewed statistically. The results would be based on historical data where available, and adjusted by the user to predict behavior in the circumstances to be modeled. The model therefore actually imitates the resupply process, and would be a useful tool for

evaluating different combinations of inputs.

Theoretically, the output from the simulation model would be slightly less accurate than that from the math programming model. However, the difference is negligible and the simulation model would generate more detailed information than the math programming approach.

The simulation modeling approach would require slightly more development effort than the math programming approach. The effort to develop the simulation model data analyzer will be similar to the effort required to develop the math programming model data analyzer. The main difference from the math programming alternative will be the focus of the technical effort. Whereas math programming requires a detailed definition of the relationships between factors to calculate a PDRS plan, the simulation approach will require more effort to build and "tune" the model after it is constructed, so it can be used for all terminals and products.

The simulation model, like the math programming model, requires complex mathematical calculations. Therefore, the model would be implemented on either a mainframe, a minicomputer, or a microcomputer. The software could be developed using any of the following computer languages: GPSS, SIMULA, SLAM or equivalent, FORTRAN, or BASIC. The preferable

software approach would be FORTRAN-based to provide compatibility with most computer systems.

### **Evaluation Criteria**

The evaluation criteria developed for the selection of the preferred model alternative reflect DFSC management concerns and issues regarding the operation of the current and future fuels management system. These criteria are used in the next section of this report to evaluate the effectiveness of each alternative. The criteria are grouped into three categories in order of importance.

The first category of evaluation criteria, decided in conjunction with the DFSC, involves the ability of the alternative models to address both management and technical issues. To be a useful planning tool, the model must be:

- Able to determine the inventory required to provide a specified level of service or confidence,
- Sensitive to variations energy policy,
- Flexible to cover a full range of constraints for all terminals and products, and
- Accurate and reliable so that the model results can be confidently used as a basis for management decisions.

The second category of evaluation criteria deals with the ease of understanding of the model and the model results. To be useful as a decision aid, the model must be easy to use and interpret. Part of this would involve using terminology, definitions, reporting procedures, and concepts that are standard to the DFSC. Another part would be designing the model so that a person with a non-ADP background could understand the model. A final criterion in this group involves determining how well the model provides insights into the planning process. As the planners learn more about the resupply process, they can plan better in the future.

The final category of evaluation criteria involves the costs and the benefits of the model. The analysis will closely examine the costs versus the benefits of the alternative models. The benefits to be derived would fall into the first two categories of criteria listed above. The costs include such factors as:

- Level of effort, cost, and time to develop the model;
- Level of effort, cost, and time to build, maintain, and operate the data needed for the model;
- Computer resources required; and
- Staffing required to run the model.

## **Evaluation of PDRS Modeling Alternatives**

The evaluation of modeling alternatives is based upon the evaluation criteria presented in the previous section. All three alternatives have distinct advantages and disadvantages. With the proper implementation, all of the alternatives would improve the PDRS planning process. The degree of benefit varies between alternatives, however.

### **a. Spreadsheet**

The spreadsheet approach is the least complicated of the three alternatives. It would be relatively easy to apply and develop. As a result, its development time and level of effort to implement are low. The preliminary estimate for implementation is 6 months.

The spreadsheet alternative has several disadvantages. The major disadvantage is its limited ability to resolve the key technical issues. A spreadsheet is a simplified deterministic method with limited accuracy. The advantages and disadvantages of the spreadsheet are as follows:

Advantages:

- Simplicity of implementation, and
- Development time and level of effort is low.

Disadvantages:

- Limited ability to evaluate alternative operation scenarios,
- Does not facilitate planner and scheduler understanding of decision implications, and
- Not designed to evaluate constraints on system.

**b. Math Programming**

The math programming approach requires more complexity, development, and data than the spreadsheet. However, math programming provides much higher quality results in satisfying the management and technical issues. Based upon the relatively high level of effort, math programming would require 12 months for implementation.

Math programming would require that the model be fairly complex to maintain and use. It would result in the ability to evaluate alternative operating scenarios and improved accuracy of the results. The advantages and

disadvantages of math programming are as follows:

Advantages:

- Most flexible alternative to address all terminals and fuel types,
- High degree of accuracy of the results,
- Best ability to evaluate alternative operation scenarios,
- Involves the use of constraints to optimize an objective function,
- Facilitates planner and scheduler understanding of decision implications, and
- Potential to extend to optimization of the fuels storage and distribution network.

Disadvantages:

- Development time and level of effort is high,
- Fairly complex to maintain and use.

**c. Simulation**

The simulation approach is similar to math programming in the level of effort required for PDRS implementation. The preliminary estimate for implementation is 14 months. The advantages and disadvantages of simulation are as follows:

Advantages:

- More flexible alternative to address all terminals and fuel types,
- High degree of accuracy of the results,
- Good ability to evaluate alternative operation scenarios,
- Facilitates planner and scheduler understanding of decision implications, and
- Potential to extend to optimization of the fuels storage and distribution network.

Disadvantages:

- Cannot optimize an objective function,
- Development time and level of effort is high,
- Computer time and user response time is high.

**Modeling Recommendations**

The spreadsheet would be a short-term or interim solution that would provide some improvements to the current planning process. The main advantages of the spreadsheet alternative are simplicity, a low level of effort, and a short implementation time. However, its expected long-term benefits fall short of the other two alternatives. The spreadsheet does not fully satisfy many of the important DFSC management requirements, and it marginally addresses the technical issues. It is believed that the results would be too weak to

use as a basis for management decisions, the spreadsheet approach is not recommended for the PDRS.

Math programming and simulation are essentially equal in several key areas and both are viable options. They are similar in the level of complexity, accuracy, and validity; cost and time to implement; and data collection requirements. Both options would satisfy the management and technical issues and provide a strong basis for management decisions. Their basic differences are in the areas of flexibility to cover all conditions and the degree of user interaction and understanding.

Math programming has several significant advantages. It would require less computer time and shorter response times than simulation. It would provide more flexibility to cover full range of constraints. This would provide more sensitivity analysis capability to evaluate alternative operating scenarios. By its nature, math programming that is used in distribution modeling provides a greater degree of user insight into the fuels resupply process. It can provide an optimum solution. Also, it would be simpler to use and interpret than a simulation model. Therefore, a math programming approach is the recommended alternative for the PDRS.