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PRIORITY DISPATCH AND AIRCRAFT SCHEDULING: A STUDY OF STRATEGIC AIRLIFT SCHEDULING

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This paper demonstrates the development of a flexible methodology for examining strategic airlift resource allocation and cargo priority rules. The work was motivated by the need to develop and test heuristic rules to reduce the amount of cargo delivered late in a contingency operation. Priority rules derived from machine scheduling are adapted and used in conjunction with alternative aircraft allocation procedures to determine an improved method for scheduling C-5 aircraft. To test the different scheduling policies in a dynamic environment, a simulation model was developed, using SLAM. Multiattribute utility theory was also used to develop a scalar scoring function (SSF) which effectively combined the response variables into a single value for each policy to facilitate comparison among the various scheduling policies. A full factorial experiment was performed, using five levels of cargo priority rules and three levels of aircraft allocation rules. A one-way analysis of variance was used to compare the mean SSF values for each policy.

II. INTRODUCTION AND BACKGROUND

Strategic airlift plays a significant role in current United States (U.S.) national policy. The Military Airlift Command (MAC) is tasked by the Joint Chief of Staff (JCS) with the mission of providing on-call strategic and tactical airlift for the Department of Defense anywhere in the world. "Airlift embodies a key fault of a fundamental capability--rapid, long-range mobility" (1:3).

To accomplish this mission, MAC operates a fleet of both strategic and tactical airlift aircraft. The strategic arm of this airlift fleet includes 70 wide-bodied C-5s whose theoretical maximum capacity is some 100 tons and practical capacity is 50 tons; 234 C-141s whose maximum capacity is approximately 40 tons; 250 Civil Reserve Air Fleet (CRAF) passenger-configured aircraft; and 123 CRAF cargo-configured aircraft (Ref 3). MAC also maintains a network of aerial ports, support bases, and other facilities throughout the world.

In this paper we will present an intertheatre airlift scenario which requires the efficient and timely delivery of cargo and passengers from the Continental United States (CONUS) to locations in various parts of Southwest Asia, in response to a hypothetical contingency plan. Although of limited scope, it will provide realistic methods to allocate strategic airlift resources for this particular scenario.

Headquarters MAC sponsored this research effort based on their need for a study method to determine how to allocate airlift resources to cargo and passenger requirements during a deployment. MAC's objective was to increase the tonnage delivered and reduce late cargo deliveries, while at the same time attempting to meet scheduled closure dates. This objective is critical to MAC operations; however, very little work has been expended in evaluating this problem.

Although Headquarters MAC currently possesses an airlift model (M-14), this model does not provide the flexibility nor the ease of implementation which is necessary for the study of aircraft allocation. The M-14 model is highly complex and requires six to eight weeks reconfiguration time for relatively minor modifications. If a simpler model could be developed which would permit MAC to be able to experiment with various scheduling algorithms before making major changes to M-14, the planning and scheduling processes could be significantly enhanced (Ref 9).

A model was developed for this paper using the Simulation Language for Alternative Modeling (SLAM) to facilitate studying scheduling effectiveness. Heuristic scheduling algorithms were developed and tested, using the SLAM model to determine the most efficient allocation of aircraft resources. The analysis is directed toward providing Headquarters MAC operations planners and aircraft schedulers with a study method for evaluating scheduling algorithms.

Aircraft allocation procedures presently used by MAC are based on aircraft cargo preference. The first preference is that C-5s prefer outsize, oversize, bulk, and passengers. Then the C-141s prefer oversize, bulk, and passengers. With these preferences established, a search is made of available cargo, oldest cargo having priority (cargo having the earliest due date). If no preferred cargo is available, the search is reinitiated for the next preferred cargo type. This process continues until all cargo has been scheduled for airlift.

2.1 Scenario

A hypothetical contingency plan requires the transportation of cargo and passengers from known locations within CONUS to several locations in Southwest Asia. The types of cargo which will be addressed are:

1. Outsize cargo--cargo which can only be transported on C-5 aircraft.

2. Oversize cargo--cargo which may be transported on either C-5 or C-141 aircraft.

3. Bulk cargo--cargo which may be transported on either C-5 or C-141 aircraft.

4. Passengers may be transported on either C-5 or C-141 aircraft.

Each cargo requirement has a designated pick-up point (origin) and a designated delivery point (destination). In addition, each cargo requirement will have time windows associated with it. In other words, each requirement will have an available to load date (ALD) at its origin and a latest arrival date (LAD) at its destination. There may be multiple airlift requirements at a particular base of origin, each of which may be an individual cargo type.

The aircraft to be utilized during the first twelve days of this contingency will be the C-5 and C-141. The military aircraft have varying speeds, varying cargo capacities, and variable ground times which impact the time cargo spends in the system.

When a cargo airlift requirement is generated at a particular base, aircraft available are allocated to satisfy the airlift requirement. Once tasked for a mission, the aircraft departs its home station, proceeds to the cargo origin base, loads cargo, and eparts for Lajes, Azores. The time from the aircraft's departure from its home station to its arrival in international airspace off the U.S. coast is called set-up time. Due to projected cargo loads, and the distances involved in deployment to Wouthwest Asia, aircraft must make two enroute stops before arrival at cargo destination bases. For the return flights, aircraft must again make two enroute stops at other airfields.

The air base network consists of aircraft home stations, onload bases, offload bases, and enroute stations. Each base possesses a limited amount of ramp space and either one or two runways. The airfields to be utilized for required enroute stops consist of Lajes, Azores; Cairo, International Airport, Egypt; [illegible] Egypt; Jeddah, Saudi Arabia; and Prestwick, England. (The first two airfields will be utilized for flights enroute to destinations while the latter two will be used for flights returning to the CONUS.)

2.2 Assumptions

The discussion can be summarized by formally stating the following assumptions:

1. Although only the first twelve days of the deployment period are considered, critical measures of performance (closures, cargo tardiness, and tonnage delivered) may be obtained to evaluate the effectiveness of algorithms tested.

2. Each individual cargo requirement at a base of origin will have an ALD of one-to-eleven and an LAD at destination equal to ALD + five.

3. Aircraft allocated to transport cargo always depart from home stations. This implies that aircraft returning to CONUS after mission completion proceed to home stations for post-mission maintenance and preparation for subsequent missions.

4. Distributions of ground time for each type aircraft and airfield are based upon the best information available and accurately reflect ground time for all activities at a given base, which may include time for taxi, maintenance, loading operations, and crew duties. As noted earlier, airfields include cargo onload bases, enroute stations, and offload bases. True ground times for an actual deployment of this type are unknown.

5. The only critical resources in the problem under study are aircraft, ramp space, and runways. This assumption is based primarily on the analyses previously performed by MAC. Since the origin and destination groups in the model are aggregates of numerous airfields, it is inferred that the dispersal of aircraft for onloads and offloads will preclude congestion; however, the use of a specific network of enroute airfields would probably cause various degrees of congestion at those particular bases. Although support resources do affect the potential activity level, this relaxation follows the stated objective of evaluating aircraft selection and allocation schemes rather than estimating the system capability.

6. Aircraft are generated for the contingency over a period of 48 hours. This takes into consideration those aircraft away from home station when the mobilization process is initiated and which must return to home stations for deployment mission preparation.

7. Cargo requirements enter the system incrementally over an eleven-day period.

8. The time required for delivery of cargo was a function of the priority dispatch rule utilized in scheduling, and the type aircraft allocated to transport the cargo. Although flight times for routes were specified, the ground service times were stochastic.

9. Once a particular cargo requirement was scheduled for transport and loaded aboard an aircraft, it was not preempted (i.e., removed and

replaced by another cargo requirement).

10. Due dates were fixed.

11. Aircraft were not allocated to replace other aircraft which experienced maintenance difficulties during a scheduled mission. Once cargo was loaded on an aircraft, it remained on that aircraft until delivery occurred. Repair time was included in ground service distribution times.

12. No subcontracting was permitted.

2.3 Research Objectives

The objective of this research was to develop and demonstrate a flexible study methodology for examining various algorithms used to allocate strategic airlift resources. This entailed the development of heuristic scheduling algorithms and a simulation model used as a test vehicle for the algorithms. The heuristics tested included cargo priority dispatch rules, in addition to aircraft allocation rules based upon cargo available for airlift. The simulation implemented the scenario discussed above.

2.4 Overview of Paper

Section III deals with the methodology (algorithm development) and experimental design for this paper. Section IV includes a discussion of the SLAM model, which was used as a test vehicle to evaluate algorithms. In Section V, the results, analysis, and conclusions are covered.

III. EXPERIMENTAL DESIGN

The most critical area to the development of the methodology was the selection of measures of performance. The ones selected were to:

1. maximize cargo requirements meeting closure dates (those requirements arriving at destinations prior to or on the latest arrival date), measured as a percentage;

2. minimize amount of tardy cargo, measured in ton-days; and

3. maximize tonnage delivered, measured in tons for the twelve-day period.

The selection of these three measures was made after interviews with HQ MAC staff members and the authors' interpretation and evaluation of the problem's scope. They are listed in order of importance to a theatre commander, who desired that unit requirements arrive at destinations in close proximity to one another and within appropriate time windows.

Having earlier specified the appropriate assumptions, the aircraft allocation rules and cargo priority dispatch rules were then developed. Current HQ MAC scheduling policy dictates that C-5 aircraft be allocated only (scheduled for a mission) if outsize cargo requires airlift. There must be outsize cargo requiring transport or the mission is not scheduled. Since the purpose of this research effort was to identify improved allocation policies, a determination was made to test two other allocation policies for the C-5. The first of these involved scheduling C-5s if either outsize or oversize cargo were available. The second required the allocation of C-5s if outsize, oversize, or bulk cargo were available. Therefore, three aircraft allocation rules were tested along with cargo dispatch rules.

The cargo priority dispatch rules selected for testing were as follows:

1. Aircraft preference--cargo requirements were grouped by cargo type (outsize, oversize, bulk, or passengers) and dispatched according to aircraft preference. Entries in each of these groups were ranked by EDD.

2. Earliest due date (EDD)--cargo requirements ranked by due dates in nondecreasing order.

3. Smallest weight (SWT)--cargo requirements in the job file were ranked according to weight in nondecreasing order.

4. Largest weight (LWT)--cargo requirements in the job file were ranked according to weight in nonincreasing order.

5. Slack per operation--the number of days available before the due date, divided by the number of operations.

The aircraft preference dispatch rule was selected as the base case, since this is present HQ MAC policy. For the particular aircraft allocation rule described above, cargo requirements were scheduled for airlift, based upon aircraft preference.

3.1 Response Variables

The design of this experiment required the identification of the following response variables derived from the measures of performance discussed above:

1. Closures--those cargo requirements delivered on or before their due dates.

2. Tardiness--the number of tons delivered late times the number of days tardy.

3. Tonnage delivered--the actual amount of cargo delivered in tons over the twelve-day period.

Because three response variables were involved, a method to combine these variables into a single value was needed. The authors chose to utilize a multiple-attribute utility theory (MAUT) technique to accomplish this task. A scalar scording function was developed using the decision-makers' preferences. This technique, called simple multiattribute rating technique (SMART), is described by Edwards (Ref 10). This SSF is then computed for each alternative policy. The actual development of the SSF is discussed in Section V.

To investigate the interactive effect of each factor, a full factorial design was employed, combining all levels of each factor with the levels of all other factors. This design varied the levels of only one factor at a time while keeping the others constant. This routine was repeated until all levels of all factors were examined. Since there were three factor levels for aircraft allocation rules and five factor levels for cargo priority rules, fifteen treatments (scheduling policies) were evaluated. A one-way analysis of variance (ANOVA) was used on the output from the simulation of these fifteen scheduling policies to test the hypothesis: HO: group means are equal, H1: group means differ. The sample used in the model was a twelve-day period. Thirty runs of each scheduling policy were made in the SLAM model to test the outcome on the response variables and SSF.

The next section provides the reader with an in-depth discussion of the SLAM model, the vehicle chosen to test the scheduling policies.

IV. THE MODEL

Careful construction of a representative model is a key factor in performing a simulation experiment. While it is desirable to accurately represent the system being modeled, some judgment is necessary to determine the level of detail captured in the model. For this experiment, the primary purpose of the simulation model was to provide a framework for comparing the relative effects of factors (cargo dispatching and aircraft allocation) on specific response variables (unit closures, cargo tardiness, and system throughput) under a set of conditions specified by MAC operations research analysts.

The modeling of a system is made easier if a pictorial representation can be made of it (Figure 1). The system modeled here was a strategic airlift network for a specified contingency operation which required the allocation of airlift resources for transporting cargo. This model was developed to define the boundaries of the system and establish the modeling detail desired.

The dotted line depicts the boundary of the MAC aircraft allocation process, and reveals that some parts of the input and output are external to the area. This suggests that the allocation system does not operate in a vacuum, but is related to both exogenous elements (inputs) and endogenous factors (outputs). The input block for this system includes the base structure, aircraft resources available, ground service time, cargo airlift requirements, and set-up time.

The primary output variables relevant to this study are those which directly reflect the movement of cargo. An obvious choice is system throughput, or the total quantity of cargo delivered in a set time period. This may be further refined by considering the amount of cargo delivered on or before its due date versus the amount tardy. Cargo tardiness, as well as the degree of tardiness, are both related to the time that a shipment remains in the airlift system. Various measures of system performance may also be related to the utilization (or availability) of key resources, which observably affect cargo movements. A simplified diagram portraying the sequence of events and network flow for aircraft and cargo entities is provided in Figure 2.

4.1 SLAM Network

The SLAM network was divided into four interrelated subnetworks. These networks are discussed under the following topic headings: aircraft generation; mission generation, which contains two subnetworks; and operations. Resources (aircraft, runways, and ramp space) were defined in both the network and control statements. The time unit utilized in the simulation was hours. The subnetwork concerning aircraft generation and mission generation is shown in Figure 3.

4.2 Aircraft Generation

The purpose of the aircraft generation network was to phase in the number of aircraft available to support the contingency plan. This network is based upon the assumption that a full complement of aircraft would be made available deterministically over a period of 48 hours. The network consists of three nodes: a CREATE node which serves as a timer, and two ALTER nodes, used to increment the number of aircraft resources available.

4.3 Mission Generation

The purpose of the first network of mission generation was to generate cargo requirements for each of the first eleven days of the deployment period. This network consists of only two nodes connected by one activity. The CREATE node (TIMR) releases an entity at the beginning of each 24-hour period (for eleven periods), and effectively initiates each day of the deployment. Each entity created by TIMR proceeds to an EVENT node (CGEN), which calls a FORTRAN subroutine (CTREQ) to select cargo requirements for the current day from a master file created before the simulation began. GTREQ also files these requirements in the priority order spacified by a SLAM card. These requirements are copied to other files for processing by a second EVENT node (SCHD) to be discussed below.

The purpose of the second network of mission generation was to generate mission entities by scheduling aircraft to transport those cargo requirements generated in the previous network. This network consists of two nodes and a single activity. The CREATE node, at time zero and every two hours thereafter for 11 days (132 total creation), creates an entity which proceeds to SCHD. Node SCHD calls subroutine SCHED, which checks the number of aircraft currently available and schedules missions until either cargo or airlift resources are depleted. These mission entities were entered into the operations network, where they seized appropriate aircraft resources, thus beginning a mission.

4.4 Operations

The primary purpose of the operations network was to control mission progress according to specified conditions and to provide a framework for collection of necessary model statistics. Subroutine SCHED returns mission entities to ENTER nodes one or two, based upon which type aircraft was projected to transport the mission entity. Mission entities are required to flow through this network, which represents the underlying network of airfields utilized for the contingency operation addressed. A number of factors were aggregated, including cargo origin bases, aircraft home stations for each type aircraft, and cargo destination bases.

V EXPERIMENTAL RESULTS & CONCLUSIONS

This section reports the results obtained by controlling aircraft allocation and cargo dispatching rules in the simulation of a contingency airlift to Southwest Asia. As reported in the section on experimental design, fifteen policies were evaluated and thirty replications were run for each policy (Table 1). The output data were scaled and used to computate a scalar scording function (SSF) for each policy, which was then used to make relative comparisons among the policies. Finally, a sensitivity analysis was performed to evaluate the effects of changes in the weight (importance) assigned to the response variables.

5.1 Calculations

In an effort to improve the readability of the data and analysis, a summary of the calculations used in data reduction is provided here. The total unit closures are computed by tallying the sum of (0,1) indicator variables. The tardiness of each late shipment (ton-days) is summed with the tardiness of undelivered cargo at the end of the measurement period. Total cargo delivered is the sum of cargo delivered on time and cargo delivered late (tons). Each of the ratios calculated above is dimensionless, and lies between zero and one (inclusive).

Customer needs were represented by the importance placed on each response variable. Each variable was rated separately by the user on a scale of zero (least important) to one (most important). The initial ratings were: closures (0.8), tardiness (0.6), and deliveries (0.2). Relative weights were calculated so that the sum of the weights was one. The following relationships were derived:

Sum of all weights = 0.2 + 0.6 + 0.8 = 1.6

WT1 = normalized closure weight = .8/1.6 = 0.5

WT2 = normalized tardiness weight = .6/1.6 = 0.375

WT3 = normalized delivery weight = .2/1.6 = 0.125

Using these, the scalar scoring function (SSF) can be specified as:

$$\begin{aligned} SSF &= (WT1)(C) + (WT2)(1-T) + (WT3)(D) \\ &= (0.5)(C) + (0.375)(1-T) + (0.125)(D) \end{aligned}$$

where

C = total unit closures/total unit requirements

T = actual ton-days tardy/total potential ton-days

and

D = actual tons delivered/total tons available.

This SSF is then computed for each alternative policy.

The ratios calculated for the closure (C) and delivery (D) variables are multiplied by their relative weights in the SSF. In order to make zero the minimum value of the function (and one the maximum value), the tardiness (T) ratio is subtracted from one before being multiplied by its relative weight.

5.2 Results

Table II gives a presentation output of the mean values obtained for a single series of simulations along with the associated scalar scoring function. In general terms, a policy reserving C-5 aircraft for outsize cargo scored lower than the other two C-5 allocation policies when combined with the same cargo selection (priority) rule. Eliminating this set of policies (Policies 1, 4, 7, 10, 13) from consideration, then, the Earliest Due Date rule ranked highest (Policies 5 and 6), followed by the Slack per Operation rule (Policies 14 and 15). The range tests fail to distinguish between policies five and six, which have the highest mean values for each set of scoring functions calculated. Policies fourteen and fifteen form another group which consistently ranks second for each set of scoring functions. Below this group, the rankings tend to vary from one scoring function to the next, except for policy seven, which has the lowest mean in each case. These results indicate that policies five and six dominate all other policies under the conditions of this experiment. The term "dominate," as used here, means that the scores of these two policies are never less than those of other policies--and they are often better. Similarly, policies fourteen and fifteen dominate all policies except five and six. Policy seven is dominated by the other fourteen policies. Sensitivity analysis with respect to the weights of the scalar scoring function did not alter these results.

5.3 Conclusions

This research project was undertaken to develop and test a method for using classical scheduling techniques in a strategic airlift simulation. The specific issues selected were: (1) allocation of C-5 aircraft to various types of cargo, and (2) adaptation of priority dispatching rules from job shop problems to strategic airlift. The general conclusion of the authors is that a useful method has been developed in this project, and the method indicates that certain combinations of priority dispatching and C-5 allocation rules offer improvement over procedures currently in use.

The use of adapted job shop scheduling rules to prioritize cargo requirements could increase cargo throughput and decrease cargo tardiness, compared with the results achieved by prioritizing requirements according to cargo type. In the course of this project cargo priorities were established by other predetermined attributes (e.g., due date, weight), as well as by a computed attribute (slack per operation) which was assigned when the cargo entered the airlift system. Both the due date and slack per operation rules consistently performed better than priorities assigned by cargo type.

Policies that reserve C-5 aircraft for missions with outsize cargo produce lower system performance levels (as measured by the scalar scoring function) than policies that release the C-5 for missions with oversize and/or bulk cargo, but no outsize cargo. In most cases, little difference was observed between the scores for policies that released C-5s for both oversize and bulk cargo under a single cargo priority rule. On the other hand, the score of the policy using that same cargo priority rule, but reserving C-5s for missions with outsize cargo, was always significantly lower.

Cargo priority rules have a greater effect on policy scores than do C-5 allocation rules. This conclusion is based on the observation that equal rankings of two policies which used the same priority rule occurred frequently, while there were no equal rankings of policies using the same aircraft allocation rule.

Assigning highest priority to cargo requirements having the largest cargo weight resulted in lower performance scores than any of the other priority rules, in most cases. Policy seven, which contained "largest weight" priority with "reserved for outsize" C-5 allocation, ranked lowest in every case tested.

The ranking of scheduling policies was rather robust to changes in the weights assigned to the response variables. Robustness was tested in a scenario-oriented sensitivity analysis. The policies ranked first and second were ranked the same in all cases, as was the policy ranked last. While there were shifts in other rankings among subgroups, there was almost no inversion of policy rank.

In a more general sense, the conclusions to be drawn from the project are that: (1) job shop priority dispatching rules are applicable to cargo selection procedures in strategic airlift; (2) the use of a scalar scoring function permits straightforward comparisons among airlift scheduling policies, and (3) an aggregate simulation model is adequate for comparing scheduling policies with regard to the response variables under consideration.

REFERENCES

AFM 1-1. Functions and Basic Doctrine of the United States Air Force. Washington D.C., HQ U.S. Air Force, 14 Feb 1979.

Baker, Kenneth R. Introduction to Sequencing and Scheduling. New York: John Wiley & Sons, Inc., 1974.

Brown, Harold, Department of Defense Annual Report, Fiscal Year 1981. Washington D.C.: U.S.

Conway, Richard W., William L. Maxwell and Louis W. Miller. Theory of Scheduling. Reading, MA: Addison-Wesley Publishing Co., 1967.

Conway, Richard W. "Priority Dispatching and Job Lateness in a Job Shop," Journal of Industrial Engineering, 16 (4): 228-237 (Jul-Aug 1965a).

Conway, Richard W. "Priority Dispatching and Work-in-Process Inventory in a Job Shop," Journal of Industrial Engineering, 16 (2): 123-130 (March-April 1965b).

Day, James E. and Michael P. Hottenstein. "Review of Sequencing Research," Naval Research Logistics Quarterly, 17 (1): 11-39 (March 1970).

Dewispelare, Aaron R. and Andrew P. Sage. "On Combined Multiple Objective Optimization Theory and Multiple Attribute Utility Theory for Evaluation and Choicemaking," Journal of Large Scale Systems, 2: 1-19 (1981).

Dillard, Maj Charlie, Operations Research Div., HQ MAC, Scott AFB IL (telephone conversation). 3 Nov 1982.

Edwards, Ward. "How to Use Multiattribute Utility Measurement for Social Decisionmaking," IEEE Transactions on Systems, Man, and Cypernetics, SMC -7 (5): 328-340 (May 1977).

Elmaghraby, Salah E. "The Sequencing of 'Related' Jobs," Naval Research Logistics Quarterly, 15 (1), 205-232 (March 1968).

Fabyanic, Thomas A. "Conceptual Planning and the Rapid Deployment Joint Task Force," Armed Forces and Society, 7(3): 343-365 (Spring 1981).

Gere, William S. "Heuristics in Job Shop Scheduling," Management Science, 13 (3): 167-190 (November 1966).

Greenberger, Martin, Matthew A. Crenson and Brian L. Crissey. Models in the Policy Process. New York: Russell SACE Foundation, 1976.

JDA Staff. "Joint Deployment Agency, A Deployment Broker," Airlift Operations Review, 3(1): 8-13 (Jan-Mar 1981).

Monrer, Adm Thomas H. and Alvin J. Cottrell. "The Search for U.S. Bases in the Indian Ocean: A Last Change," Strategic Review, 8(2): 30-38 (Spring 1980).

Montgomery, Robin N. "The Questionable U.S. Strategy for the Middle East," National Defense, 65: (365): 64-68+ (May-June 1981).

Pritsker, A. Alan B. and Claude D. Pegden. Introduction to Simulation and SLAM. New York: John Wiley & Sons, 1979.

Rowe, A. J. "Toward a Theory of Scheduling," Journal of Industrial Engineering, 11(2): 125-136 (Mar-Apr 1960).

Trilling, Donald R. "Job Shop Simulation of Orders that are Networks," Journal of Industrial Engineering, 17 (2) (February 1966).

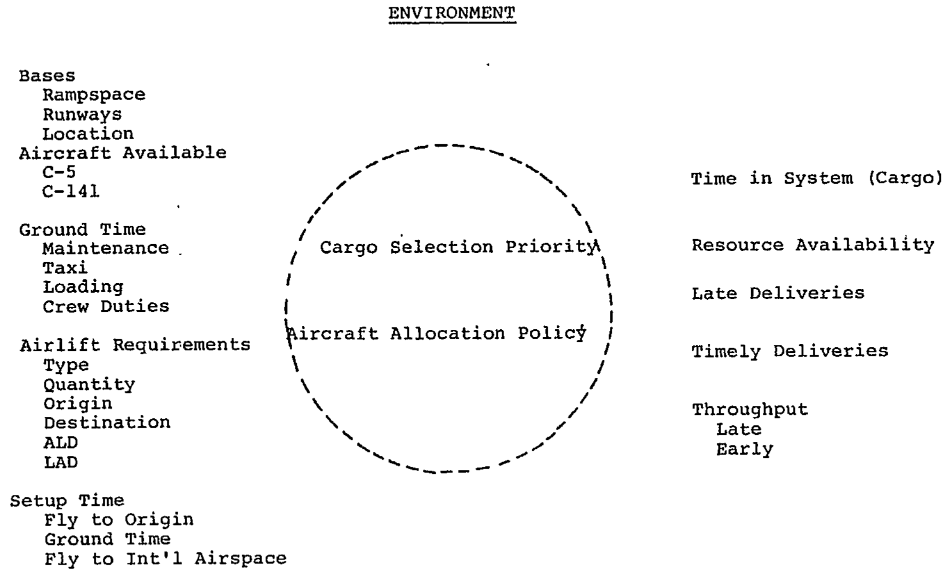

Figure 1 Structural Model Diagram

Figure 2 Aircraft Generation and Mission Generation Subnetworks

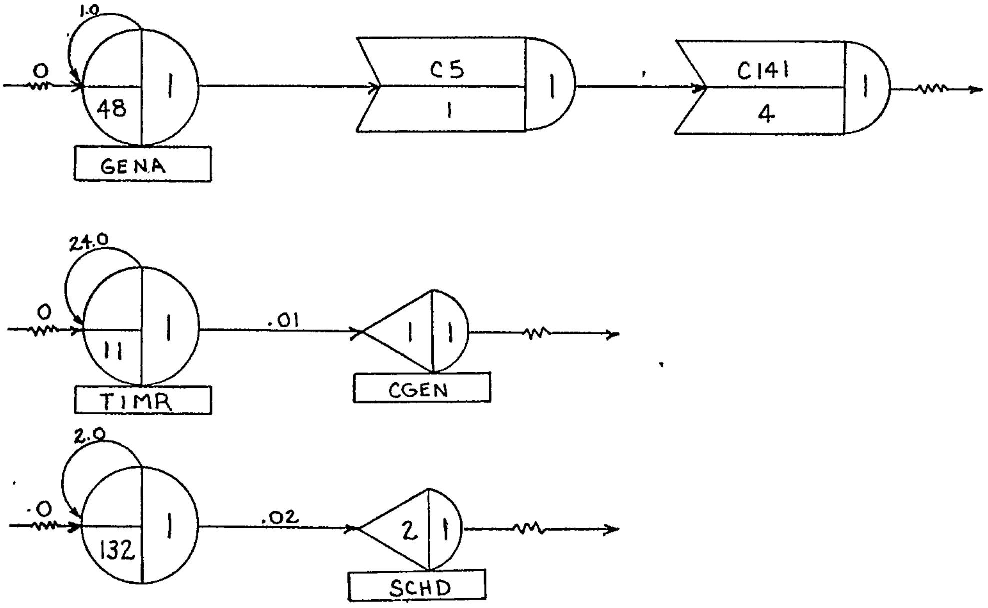

Figure 3 Simplified Aircraft and Cargo Flowchart

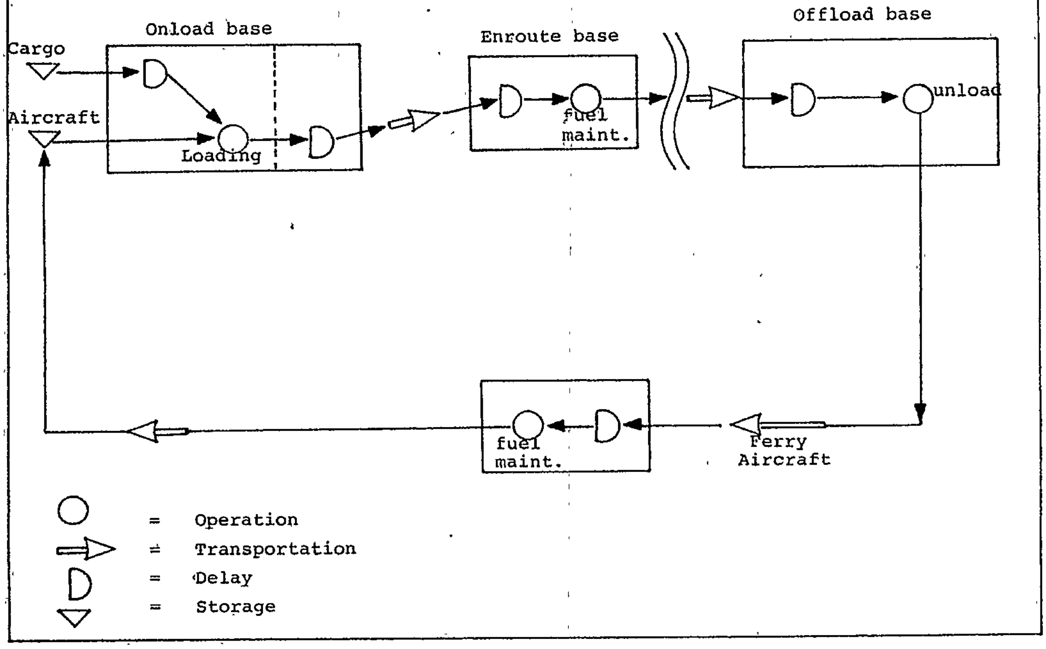

TABLE I

SCHEDULING POLICIES

		Aircraft Allocation Rules		
		C-5 Outsize	C-5 Outsize Oversize	C-5 Outsize Oversize Bulk
Cargo Priority Rules	Aircraft Preference	1	2	3
	EDD	4	5	6
	LWT	7	8	9
	SWT	10	11	12
	Slack Operation	13	14	15

Note: Although only C-5s are specified above in allocation rules, C-141s are launched for oversize, bulk, or passenger airlift requirements for each rule.

TABLE II ACTUAL SCALED OUTPUT DATA

POLICY	MEAN CLOSURES	CLOSURE RATIO	MEAN TARDINESS	TARDINESS RATIO	MEAN DELIVERIES	DELIVERY RATIO	SSF1
1	18.77	0.1104	53,635	0.3570	22,590	0.6008	0.3162
2	20.09	0.1182	49,007	0.3262	23,714	0.6307	0.3315
3	23.70	0.1394	47,114	0.3136	23,782	0.6325	0.3365
4	49.33	0.2902	66,345	0.4416	18,856	0.5015	0.2721
5	95.80	0.5635	21,244	0.1414	30,663	0.8155	0.4239
6	97.00	0.5706	21,424	0.1426	30,678	0.8159	0.4235
7	0.24	0.0014	91,960	0.6121	13,893	0.3695	0.1916
8	4.27	0.0251	59,764	0.3978	20,631	0.5487	0.2944
9	10.47	0.0616	60,065	0.3998	20,627	0.5486	0.2937
10	106.44	0.6261	71,573	0.4764	18,823	0.5006	0.2589
11	123.86	0.7286	61,838	0.4116	22,804	0.6065	0.2965
12	126.60	0.7447	60,786	0.4046	22,067	0.5869	0.2967
13	47.57	0.2798	69,440	0.4622	18,917	0.5031	0.2646
14	88.50	0.5206	30,543	0.2033	29,727	0.7906	0.3976
15	91.27	0.5369	31,099	0.2070	29,430	0.7827	0.3952