NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

IMPACT OF U.S. NAVAL VESSEL MOVEMENTS WITHIN SAN FRANCISCO BAY AREA ON NAVAL SUPPLY CENTER OAKLAND'S TRANSPORTATION SYSTEM

by
Gary John Angelopoulos

September 1979

Thesis Advisor: A. W. McMasters
Thesis Co-Advisor: E. F. Roland

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| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) |

This simulation is a versatile SIMSCRIPT program designed to determine transportation destination fluctuations caused by U.S. Naval Vessel movements in the San Francisco Bay Area. The throughput model was designed to investigate the relationship between the annual number of delivery trips and the average material delivery delay. Numerous parameters have been taken into consideration in the generation of a model that is as realistic as possible. Requirement priority, item quantity, customer movement, ultimate destination, and request time.
are the significant random variables which have been assigned probabilistic distributions. In view of the simulation results, it would appear that actual modification of the current shipping parameters may yield substantial transportation savings.
IMPACT OF U.S. NAVAL VESSEL MOVEMENTS WITHIN THE SAN FRANCISCO BAY AREA ON NAVAL SUPPLY CENTER OAKLAND'S TRANSPORTATION SYSTEM

by

Gary J. Angelopoulos
Lieutenant Commander, Supply Corps, United States Navy
B.S., Philadelphia College of Textiles and Science, 1965

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the
NAVAL POSTGRADUATE SCHOOL
September 1979

Author: _____________________________

Approved by: ________________________
Thesis Advisor

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Co-Advisor

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Chairman, Department of Operations Research

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Dean of Information and Policy Sciences

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ABSTRACT

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TABLE OF CONTENTS

I. INTRODUCTION ....................................................... 9
   A. BACKGROUND .................................................. 9
   B. OBJECTIVE .................................................. 12
   C. SCOPE ....................................................... 12
II. ASSUMPTIONS AND PARAMETER EVALUATIONS ...................... 13
   A. MOBILE CUSTOMERS .......................................... 13
      1. Ship Movement ........................................... 13
      2. In Port Duration ......................................... 15
   B. MATERIAL REQUIREMENTS AND PROCESSING .................... 25
      1. Historical Demand File .................................. 25
      2. Data Base Establishment ................................ 28
      3. Data Extraction ......................................... 28
      4. Sample Size ............................................. 29
      5. Data Reduction ......................................... 30
      6. Bundle Preparation Time ................................ 31
      7. Mail Time per Bundle .................................... 37
      8. Number of Requisitions per Bundle ..................... 38
      9. Requisition Priority .................................... 39
     10. Process Times ............................................ 40
     11. Quantity per Requisition ................................ 41
     12. Weight per Requisition .................................. 42
III. SIMULATION .......................................................... 44
   A. GENERAL ...................................................... 44
   B. PROGRAM DESCRIPTION ....................................... 44
      1. Detailed Analysis ........................................ 45
      2. Seeds ..................................................... 46
      3. Equilibrium Determination ............................... 47
      4. Shipping Strategies ..................................... 48
      5. Measures of Effectiveness ............................... 48
   C. RESULTS ....................................................... 48
IV. DISCUSSION AND CONCLUSIONS ........................................ 51
A. DISCUSSION ......................................................... 51
B. CONCLUSIONS .................................................... 54
Appendix A: SHIPS INFORMATION BULLETIN ....................... 56
Appendix B: FORTRAN PROGRAM AND DATA ................. 57
Appendix C: FORTRAN PROGRAM ANGSDATI .................. 58
Appendix D: SIMSCRIPT PROGRAM ANGSSIM ................. 60
Appendix E: CASE II CHANGES .................................. 63
Appendix F: CASE III CHANGES ................................ 80
Appendix G: CASE IV CHANGES ................................ 81
Appendix H: DETAILED RESULTS ................................ 85
LIST OF REFERENCES ............................................... 87
INITIAL DISTRIBUTION LIST ..................................... 89
LIST OF FIGURES .................................................. 7
LIST OF TABLES .................................................... 8
LIST OF FIGURES

1. Vessel Schedule.............................................. 19
2. Auxiliary Ammunition Transition Matrix................. 20
3. Auxiliary Replenishment Transition Matrix.............. 21
4. Auxiliary Refrigerated Stores Matrix................... 22
5. Auxiliary Repair Transition Matrix..................... 23
6. Mine Sweeper Ocean Transition Matrix.................. 24
7. Historical Demand Record Format....................... 27
8. AE 24 Bundle Inter-preparation Histogram............... 33
9. AE 28 Bundle Inter-preparation Histogram............... 34
10. Shipments 7S Waiting Time.............................. 53
LIST OF TABLES

1. Local Vessel Demand Data................................. 11
2. In-port Frequency Data.................................... 15
3. Relative Frequencies Of Inter-preparation Time........ 32
4. Probabilities Of Requisitions Per Bundle............... 59
5. Averaged Results........................................... 50
I. INTRODUCTION

A. BACKGROUND

Naval Supply Center (NSC), Oakland, California is one of five major support facilities in the United States Navy. Approximately 500,000 line items have been positioned at NSC Oakland to provide material support to active and reserve fleet units, local and overseas shipyards, naval air stations, several overseas depots, and numerous smaller commands. It also has the capability of responding effectively to a wide variety of functional tasks. These services provided include accounting functions, household goods storage and movement, central area procurement, operation of a fuel support facility, and support to foreign governments.

NSC Oakland is further tasked with implementing these mission requirements over a vast area of the globe. In fact, it includes the Pacific Ocean (Hawaii Area excluded), the Indian Ocean, and Northern California.

In Northern California, direct support is provided to 174 local commands. The size of these commands varies from a major shipyard to small boats, and within this spectrum there is a group of unique customers. They are U. S. Naval vessels which are mobile; each ship may be found at several different locations during the course of a year. Such movement has impact on the material segregation function and the transportation requirements of NSC Oakland. During
fiscal year 1978, seventeen vessels represented those local customers whose transportation destinations varied significantly. Many more than seventeen ships are homeported in the Bay Area. However, the other vessels, when present, always berthed at the same location. Thus, their delivery distance requirements were known. The seventeen mobile customers include:

Eight Auxiliary Ammunition Vessels (AE's),
Three Auxiliary Refrigerated and Stores Vessels (ARS's),
Three Auxiliary Oiler and Replenishment Vessels (AOR's),
Two Mine Sweeper Ocean Vessels (MSS's),
One Auxiliary Repair Vessel (AR).

Table 1 is a statistical review of all vessels requisitions as documented in the Historical Demand File at NSC Oakland from September 1977 to September 1978. It amplifies the relative significance of vessel support on both a local and global level. Those vessels marked by an "*" berthed at more than one location in the bay area during the year.
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The seventeen mobile ships represented 24.46 percent of NSC Oakland's local business as shown in Table 1. The ships in this group were found to change location from as few as four to as many as eighteen times in a one year period. It should be noted that trips in which vessels returned to their place of departure were not included. A mobile customer located at NSC Oakland today may be found tomorrow at the Naval Weapons Station Concord, some thirty-three miles away. Thus, over a short period of time, transportation requirements may materialize or disappear. Such fluctuations have had a significant impact on the Bay Area Local Delivery (BALD) system which transports material from NSC Oakland to these ships.

B. OBJECTIVE
It is the intent of this paper to quantify, through simulation, the impact of local mobile customers on the transportation requirements of NESC Oakland's Bay Area Local Delivery system (SALD).

C. SCOPE

Simulation was chosen as the technique for evaluation of this problem for the following reasons: 1. The actual material transportation requirements for the mobile customers were not available, and the cost to obtain such data was considered to be prohibitive; 2. Alternative delivery schemes can be evaluated prior to imposing them on the actual system.

Only those previously identified local vessels, their movements, and the associated NESC Oakland material support during the year from September 1977 to September 1978 was considered in this simulation.

The decision parameters utilized included both empirical distributions and classical distributions. They were developed through the use of historical and standard data analysis techniques. However, when data was limited, some distributions were subjectively developed. This approach was taken under the assumption that it was better to utilize what information was available, rather than to use entirely arbitrary values.
II. ASSUMPTIONS AND PARAMETER EVALUATIONS

Exact identification and quantification of all simulation parameters and variables is not only a formidable task but, in general, an impossible one. It is apparent that any process complex enough to warrant computer simulation will also require simplifying assumptions. In the interest of realizing a viable finding within a constrained time period and with limited assets, numerous suppositions were required. Whenever possible, each premise has been analytically or logically justified in the following subsections.

A. MOBILE CUSTOMERS

The vessel movement data analyzed was extracted from fifty-four weekly Ships Information Bulletins (NASUPPACT-30) published by the Naval Support Activity, Treasure Island, San Francisco, California. Appendix A is an example of one such bulletin.

Figure 1 is a graphical representation of the operating cycles of the seventeen port-mobile vessels for fiscal year 1978. It is the basis of the vessel mobility section of the simulation.

1. Ship Movement

Ship movement between local Bay Area ports was
assumed to be a Markov Process. As a consequence, knowledge of past movements of a vessel will not change the probability of moving from one location to another or, stated differently, the system is memoryless and will not modify future behavior because of knowledge of past movement. Thus, a stochastic matrix of the transition process from one location to another was constructed.

Since ships of the same class (for example, Auxiliary Ammunition Vessels) are operationally funded at the same level, operate with similar life cycles, perform the same mission, and are manned at the same compliment; ship movements were aggregated by class and Markov chains were developed for each class.

Figures 2, 3, 4, 5, and 6 show the matrices for each ship class. They were developed by first identifying the ports visited by each ship class. Those ports were then annotated on the left vertical and top horizontal sides of the class matrix. Next, these vessels' movements (Figure 1) were annotated in the matrix as follows: a. The initial location of a vessel was identified on the left vertical side of the matrix; b. The location that this vessel next moved to was then noted at the top horizontal side of the matrix; c. A check mark was then entered within the matrix based on these two locations. This procedure was then repeated using this ship's new location as the left vertical starting port of the matrix. When all the vessel movements within a class had been processed, the probabilities of movement from one location to another were determined across each row of the matrix by dividing all elements' values (sum of a group of check marks) in a row by the total row sum.

If one were interested in determining the probabilities where an APS would be expected to move given it is at Alameda, Figure 4 would be utilized. Starting with
US Alam on the left vertical side one would move along this row and note that there is a sixty percent chance of going to NSC Oakland or a forty percent chance of deploying.

2. **In Port Duration**

It was assumed that in-port duration times were independent of ship type, but were a function of their associated location. Thus, these times were aggregated by location and probabilistic distributions were assigned. It should be noted, that a scarcity of data and difficulties in fitting this data has resulted in some uncertainty about these distributions.

If a ship was conducting local operations and returned to its departure location, it was considered located at that port for the time period under investigation. However, if a vessel departed and returned to another local port, the time in local transit/operations was included in the arriving location calculation. These time periods were included in the in-port computations because it was assumed that material not delivered prior to a vessel's departure would be delivered to the vessel's "new" location, and any material requirements received for an underway vessel would be sent to the "new" port. Also, if a vessel departed from a location and did not return to a local port within sixty days, it was assumed that it was on an eight-month deployment to the Western Pacific.

The following results represent the number of in-port periods contained in each time interval and is a general overview of the time frequency results. The in-port time interval corresponds to a cell in table 2. In-port time intervals were determined by first calculating the in-port time periods for all vessels which visited each
port. These periods were then sorted by port. Time interval (cells) were next selected which would result in approximately five in-port duration observations per cell. Due to the extreme spread of the data it was not possible to display the complete cell data for all ports. In some cases so few data points were available that the above procedure could not be done, and these cases were omitted from the Table. In other cases extreme values were observed which were more than double the next largest value. These values were in general considered outliers and were truncated from the data set.

For example, the in-port durations for NAS Alameda were calculated utilizing Figure 1. They were then ordered and analyzed. The data was segmented into two groups. Table 2 shows the first three cells of this segmentation. In this case, each cell represents four days. The remainder of the distribution was also observed to be uniform (no significant upward or downward trends) and they ranged from twenty-seven to one-hundred and twenty-nine days.

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These results are presented as a partial explanation of the subjective determination of the in-port time distributions. Upon completion of the inter-departure time analysis, probabilistic distributions were assigned by
geographic location as follows:

a. Naval Station Alameda: The in-port time is uniformly distributed between four and seventeen days with probability .5, and uniformly distributed between twenty-seven and one hundred twenty-nine days with probability .5.

b. Naval Weapons Station Concord: The in-port time was found to be exponentially distributed with the parameter equal to .00012.

c. NSC Oakland: The distribution was found to be uniform between nine and fifty-six days.

d. Naval Station Treasure Island: The in-port time is uniformly distributed between three and seventy-eight days.

e. San Francisco Shipyard: The maintenance time was seven days with a .65 probability, or was two-hundred-forty days with a .35 probability.

f. Todd Shipyard (Alameda): The time distribution was found to be uniform from thirty-eight to eighty-four days.

g. Bethlehem Steel Shipyard (San Francisco) : Maintenance periods were either thirty or one-hundred-eighty days with equal probability.

h. Triple A Shipyard (San Francisco) : In-port time was found to be seven days.

i. Merritt and Pacific Shipyards (Oakland) : Maintenance time was forty-four days for both locations.
j. Mare Island Naval Shipyard: The maintenance periods were uniformly distributed between three and twenty-eight days with probability .568 or uniformly distributed between forty-three and ninety-one days with a .332 probability.

k. Deployed: The time in this category was assumed to be uniformly distributed between fifteen and sixty days with probability .65, and was two hundred and forty days (eight-month deployment to the Western Pacific) with probability .35.
Figure 1 - VESSEL SCHEDULE
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**Figure 2 - Auxiliary Ammunition Transition Matrix**
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**Figure 3 - Auxiliary Replenishment Transition Matrix**
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Figure 4 - AUXILIARY REFRIGERATED STORES MATRIX
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**Figure 5 - AUXILIARY REPAIR TRANSITION MATRIX**
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Figure 6 - Mine Sweeper Ocean Transition Matrix
B. MATERIAL REQUIREMENTS AND PROCESSING

The material requirements and distribution processes experienced by NSC Oakland were reduced to a series of inter-related functions. The criteria for this breakdown was twofold: first, the function must be estimatable; and second, only realistic processes were considered.

Subsequent paragraphs discuss the various assumptions and procedures undertaken to quantify the inter-linking segments of the material pipeline under investigation.

1. Historical Demand File

Numerous mechanized data bases were available at NSC Oakland. However, after a detailed evaluation, it was decided that the Requisition Demand History File (RDHF) would provide the most useful data. The Requisition Demand History File is a readily available mechanized file encompassing transactions from two fiscal years. Figure 7 depicts the standard format of the file's five possible one-hundred character records. These records will be discussed below. This file is composed of those material actions (requisitions) which have been transferred from the Requisition Status File because of their historical significance. Both the Requisition Status File and the Requisition Demand History File are composed of records. The initial basic entry which establishes the record is a requisition and other pertinent data is subsequently added.

A record-by-record scanning of the Requisition Status File is conducted to determine which records should
be retained because of their historical value. The following decision parameters represent the significant categories of records which are transferred to the RDHF[11]:

a. Requisitions issued with and without proof of shipment as follows: (1) if the record has been in the file sixty or more days, without proof of shipment, a Record Type four is assigned; (2) if the record has been in the file sixty or more days with proof of delivery and the issue group is one or two, a Record Type one is assigned; (3) if the record has been in the file thirty days or more with a proof of shipment and the issue group is three, a Record Type one is assigned.

b. Those records with exception supply status (rejected/canceled) as follows: (1) requisitions in the file for sixty or more days and in issue group one or two are assigned Type Code five; (2) requisitions in the file for thirty or more days and in issue group three are assigned a Type Code five.

c. Records which indicate the item was sent to purchase as follows: (1) if the record has been in the file ninety or more days without purchase order data and is in issue group one or two, or if the record has been in the file thirty days or more without purchase order data and is in issue group three, a Type Code three is assigned; (2) if the record has been in the file sixty days or more with purchase order data and the associated issue group is one or two or if the record has been in the file for thirty days or more and the issue group is three, a Type Code of two is assigned.
2. Data Base Establishment

Eight standard labeled IBM tapes were obtained from MSC Oakland. These tapes were generated from the RDHF and they contained all material transactions from September 1, 1976 to August 30, 1977. Over two million records were on these tapes. The transactions encompassed local material issues, demands for material not stocked at MSC Oakland, inter-depot transfers of material, and local procurements. The customers creating the majority of these demands for material were located worldwide and numbered over eight thousand.

As only data for local customers was desired, numerous extraction programs were developed. The resulting data base contained only issues from stock for local customers, including local procurements. Much of the purification (duplicate records were discovered) and extraction of this data was conducted with the assistance of W. B. Nelson, LCGR, SC, USN, a fellow student at the Naval Postgraduate School. Upon completion of this reduction approximately 600,000 records (four tapes) remained and it was from this base that the vessel data was developed.

3. Data Extraction

Those data elements actually extracted for further analysis were common to all file records and in the same data fields. Specifically, the data fields used were as follows: a. the document number's unit identification code (UIC) and date; b. the date received; c. the supply action date; e. the quantity; and f. the priority.
The Appendix B program, ANG$DATA, extracted those records from the local customer transactions data base which met the following conditions:

a. Only those records of the previously identified mobile customers were considered.

b. Of the above records, only those records which the supply status code indicated that material had been locally issued were actually extracted (supply status code BA).

Each data record which met the above criteria, was also coded to facilitate the identity of its owner and the owner's ship class.

4. Sample Size

In most cases the entire data base was used in the determination of the simulation parameters. The quantity, submission time, and process time parameters (as described later in this chapter) were the only variables in which a sample was intentionally taken. This action was due to the limited memory space available for the execution of the FORTRAN program ANG$DATA and to keep the requirements down to reasonable values so that the required data runs could be made. In another case (Issue Group One priorities) a smaller sample size resulted because its occurrence was very scarce.

Tchebycheff's Theorem of Inequality [12] was utilized to determine sample size because normality could not be assumed to describe the underlying population.

Since it was desired that the sample mean would be
within one fifth of a standard deviation of the true mean with a probability of at least 0.95, a sample size of 500 was selected whenever possible.

5. Data Reduction

The FORTRAN program which begins the data analysis required for the simulation model is ANGDAT1, Appendix C. Numerous data arrays were developed for further analysis, as follows:

a. Total daily requisitions submitted by each customer were represented by a matrix (365x17). The 365 dimension is the day of the year the requisition was prepared, and the 17 dimension represents the seventeen vessels under consideration. Quantities within the matrix were the actual number of requisitions prepared on a specific day by a particular vessel (we will call this a requisition bundle). Date differences for a given customer within this matrix will be called the "inter-preparation times" for the bundles shown.

b. From the quantity field of the first 500 requisitions per local customer another matrix (500x17) was developed. This was done because the data base was random by customer and the quantity was assumed to be independent of the ship's location and time. The 500 dimension in this data array corresponds to the size of the sample, and the seventeen dimension again represented those vessels under consideration. The actual data elements in the matrix were the quantities ordered per requisition.

c. Submission time data for bundles of requisitions was also considered independent of the vessel or its class, and thus only one sample of 500 inter-arrival times was
extracted by selecting every one-hundred and eightieth requisition. Its value was computed by subtracting the document’s date of preparation from the date of the document’s receipt. This action was considered appropriate since groups of requisitions were modeled, and it was assumed all requisitions ready for submission would be submitted together.

d. The process time for a requisition was modeled as being dependent on the Issue Group of the requisition. This parameter was computed by subtracting the document’s receipt date from the document’s ready for shipment date, and was arranged into a matrix (500x10). The 500 dimension was the sample size, and the three dimension represents the Issue Group. Individual data elements corresponded to process times per requisition priority by NSC Oakland.

6. Bundle Preparation Time

Appendix D, ANGSFPHIS, is the FORTRAN program which differedenced the document number dates as recorded in the inter-preparation time matrix and utilized the standard library routine HISTG to produce a listing of the relative frequencies of times’ from one to nine days for each customer.

Analysis of this data revealed a significant similarity of the output by vessel class. Figures 8 and 9, and Table 3 illustrate this similarity. Note the small values for the standard deviations of the relative frequencies at the bottom of Table 3. Because the relative frequencies were so alike, the vessels were grouped by class in this and all other vessel dependent parameter evaluations.
Table No. 3. Relative Frequencies of Inter-Preparation Time

Times Between Bundle Preparations in Days

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32
Figure 3 - AE 22 BUNDLE INTER-PREPARATION HISTOGRAM
Upon completion of the class pooling of the data several probabilistic distributions were examined for applicability. Since the histograms were exponentially shaped this was the first distribution tested. The inverse of the mean value was used as the exponential parameter. However, this hypothesis failed the Chi-square goodness of fit test at the five per cent level.

Next an attempt was made to fit a geometric distribution to the data. Inter-preparation times were measured in the data base by one day increments. Therefore, geometric parameters were established by assuming that if a bundle was prepared within one day, there were zero days in which a bundle was not prepared. We will denote $P$ as the probability of a bundle being prepared in one day. However, if an actual bundle required two days to prepare, then we will assume that there was one day in which a failure occurred, i.e. no bundle preparation, and then a success. If a bundle required three days to prepare, we will assume there were two failures, i.e. day one and day two with no bundle preparations, and then a success; and so on. This results in a classical distribution with the following probability mass function:

$$f(x) = P(1-P)^x \text{ for } x = 0, 1, 2, ...$$

where,

$x =$ the number of "failures" prior to a success

$P =$ the probability of a success

Unfortunately this distribution also failed to fit the data, although, it did provide a better chi-square statistic than did the exponential distribution.
A combination of two distributions was attempted next. The author considered this approach because there was a strong possibility that any single distribution would be overwhelmed by the inter-preparations of one day. The hypothetical probabilistic distribution was constructed as follows:

1. Inter-preparation data of one day was separately modeled. Therefore, the probability of a bundle preparation occurring within one day was equal to "P_1".

2. The remaining data was assumed to be geometric and the probability of preparing a bundle in two days, "P_2", was computed from the remainder of the data.

The detailed derivation of the above distribution follows:

\[
f(x) = \begin{cases} 
    P_1 & \text{for } x = 0 \\
    C P_2 (1 - P_2)^x & x = 1, 2, \ldots 
\end{cases}
\]

where,

\[P_1 = \text{probability of a bundle preparation during the first day}\]

\[P_2 = \text{probability of a bundle preparation in two days}\]

\[f(x) = \text{probability density function}\]

\[x = \text{number of days with no bundle preparations}\]
General solution for C:

\[ P_1 + \sum_{x=1}^{n} CP_2 (1 - P_2)^x = 1 \]

\[ CP_2 (1 - P_2) \sum_{x=0}^{n} (1 - P_2)^x = 1 - P_1 \]

\[ \sum_{x=0}^{n} (1 - P_2)^x = 1/P_2 \text{ if } 0 < (1 - P_2) < 1 \]

Therefore

\[ C = (1 - P_1)/(1 - P_2) \]

The Chi-square statistic at the five per cent level of significance and with nine degrees of freedom is 16.92. One would accept this hypothesis if the computed statistic is less than or equal to 16.92. The computed statistics for AE class, APS class, A0R class, MSO class, and AR class vessels were respectively 7.544, 10.917, 19.419, 11.450, and 38.57. The hypothesis that the distribution fits the data is acceptable in three of the five classes. The AR class, which had the largest error, was also the smallest in sample size (only one ship was in the sample). There were three vessels in the other group which did not pass, however the smallest value was generated by the largest sample.

It is concluded that this developed distribution was an acceptable simulation tool for the determination of bundle inter-preparation times. The variable names AE.1UNDL.E.INTER.ARRIVAL, APS.1UNDL.E.INTER.ARRIVAL, AOR.1UNDL.E.INTER.ARRIVAL, MSO.1UNDL.E.INTER.ARRIVAL, and AF.1UNDL.E.INTER.ARRIVAL apply in the simulation.

7. Mail Time per Bundle

The inter-arrival time distribution for bundles sent by local vessels to MSC Oakland was modeled as being
influenced only by the US Postal Service and as such was independent of both the vessel class and the material requirements.

This distribution was tested using the Chi-Square goodness of fit test and was found to be exponential with a mean of 3.986 days at both the five per cent and the one percent levels of significance. It was assigned the variable name MAIL.TIME in the simulation.

3. **Number of Requisitions per Bundle**

All the following distributions developed and implemented in the simulation are empirical, except as noted.

Five empirical distributions, one for each class, were developed from the data to describe the number of requisitions per bundle. The following table lists the probabilities of falling in the ranges shown based on those distributions by ship class:
**Table No. 1. Probabilities of Requisitions per Bundle**

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<td>0-5 6-10 11-15 16-20 21-25 26-30 31-35 36-</td>
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<tr>
<td>MSO</td>
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</table>

Although ranges were used in the above table, all values utilized in the simulation were converted to integers. These parameters were modeled as random linear empirical distributions in the simulation. Their identification is AE•REQ•PER•BUNDLE, APS•REQ•PER•BUNDLE, AOR•REQ•PER•BUNDLE, AR•REQ•PER•BUNDLE, and MSO•REQ•PER•BUNDLE respectively.

9. Requisition Priority

A probability distribution for material priorities was determined by calculating the percent of requisitions which were in Issue Group One (priority one through three), the percent which were in Issue Group Two (priority four through eight), and the percent which were in Issue Group
Three (priority nine through fifteen). It should be noted that the requisition priority was considered independent of both the individual ship and the ship class. Thus, only one distribution was developed for all vessels. This approach can be considered appropriate since all of these particular vessels operate under the same priority determination criteria. It was developed from the data as follows:

The issue Group One, requisitions of priorities 1 through 3, were tabulated and only 72 out of 94,434 cases occurred. It was therefore very unlikely that an Issue Group One event would be observed. In fact, this event would be realized only .08 of one per cent of the time.

Issue Group Two, priorities 4 through 8, requisitions were found to be more prevalent, being 14,157, and their probability of occurrence was computed to be .1499.

Issue Group Three, priorities 9 through 15, had the highest observed incidence with a probability of .8493.

The simulation variable for this parameter is REQ·PRIORITY.

10. Process Times

The requisition process time was modeled as being dependent on only the priority (Issue Group) of the requisition. This approach was considered reasonable because different Issue Groups are actually processed differently. The various picking documents for the material are expedited to the warehouse and are colored differently for high priority material (Issue Group One and Two).
The following distributions were developed by subtracting the date of document receipt at NSC Oakland from the date that the material was ready for shipment in the data base.

The Issue Group One requisition process time cumulative distribution was determined to be between 0.0 and 1.95 with probability .394, between 1.96 and 7.77 days with probability .423, and between 7.8 and 29 days with probability .183. It should be further noted that the number of usable data points was less than 72 for the following reasons: (1) the original number of data points in this Issue Group was only 72, (2) entries in the data base were discovered which showed that certain requisitions had been shipped prior to receipt of the requisition, (3) other date errors occurred; for example, several requisitions showed that over 300 days were used in the processing time. These types of errors also occurred in the other Issue Group data bases and were also ignored in the distribution computations.

The Issue Group Two process time cumulative distribution was also between zero and 1.2 days with probability .50, between 1.3 and 14.3 days with probability .42, and between 14.4 and 38 days with a .08 probability.

The process time for Issue Group Three requisitions was between zero and 1.2 days with probability .50, between 1.2 and 15.5 days with probability .395, and between 15.5 and 38 days with probability .045.

11. Quantity per Requisition

Since requisitions for material may be a request for more than one of an item, the appropriate field in the data
base was utilized to evaluate the process. It was assumed that the various quantities ordered per requisition would be dependent on the vessel class. Thus, five cumulative distributions were developed.

Those quantities expected for an AE class vessel were found to be between one and five with probability .608, between six and ten with probability .238, and between 11 and 100 with a .154 probability.

The other vessel class distributions were modeled with the same uniform ranges but differing probabilities. In the APS class, the probabilities are .575, .171, and .253 respectively. The probabilities for the ADR class are .612, .161, and .227; for the M30 class .559, .143, and .298; and, for the AS class .496, .164, and .340 respectively.

12. **Weight per Requisition**

That data required for the parameter determination of this attribute was not available. However the author assumed a classical exponential distribution with an expected value of two pounds per each item. The mean weight per requisition generated by this simulation was 193 pounds. Hernandez and Gallitz [3] stated that 28,586,168 pounds (fiscal year 1975), and 26,805,662 pounds (fiscal year 1976) of material were delivered by the BALD system. This equates to an average of 73 pounds per requisition and 59 pounds per requisition respectively (assuming that there was not a significant change in the total number of requisitions per year from 1976). Observations by this author at the BALD shipping and delivery points revealed that it was uncommon to witness a full truck load shipped. In fact most shipments were only one pallet level high, yet statistically
full truckload weights were recorded on the shipment records. Because of this, it was suspected that the weights [12] are overstated.

It is therefore concluded that the parameter of two pounds chosen for the mean of the distribution was too large. Thus, the actual number of shipments made was selected at a proxy measure of effectiveness for this variable. Resultant outputs from this assumption have not been included in the results section of this thesis.
III. SIMULATION

A. GENERAL

SIMSCRIPT II.5 is a language particularly suited to discrete-event step simulations. It has been designed to facilitate the simulation of large complex systems with a minimum of effort in programming, designing, and testing the model.

It is not the intent of this paper to discuss the details of this unique programming language, and anyone desiring to examine it in depth should refer to references 9 and 13.

B. PROGRAM DESCRIPTION

The modeling of that segment of the SALD system impacted by the random movement of vessels between various ports was developed by considering two major series of events.

First, the vessel movements were modeled using the previously discussed parameters and techniques. This series of events deals primarily with vessel movement impacts on the ultimate destination of shipped material. This series also removes material from a "old" shipping queue and relocates the material in the appropriate "new" shipping queue corresponding to the vessel's new location.
The remaining series of events recreates the material processing involved. Their logical functional order commences with the preparation of a group of material requirements. Next, this group of material requirements arrives at MSC Oakland and is reduced to its individual material requests. These requisitions then are scheduled through the material processing system and a shipment availability time is determined. The final events collect statistics and determine the frequency and the destination of the various shipments.

1. Detailed Analysis

The preamble defines various system variables, events, and entities. Actual execution commences with the main program. It first assigns user defined values to the permanent entities (ships). This segment then reads all the program decision variable distributions, schedules an initial port change and bundle preparation for each vessel, schedules the initial shipments to each port, and schedules the two one-time events, Stop.simulation and Equilibrium.

From this time on the SIMSCRIPT event step simulation time scheduling routine takes over. Events will occur as determined by the scheduling parameters throughout the program. The specific events are detailed below.

Bundle.preparation: This event schedules the next bundle preparation for each vessel based on the class of the vessel. It then determines the the value of the number.of.requisitions(bundle) and then schedules an arrival time at MSC Oakland.

Arrival.of.bundle: The temporary entities, requisitions, are created in this event. They are assigned
all their attributes (priority, quantity, and customer) based on the previously discussed parameters. Then a **Ready.for.shipment** event is scheduled based on the requisition's priority. Finally, the temporary entity bundle is destroyed to release memory space in the computer.

**Change.location:** The vessel's new location is determined based on ship class markov chains. Statistics are accumulated to record both the number of location changes per vessel and per vessel class. At this time, if this vessel has any material in one of the port shipping queues, it is removed and put in the newly determined port shipping queue. The system statistics are also appropriately adjusted. Finally, the next port change for this vessel is scheduled based on the vessel's current location.

**Ready.for.shipment:** The shipping location is first determined, and the requisition is filed in the appropriate shipping queue. This event also may schedule an immediate shipment of material depending on the decision rules involved.

**Shipment.to:** This event computes the majority of the statistics. It also contains all decision rules on shipping strategy. Upon completion of this event the next shipment to is scheduled for this port.

2. **Seeds**

Since the pseudo random number generator was seed dependent, ten seeds were initially selected and program runs were made to identify equilibrium conditions and reverify the simulation's validity. The seeds were selected at least 800,000 numbers apart to preclude overlapping of
the number stream.

In order to evaluate the stability of the measures of effectiveness as related to seed changes, ten runs (one run per seed) were made with each decision rule. It was noted that in some instances the SIMSCRIPT program exceeded the 430,000 bytes allocated. Since the variations in the measures of effectiveness (average wait time and the number of shipments) were minimal, it was not considered necessary to rerun these programs, see Appendix H.

3. Equilibrium Determination

The equilibrium or steady-state of the system is defined as a condition of regularity of stability in which opposing influences are balanced. Thus, it is assumed that for this model there is a limiting probability distribution of the responses that is characteristic of the system. This state was determined by a method stated by Conway[5]. Specifically, the series of measurements were truncated until the first of the series was neither the maximum nor the minimum of the remaining set.

The number of requisitions shipped to each port was one of the measurements evaluated in the above manner. The determining port was W.A.S. Alameda and the time to steady-state was two weeks. Inadvertently, the number of shipments' variable was not adjusted for this two-week period and a lack of time precluded the rerunning of this computer simulation. Thus, this measure of effectiveness was accumulated over a fifty-four-week interval.

A determination of the equilibrium condition for the ship movements was not made. The initial starting conditions for the simulation were chosen so that they were
typical of the steady-state condition. For example, all vessels were initially located at factual locations, rather than positioning them arbitrarily and then determining the steady-state condition.

4. **Shipping Strategies**

Four shipping decision rules were analysed as follows: a. CASE I - all material ready for shipment is shipped daily; b. CASE II - all material ready for shipment is shipped weekly; c. CASE III - in addition to CASE II actions, Issue Group 1 material (with all other destined for the same location) is shipped immediately; d. CASE IV - in addition to the CASE III decision rules, Issue Group 2 material (again with all other material in the appropriate queue) is shipped once a day.

Appendices E, F, and G contain those events which were modified for each decision rule.

5. **Measures of Effectiveness**

Two measures of effectiveness were selected. First, the amount of time requisitions were waiting to be shipped was chosen as a measure of customer service. Second, the actual number of shipments released was selected as an evaluation of the cost of the chosen strategy. The total number of shipments is considered a proxy variable for shipping costs.

C. **RESULTS**
The outputs from the forty program runs have been tabulated by each decision rule and are presented in Appendix H. The logically expected results in the mean waiting times was observed. Mean waiting times of .48 to .53 were observed when shipments were daily. Under weekly shipping rules the mean waiting times were 3.41 to 3.61 days.

Since program runs were seed dependent and a comparison of decision rules was desired, only those runs in which all results were obtained for all cases will be examined here. These runs were numbers 2, 3, 5, 5, and 6 as found in Appendix H. Data from these runs were then averaged by Issue Group within each decision rule (case). Weighted averages were then computed per case by assigning weights which were representative of each Issue Group's probability of occurrence. The values used were .0083 (Issue Group One), .1499 (Issue Group Two), and .8493 (Issue Group Three). The results of these computations represent five years worth of simulation per case and are presented in Table 5.
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IV. DISCUSSION AND CONCLUSIONS

A. DISCUSSION

It is noteworthy that minor variations in the average waiting times have significant impact in the total number of shipments. Increasing the waiting time per shipment from .5 to 3.5 days has the effect of reducing the number of shipments from an average of 2076 to an average of 319 trips per fifty-four weeks, or a 0.6-fold decrease.

However, adjusting the weekly shipments by shipping Issue Group One material immediately (CASE III) reduced their waiting times to zero, yet did not significantly increase the total number of shipments experienced. In fact, they only increased from 319 to 387 per 54 weeks. This is not an unexpected result since there was only a .08 per cent chance of a vessel generating an Issue Group One shipping requirement.

Finally, CASE IV decision parameters resulted in almost the same number of shipments as when daily shipments were made. The average number observed for 54 weeks was 1853, on the average only 263 shipments less per year.

The weighted averages of each case were used to construct Figure 10. The dependent variable was the mean wait time in days and the independent variable was the number of shipments made in fifty-four weeks. The curve was constructed assuming that the unknown function was
"hyperbolically" shaped. This assumption was supported by the observation that as the number of shipments approach infinity the average waiting time would be expected to become zero, and as the number of shipments approach zero the average waiting time would be expected to become infinite.
The curve of Figure 10 provides a practical tool for a decision maker. If an objective function is known (such as a decision maker's relationship between the relative importance of waiting times and the number of shipments), the "optimum" number of shipments could be determined. For example, if it was decided that the number of shipments was twice as important as waiting times, an objective function could be constructed as follows: total cost = (cost constant) x (waiting time) + (cost constant) x (2 x (number of shipments)). The appropriate cost constants would have to be selected to convert the variables to dollars. This objective function could then be used with the curve to determine an "optimal" solution. However, this solution should not be attempted until additional simulations are run to verify the midrange of the curve.

B. CONCLUSIONS

In view of the simulation results, it would appear that actual modification of the current shipping parameters may yield substantial transportation savings. However, because such parameters as the weight and volume of the larger shipments were not evaluated, delaying a shipment beyond the time when a full truck load is ready for shipping would not be expected to result in any savings.

It is recommended that follow-on modeling in this area be conducted. The weight and volume parameters should be identified and decision rules should be modified to include maximum and/or minimum weight/volume shipping restrictions. Additional shipping strategies (cases) also need to be proposed and analyzed (for example, allow Issue Group II's to be shipped every other day, every third day, etc.)
fill in the middle of the curve of Figure 10. Finally, the simplifying assumptions of the model presented in this paper need to be critically reviewed and any which seriously violate reality should be replaced by more realistic ones and the analysis repeated.
**APPENDIX A**

**SHIPS INFORMATION BULLETIN**

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**SHIPS PRESENT SAN FRANCISCO BAY AREA**

**INCORPORATED SHIP**

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APPENDIX B

FORTRAN PROGRAM AND DATA

//ANGSCATA JCB (8407, 0331, 22481). "EX"=2740, "TM"=75
// EXEC FOR CPC
//FORTAN SYSIN 00

INTEGER*2 ISTAT, IR
DATA IRAD/1/ , INP1/1/ , INR7/0/
DIMENSION CATA(13), DAT(13)
FORMAT (1X, 100, END = 9999) CATA, DAT, IUC, ILCUS

10 READ(13, 100, END = 9999) CATA, DAT, IUC, ILCUS

100 FORMT (1, 12, 12, 13, 13, 13)

IN = IN 1 + 1
IF (STAT .NE. 10) GOTO 10
INR = IN 2 + 1
IF (IUC .NE. 10) GOTO 20
IUC = 103
WRITE(20, 100) CATA, DAT, IUC, ILCUS
IF (INR .LE. 1000) WRITE (31, 100) CATA, DAT, IUC, ILCUS

20 IF (IUC .NE. 29) GOTO 22
IUC = 102
WRITE(20, 100) CATA, DAT, IUC, ILCUS
IF (INR .LE. 1000) WRITE (31, 100) CATA, DAT, IUC, ILCUS

22 IF (IUC .NE. 37) GOTO 24
IUC = 103
WRITE(20, 100) CATA, DAT, IUC, ILCUS
IF (INR .LE. 1000) WRITE (31, 100) CATA, DAT, IUC, ILCUS

24 IF (IUC .NE. 29) GOTO 26
IUC = 104
WRITE(20, 100) CATA, DAT, IUC, ILCUS
IF (INR .LE. 1000) WRITE (31, 100) CATA, DAT, IUC, ILCUS

26 IF (IUC .NE. 29) GOTO 29
IUC = 105
WRITE(20, 100) CATA, DAT, IUC, ILCUS
IF (INR .LE. 1000) WRITE (31, 100) CATA, DAT, IUC, ILCUS

29 IF (IUC .NE. 37) GOTO 31
IUC = 106
WRITE(20, 100) CATA, DAT, IUC, ILCUS
IF (INR .LE. 1000) WRITE (31, 100) CATA, DAT, IUC, ILCUS

31 IF (IUC .NE. 15) GOTO 32
IUC = 107
WRITE(20, 100) CATA, DAT, IUC, ILCUS
IF (INR .LE. 1000) WRITE (31, 100) CATA, DAT, IUC, ILCUS

32 IF (IUC .NE. 29) GOTO 34
IUC = 108
WRITE(20, 100) CATA, DAT, IUC, ILCUS
IF (INR .LE. 1000) WRITE (31, 100) CATA, DAT, IUC, ILCUS

34 IF (IUC .NE. 9) GOTO 36
IUC = 204
WRITE(20, 100) CATA, DAT, IUC, ILCUS
IF (INR .LE. 1000) WRITE (31, 100) CATA, DAT, IUC, ILCUS

36 IF (IUC .NE. 3) GOTO 38
IUC = 210
WRITE(20, 100) CATA, DAT, IUC, ILCUS

57
IF(INR2.LE.1000)WRITE(30,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
IF(INR2.LE.1000)WRITE(30,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
38 IF(IUIC.NE.14)GO TO 40
   IUIC = 11
   WRITE(20,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
IF(INR2.LE.1000)WRITE(30,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
40 IF(IUIC.NE.21)GO TO 42
   IUIC = 312
   WRITE(20,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
IF(INR2.LE.1000)WRITE(30,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
42 IF(IUIC.NE.19)GO TO 44
   IUIC = 313
   WRITE(20,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
IF(INR2.LE.1000)WRITE(30,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
44 IF(IUIC.NE.11)GO TO 46
   IUIC = 314
   WRITE(20,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
IF(INR2.LE.1000)WRITE(30,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
46 IF(IUIC.NE.46)GO TO 48
   IUIC = 315
   WRITE(20,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
IF(INR2.LE.1000)WRITE(30,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
48 IF(IUIC.NE.45)GO TO 50
   IUIC = 316
   WRITE(20,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
IF(INR2.LE.1000)WRITE(30,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
50 IF(IUIC.NE.5)GO TO 10
   IUIC = 317
   WRITE(20,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
IF(INR2.LE.1000)WRITE(30,100)DATA1,ISTAT,DAT2,UCIC,IT
   ICLUS
GO TO 10
999 WRITE(6,200)INP1,INP2
200 FORMAT(1X, 'TOTAL RECORDS = ', I7, 1X, 'TOTAL BA RECORDS = ', I7)
   END FILE 20
   END FILE 30
STOP
END

//GO, FILE=FTDFO001,UNIT=3400-3, VOL=SER=Z2R3, LOR=O,C, KEP=
//LABEL=IN1.SL., DSN=S2390, LOC=00, SHP=247, VOL=SER=Z2R3, LOR=O,C,
//DISP=(OLD,KEEP),
//UNIT=3400-3, LABEL=IN1.SL., DSN=S2390, LOC=00, SHP=247, VOL=SER=Z2R3,
//SPACE=(2000,(55,5)), VOLUME=SER=NOFF, M1335=(OLL, KEP),
//UNIT=314
APPENDIX C

FORTRAN PROGRAM ANG DAT

THE FOLLOWING PROGRAM EXTRACTS THAT DATA NECESSARY FOR THE DETERMINATION OF THE MATERIAL PARAMETERS OF THE SIMULATION.

//ANGDAT.JOB (2427.0341.RZBA), 'EXT=2740', 'TIME=60'
//EXEC FORTRAN
//EXEC SYM
*
REAL*8 U10CLC
DIMERIC,NUMB(167,18), IQUAN(500,18), MALT(900),
* IGROUP(4), UCLOC(13), 'M(17), PGCUP(4), 'MPR(500,3)
*IPROC(500,4)
CATA NUMB/660E0/, IQUAN/9000E0/, MALT/500E0/,
* IGROUP/=0/, UCLOC/=0/, IFLG1/=0/, IFLG2/=0/, MPR(1500)/0/,
*IPROC/3000/0/
CALC SET
10 READ(i13, lcc, END=99) DATE1, IPRI, IQN, IDATE2, IDATES, '11C
IF(IPRI.EQ.0) GO TO 10
IF(I1C.EQ.14) I1C = 0
IF(IPRI.EQ.10) WRITE(6,100) IDATE1, IPRI, IQN, IDATE2,
*IDATES, I1C
100 FORMAT(27X,13,8X,'2,6X,15,2X,13,5X,13,9X,'1')
C C
IF(IDATE1.GT.IDATE2) IDATE2 = IDATE2 + 365
IF(IDATE3.GT.IDATE2) IDATE3 = IDATE3 + 365
NUMB(IDATE1, I1C) = NUMB(IDATE1, I1C) + 1
C C
IF(IPRI.GE.3) GO TO 20
IF(IPRI.GE.1) GOTO 21
IF(IPRI.GE.2) IFLG1 = IFLG1 + 1
20 IGROUP(1) = IGROUP(1) + 1
IF(I1C.LE.500) IPROC(1,1) = IDATE3 - IDATE2
IF(I1C.LE.500) MPR(1,1) = IDATE3 - IDATE2
IF(IPRI.LT.330) GOTO 24
IF(IPRI.LT.360) GOTO 24
IF(IPRI.LT.390) GOTO 24
IF(IPRI.LT.420) GOTO 24
IF(IPRI.LT.450) GOTO 24
IF(IPRI.LT.480) GOTO 24
21 IF(I1C.LE.500) IPROC(1,2) = IDATE3 - IDATE2
IF(I1C.LE.500) MPR(1,2) = IDATE3 - IDATE2
IF(I1C.LE.500) IPROC(1,3) = IDATE3 - IDATE2
IF(I1C.LE.500) MPR(1,3) = IDATE3 - IDATE2
22 IF(I1C.LE.500) IPROC(1,4) = IDATE3 - IDATE2
IF(I1C.LE.500) MPR(1,4) = IDATE3 - IDATE2
23 CONTINUE
I1C(I1C) = I1C(I1C) + 1
K = I1C(I1C)
IF(K.LE.500) IQUAN(K,I1C) = IQN
C C
COUNT = COUNT + 1
IF(COUNT.GE.130.0) A = 3
A = A + 1
14 = FIX(A)
IF (A .LE. 500) MAILT(14) = DATE2 - DATE1
GO TO 10
CONTINUE
IGROUP(1) = 1
CALL GETTIME(LET)
SECS = LET * 0.000029
WRITE (6,1111) SECS
1111 FORMAT(16,12)
IGROUP(1) = IGROUP(1) + IGROUP(2) + IGROUP(3)
PGROUP(1) = FLOAT(IGROUP(1))/FLOAT(IGROUP(4)) = 1.02
PGROUP(2) = FLOAT(IGROUP(2))/FLOAT(IGROUP(4)) = 1.00
PGROUP(3) = FLOAT(IGROUP(3))/FLOAT(IGROUP(4)) = 1.00
DO 32 J=1,17
DO 28 I=249365
IF (NUMA(I,J) .NE. 0) WRITE (20,1110) I,J,NUMA(I,J)
110 FORMAT (213,16)
28 CONTINUE
DO 30 I=1,243
IF (NUMA(I,J) .NE. 0) WRITE (20,1110) I,J,NUMA(I,J)
30 CONTINUE
32 CONTINUE
END FILE 20
C C PRINT MATRIX 9 COLUMNS AT A TIME
READ(5,115)ICLCC
115 FORMAT(la)
END = 17
XEND = JEND - 1
C C DO 34 N = L,XEND,9
134 NEND = N + 7
WRITE(6,122)
122 FORMAT(la,15x,'BREADINESS CODE BY SHIP//')
WRITE(6,120) (1JC(I),N=1,NEND)
120 FORMAT(la,15x,['IJC(I),N=1,NEND])
WRITE(6,130) (NJ,NUMA(NJ,NK),NK=1,XEND),NJ=244,365
WRITE(6,130) (NJ,NUMA(NJ,NK),NK=1,XEND),NJ=1,17
130 FORMAT(la,15x,['IJC(I),N=1,XEND'])
WRITE(6,124) (IMJX,QUANTITY PER ITEM BY SHIP//)
WRITE(6,124) (IMJX,QUANTITY PER ITEM BY SHIP//)
WRITE(6,130) (NJ,1MJX(NJ,NK),NK=1,XEND),NJ=244,365
WRITE(6,130) (NJ,1MJX(NJ,NK),NK=1,XEND),NJ=1,17
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WRITE(6,124) (IMJX,QUANTITY PER ITEM BY SHIP//)
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WRITE(6,130) (NJ,1MJX(NJ,NK),NK=1,XEND),NJ=1,17
130 FORMAT(la,15x,['IJC(I),N=1,XEND'])
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WRITE(6,124) (IMJX,QUANTITY PER ITEM BY SHIP//)
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WRITE(6,130) (NJ,NUMA(NJ,NK),NK=1,XEND),NJ=244,365
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130 FORMAT(la,15x,['IJC(I),N=1,XEND'])
WRITE(6,124) (IMJX,QUANTITY PER ITEM BY SHIP//)
WRITE(6,124) (IMJX,QUANTITY PER ITEM BY SHIP//)
WRITE(6,130) (NJ,1MJX(NJ,NK),NK=1,XEND),NJ=244,365
WRITE(6,130) (NJ,1MJX(NJ,NK),NK=1,XEND),NJ=1,17
130 FORMAT(la,15x,['IJC(I),N=1,XEND'])
WRITE(6,122)
122 FORMAT(la,15x,'BREADINESS CODE BY SHIP//')
WRITE(6,120) (1JC(I),N=1,NEND)
120 FORMAT(la,15x,['IJC(I),N=1,NEND])
WRITE(6,130) (NJ,NUMA(NJ,NK),NK=1,XEND),NJ=244,365
// DISP=(OLD,KEEP).
// UNIT=3400-3, LABEL=(1,CL..,N)
// GO=FT2F001 DC LABEL=EXD, UNIT=2314, VOL=SPE=OFFY,
// DSN=S2427.L.SHIP.R3, RUNDLE, ORIG.
// DCB=(RECIP=99, L=REC=9, ALKSIZE=6400), SPACE=(6400, (1,5)).
// DISP=(OLD,KEEP)
// GO=FT2F001 DC LABEL=EXD, UNIT=2314, VOL=SPE=OFFY,
// DSN=S2427.L.SHIP.R3, RUNDLE, ORIG.
// DCB=(RECIP=99, L=REC=9, ALKSIZE=6400), SPACE=(6400, (1,5)).
// DISP=(OLD,KEEP)
// GO=FT2F001 DC LABEL=EXD, UNIT=2314, VOL=SPE=OFFY,
// DSN=S2427.L.SHIP.R3, RUNDLE, ORIG.
// DCB=(RECIP=99, L=REC=9, ALKSIZE=6400), SPACE=(6400, (1,5)).
// DISP=(OLD,KEEP)
// GO=FT2F001 DC LABEL=EXD, UNIT=2314, VOL=SPE=OFFY,
// DSN=S2427.L.SHIP.R3, RUNDLE, ORIG.
// DCB=(RECIP=99, L=REC=9, ALKSIZE=6400), SPACE=(6400, (1,5)).
// DISP=(OLD,KEEP)
// GO=FT2F001 DC LABEL=EXD, UNIT=2314, VOL=SPE=OFFY,
// DSN=S2427.L.SHIP.R3, RUNDLE, ORIG.
// DCB=(RECIP=99, L=REC=9, ALKSIZE=6400), SPACE=(6400, (1,5)).
// DISP=10L.KEEP)
// GO=FT2F001 DC LABEL=EXD, UNIT=2314, VOL=SPE=OFFY,
// DSN=S2427.L.SHIP.R3, RUNDLE, ORIG.
// DCB=(RECIP=99, L=REC=9, ALKSIZE=6400), SPACE=(6400, (1,5)).
// DISP=10L.KEEP)
// GO=FT2F001 DC LABEL=EXD, UNIT=2314, VOL=SPE=OFFY,
// DSN=S2427.L.SHIP.R3, RUNDLE, ORIG.
// DCB=(RECIP=99, L=REC=9, ALKSIZE=6400), SPACE=(6400, (1,5)).
// DISP=10L.KEEP)
// GO=FT2F001 DC LABEL=EXD, UNIT=2314, VOL=SPE=OFFY,
// DSN=S2427.L.SHIP.R3, RUNDLE, ORIG.
// DCB=(RECIP=99, L=REC=9, ALKSIZE=6400), SPACE=(6400, (1,5)).
// DISP=10L.KEEP)
// GO=FT2F001 DC LABEL=EXD, UNIT=2314, VOL=SPE=OFFY,
// DSN=S2427.L.SHIP.R3, RUNDLE, ORIG.
// DCB=(RECIP=99, L=REC=9, ALKSIZE=6400), SPACE=(6400, (1,5)).
// DISP=10L.KEEP)
// GO=FT2F001 DC LABEL=EXD, UNIT=2314, VOL=SPE=OFFY,
// DSN=S2427.L.SHIP.R3, RUNDLE, ORIG.
// DCB=(RECIP=99, L=REC=9, ALKSIZE=6400), SPACE=(6400, (1,5)).
// DISP=10L.KEEP)
// GO=FT2F001 DC LABEL=EXD, UNIT=2314, VOL=SPE=OFFY,
APPENDIX D

SIMSCRIPT PROGRAM ANG SIM

PREAMBLE

VARIABLE DEFINITION INFORMATION FOLLOWS

GENERATE LIST ROUTINES

THE NEXT 14 STATEMENTS DECLARE THE ENTITIES AND THEIR ATTRIBUTES

PERMANENT ENTITIES

EVERY SHIP HAS A LOCATION, A TYPE, A SHIPPED, A CHANGE AND MAY
RELIGION TO A SHIP QUEUE
EVERY PORT CAN HAVE A SHIP QUEUE AND A SHIPPING QUEUE
AND HAS A MT. SHIPPED AND A VOL. SHIPPED.
A WT. FINAL SHIPPED
A VOL. FINAL SHIPPED, A TOTAL

TEMPORARY ENTITIES

EVERY BUNDLE HAS A CODE, A NUMBER OF REQUISITIONS
EVERY REQUISITION HAS AN OWNER (1/4), PRIORIT (3/4)
QUANTITY (17-32)
A WEIGHT, A VOLUME, A TIME READY FOR SHIP
AND MAY BELONG TO A SHIPPING QUEUE

THE NEXT STATEMENT NOTICES THE COMPLIANT THAT
EVENT NOTICES FOLLOW RATHER THAN ENTITIES

EVENT NOTICES INCLUDE STOP. SIMULATION AND EQUILIBRIUM

THESE STATEMENTS ESTABLISH FIVE-WORD RECORDS

EVERY BAGLE PREPARATION HAS A BAG
EVERY ARRIVAL OF BAGLE HAS A ITEM
EVERY READY FOR SHIPMENT HAS A ORDER
EVERY CHANGE LOCATION HAS A TUG
EVERY SHIPMENT TO HAS A PLACE

THE NEXT STATEMENT IDENTIFIES THE PROCESSING
PRIORITIES IN THE PROGRAM

PRIORITY ORDER IS BAGLE PREPARATION, ARRIVAL OF BAGLE,
READY FOR SHIPMENT, CHANGE LOCATION, SHIPMENT TIME
STOP SIMULATION

THE FOLLOWING LINES ESTABLISH POINTERS WHICH
ALLOWS THE SYSTEM TO OWN SETS
THE FOLLOWING 57 LINES ARE THOSE SYSTEM PARAMETERS
WHICH THE SIMULATION UTILIZES

THE SYSTEM HAS A 1 WAIT TIME, A 2 WAIT TIME, A 3 WAIT TIME,
A SHIP TIME, A SHIP TIME, A SHIP TIME,
A DEPARTURE RANDOM STEP VARIABLE
A BAGLE, SHIP INTER DEPARTURE RANDOM STEP VARIABLE,
A AVAILABLE INTER ARRIVAL RANDOM STEP VARIABLE
A SHIP LUBE, INTER ARRIVAL RANDOM STEP VARIABLE
A ARRIVAL RANDOM STEP VARIABLE
A 2ND LUBE, INTER ARRIVAL RANDOM STEP VARIABLE
A HRC LUBE, INTER ARRIVAL RANDOM STEP VARIABLE
A 3RD LUBE, INTER ARRIVAL RANDOM STEP VARIABLE

62
ALAM, PORT CHANGE RANDOM STEP VARIABLE.
ALAS, 1SL PORT CHANGE RANDOM STEP VARIABLE.
AES, WEAIR, START, PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, SANG, FEAN, PORT CHANGE RANDOM STEP VARIABLE.
AES, EW, PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, SOUTH PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM, PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
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AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
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AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
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AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
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AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
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AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM DROP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
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AES, NSC, CANT PORT CHANGE RANDOM STEP VARIABLE.
AES, DEPLOY RANDOM STEP VARIABLE.
AES, ALAM PORT CHANGE RANDOM STEP VARIABLE.
TALLY M, HT, FINAL AS THE MEAN, M, HT, FINAL AS THE STD. DEV.
MX, HT, FINAL AS
THE MAXIMUM, MIN, HT, FINAL AS THE MINIMUM OF HT, FINAL, SHIPPED
TALLY F, TOTAL, REO AS THE SUM OF TOT, REO
END
**MAIN**
**THE NEXT TWO STATEMENTS DIMENSION VARIABLES**
**RESERVE CHANGE AS 5**
**RESERVE NR.TRUCKS AS 12**
**READ SEED.1**
**THE NUMBER OF SHIPS IS READ**
**READ N.SHIP**
**CREATE EVERY SHIP**
**FOR EVERY SHIP READ TYPE(SHIP), LOCATION(SHIP)**
**THE NUMBER OF PORTS IS READ**
**READ N.PORT**
**CREATE EVERY PORT**
**FOR EVERY SHIP FILE THIS SHIP IN SHIP.QUEUE(LOCATION(SHIP))**
**PRINT 1 LINE TELS**
**PORT SHIP NR.**
**FOR EVERY PORT ON THIS**
**PRINT 1 LINE WITH PORT.N.SHIP.QUEUE(PORT) AS FOLLOWS**
**LOOP**
**FOR EACH SHIP PRINT 1 LINE WITH SHIP. LOCATION(SHIP),**
**TYPE(SHIP)**
**AS FOLLOWS**
**THE FOLLOWING LINES READ IN THE SYSTEM PARAMETERS**
**READ SAN.FRAN.SHIP.INTER.DEPARTURE,**
**BETH.STL.SHIP.INTER.DEPARTURE,**
**AE.LONDE.INTER.ARRIVAL,**
**AFS.LONDE.INTER.ARRIVAL,**
**AOR.LONDE.INTER.ARRIVAL,**
**MSC.LONDE.INTER.ARRIVAL,**
**AF.LONDE.INTER.ARRIVAL,**
**AE.ALAM.PORT.CHANGE,**
**AE.WARE.ISL.PORT.CHANGE,**
**AE.WEAP.STA.PORT.CHANGE,**
**AE.NSC.EAK.PORT.CHANGE,**
**AE.SAN.FRAN.PORT.CHANGE,**
**AE.TODD.PORT.CHANGE,**
**AE.BETH.STL.PORT.CHANGE,**
**AE.DEPLY,**
**AE.ALAM.PORT.CHANGE,**
**AFS.NSC.OAK.PORT.CHANGE,**
**AFS.TODD.PORT.CHANGE,**
**AFS.TRIP. A.PORT.CHANGE,**
**AFS.DEPLY,**
**AR.WARE.ISL.PORT.CHANGE,**
**AR.NSC.EAK.PORT.CHANGE,**
**AR.DEPLY.READ**
**MSC.ALAM.PORT.CHANGE,**
**MSC.SAN.FRAN.PORT.CHANGE,**

65
MCS, TODD, PORT CHANGE;
MSC, T. I. PORT CHANGE;
MSC, WEBB, PORT CHANGE;
MSC, PACIF, PORT CHANGE;
MSC, DEPLOY;
REG, PRIORITY;
ALAM, SHIP, INTER, DEPARTURE;
MARE, ISLAND, SHIP, INTER, DEPARTURE;
AE, REQ, PER, BUNDLE;
AFS, REQ, PER, BUNDLE;
AOR, REQ, PER, BUNDLE;
MSC, REQ, PER, BUNDLE;
AFL, REQ, PER, BUNDLE;
AFS, QUAN, PER, REQ;
AOR, QUAN, PER, REQ;
MSC, QUAN, PER, REQ;
AR, QUAN, PER, REQ;
DEPLOY, TIME;
1. ISSUE, GROUP, PROCESS, TIME;
2. ISSUE, GROUP, PROCESS, TIME;
3. ISSUE, GROUP, PROCESS, TIME;

FOR EVERY SHIP OR THIS

THIS SECTION SCHEDULES THE INITIAL BUNDLE
PREPARATIONS BY EACH SHIP USING CLASS PARAMETERS

IF TYPE(SHIP) EQUALS 1,
SCHEDULE A BUNDLE, PREPARATION
GIVEN SHIP IN ALAM, BUNDLE, INTER, ARRIVAL DAYS
ELSE
IF TYPE(SHIP) EQUALS 2,
SCHEDULE A BUNDLE, PREPARATION
GIVEN SHIP IN MARE, BUNDLE, INTER, ARRIVAL DAYS
ELSE
IF TYPE(SHIP) EQUALS 3,
SCHEDULE A BUNDLE, PREPARATION
GIVEN SHIP IN AFS, BUNDLE, INTER, ARRIVAL DAYS
ELSE
IF TYPE(SHIP) EQUALS 4,
SCHEDULE A BUNDLE, PREPARATION
GIVEN SHIP IN MSC, BUNDLE, INTER, ARRIVAL DAYS
ELSE
SCHEDULE A BUNDLE, PREPARATION GIVEN SHIP
IN AFS, BUNDLE, INTER, ARRIVAL DAYS
REGARDLESS

THE NEXT PORT MOVEMENT IS SCHEDULED BASED ON THE SHIP'S
CURRENT LOCATION

IF LOCATION(SHIP) EQUALS 1, SCHEDULE A CHANGE, LOCATION
GIVEN SHIP IN ALAM, SHIP, INTER, DEPARTURE DAYS
ELSE
IF LOCATION(SHIP) EQUALS 2, SCHEDULE A CHANGE, LOCATION
GIVEN SHIP IN MARE, ISLAND, SHIP, INTER, DEPARTURE DAYS
ELSE
IF LOCATION(SHIP) EQUALS 3, SCHEDULE A CHANGE, LOCATION
GIVEN SHIP IN EXPO(16, 3333.1) DAYS
ELSE
IF LOCATION(SHIP) EQUALS 4, SCHEDULE A CHANGE, LOCATION
GIVEN SHIP IN UNIFORM[0, 56.1] DAYS
ELSE
IF LOCATION(SHIP) EQUALS 5, SCHEDULE A CHANGE, LOCATION
GIVEN SHIP IN SAN, FRAN, SHIP, INTER, DEPARTURE DAYS
ELSE
IF LOCATION(SHIP) EQUALS 6, SCHEDULE A CHANGE, LOCATION
GIVEN SHIP IN UNIFORM[30, 34.1] DAYS
ELSE
IF LOCATION(SHIP) EQUALS 7, SCHEDULE A CHANGE, LOCATION
GIVEN SHIP IN HETH. ST. SHIP. INTER. DEPARTURE DAYS
ELSE IF LOCATION(SHIP) EQUALS 8 SCHEDULE A CHANGE LOCATION
GIVEN SHIP IN DEPLOY TIME DAYS
ELSE IF LOCATION(SHIP) EQUALS 9 SCHEDULE A CHANGE LOCATION
GIVEN SHIP IN 7 DAYS
ELSE IF LOCATION(SHIP) EQUALS 10 SCHEDULE A CHANGE LOCATION
GIVEN SHIP IN UNIFORM. (3.78.11) DAYS
ELSE IF LOCATION(SHIP) EQUALS 11 SCHEDULE A CHANGE LOCATION
GIVEN SHIP IN 44 DAYS
ELSE SCHEDULE A CHANGE LOCATION
GIVEN SHIP IN 44 DAYS
REGARDLESS
REGARDLESS
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REGARDLESS
LOOP
** THE STEADY-STATE EVENT IS SCHEDULED **
** SCHEDULE AN EQUILIBRIUM IN 10 DAYS **
** SCHEDULE A STOP SIMULATION IN 370 DAYS **
** THE INITIAL SHIPMENT FROM EACH PORT IS SCHEDULED **
** FOR EVERY PORT SCHEDULE A SHIPMENT TO GIVEN PORT IN 1 DAY **
** START SIMULATION **
STOP
END
EVENT EQUILIBRIUM
**
STATISTICS ARE RESET FOR STEADY-STATE
**
RESET THE TOTALS OF 1.WAIT.TIME, 2.WAIT.TIME AND 3.WAIT.TIME
FOR EACH PORT RESET TOTALS OF 4.FINAL.SHIPPED AND
5.TOT.RESQ
FOR EACH SHIP, DO
    LET T.SHIPPED(SHIP) = 0
    LET T.CHARGE(SHIP) = 0
LOOP
RETURN
END
EVENT  HANDLE, PREPARATION GIVEN VESSEL
DEFINE VESSEL AS AN INTEGER VARIABLE

THE NEXT BUNDLE PREPARATION FOR EACH VESSEL IS DETERMINED
AND SCHEDULED

IF TYPE(VESSEL) EQUALS 1
SCHEDULE A BUNDLE, PREPARATION
GIVEN VESSEL IN AF.BUNDLE, INTER.ARRIVAL DAYS
ELSE
IF TYPE(VESSEL) EQUALS 2
SCHEDULE A BUNDLE, PREPARATION
GIVEN VESSEL IN ACR.BUNDLE, INTER.ARRIVAL DAYS
ELSE
IF TYPE(VESSEL) EQUALS 3
SCHEDULE A BUNDLE, PREPARATION
GIVEN VESSEL IN MPS.BUNDLE, INTER.ARRIVAL DAYS
ELSE
SCHEDULE A BUNDLE, PREPARATION GIVEN VESSEL
IN AF.BUNDLE, INTER.ARRIVAL DAYS
REGARDLESS
REGARDLESS
REGARDLESS
THE NUMBER OF REQUISITIONS PER BUNDLE AND
THE OWNER OF THE BUNDLE IS DETERMINED
CREATE A BUNDLE
LET SOURCE(BUNDLE) = VESSEL
IF TYPE(VESSEL) EQUALS 1
LET NUMBER. OF. REQUISITIONS(BUNDLE) =
INT(FAE.REQ.PER.BUNDLE)
ELSE
IF TYPE(VESSEL) EQUALS 2
LET NUMBER. OF. REQUISITIONS(BUNDLE) =
INT(ACR.REQ.PER.BUNDLE)
ELSE
IF TYPE(VESSEL) EQUALS 3
LET NUMBER. OF. REQUISITIONS(BUNDLE) =
INT(MPS.REQ.PER.BUNDLE)
ELSE
LET NUMBER. OF. REQUISITIONS(BUNDLE) =
INT(AF.REQ.PER.BUNDLE)
REGARDLESS
REGARDLESS
REGARDLESS
REGARDLESS
THE ARRIVAL TIME OF THIS BUNDLE IS SCHEDULED
SCHEDULE A ARRIVAL. OF. BUNDLE GIVEN BUNDLE IN
EXPONENTIAL .F(3.838,1) DAYS
RETURN
END

69
EVENT ARRIVAL OF BUNDLE GIVEN PACKAGE
DEFINE PACKAGE AS AN INTEGER VARIABLE

AS EACH BUNDLE ARRIVES IT IS REDUCED TO
THE TOTAL NUMBER OF REQUISITIONS AND EACH REQUISITION
IS ASSIGNED ITS ATTRIBUTES

FOR I = 1 TO NUMBER OF REQUISITIONS(PACKAGE) DO THIS
CREATE A REQUISITION
LET OWNER(REQUISITION) = SOURCE(PACKAGE)
LET WEIGHT(REQUISITION) = EXPONENTIAL(F(1,1))
LET VOLUME(REQUISITION) = EXPONENTIAL(F(2,1))
LET PRIORITY(REQUISITION) = REQ.PRIORITY
LET QUANTITY(REQUISITION) = INT.(AE.QUAN.PER.REQ)
ELSE IF SOURCE(PACKAGE) < 12 LET QUANTITY(REQUISITION) = INT.(AE.QUAN.PER.REQ)
ELSE IF SOURCE(PACKAGE) < 15 LET QUANTITY(REQUISITION) = INT.(AES.QUAN.PER.REQ)
ELSE IF SOURCE(PACKAGE) < 17 LET QUANTITY(REQUISITION) = INT.(NSD.QUAN.PER.REQ)
ELSE LET QUANTITY(REQUISITION) = INT.(AP.QUAN.PER.REQ)
REGARDLESS
REGARDLESS
REGARDLESS
REGARDLESS

THE PROCESSING TIME FOR EACH REQUISITION IS DETERMINED
AND ITS READY FOR SHIPMENT TIME IS SCHEDULED

IF PRIORITY(REQUISITION) EQUALS 1 SCHEDULE A
READY FOR SHIPMENT GIVEN REQUISITION
IN 1.ISSUE.GROUP.PROCESS.TIME DAYS
ELSE IF PRIORITY(REQUISITION) EQUALS 2 SCHEDULE A
READY FOR SHIPMENT GIVEN REQUISITION
IN 2.ISSUE.GROUP.PROCESS.TIME DAYS
ELSE SCHEDULE A READY FOR SHIPMENT GIVEN REQUISITION
IN 3.ISSUE.GROUP.PROCESS.TIME DAYS
REGARDLESS
REGARDLESS
LOOP

THE BUNDLE IS REMOVED FROM THE SYSTEM AND MEMORY IS
MADE AVAILABLE

DESTROY THE BUNDLE CALLED PACKAGE
RETURN
END
EVENT CHANGE LOCATION GIVEN VESSEL
DEFINE VESSEL AND OLD LOCATION AS INTEGER VARIABLES
THE VESSEL MOVEMENT STATISTICS ARE COMPUTED
ADD 1 TO T.CHANGE(VESSEL)
ADD 1 TO CHANGE(TYPE(VESSEL))
THIS SECTION LOCATES THE NEXT PORT THE SHIP IS AT
LET OLD LOCATION = LOCATION(VESSEL)
IF TYPE(VESSEL) EQUALS 1 AND OLD LOCATION EQUALS 1
LET LOCATION(VESSEL) = AE. ALAM. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 1 AND OLD LOCATION EQUALS 2
LET LOCATION(VESSEL) = AE. MAR. ISL. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 1 AND OLD LOCATION EQUALS 3
LET LOCATION(VESSEL) = AE. WEAP. STA. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 1 AND OLD LOCATION EQUALS 4
LET LOCATION(VESSEL) = AE. NSC. PAK. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 1 AND OLD LOCATION EQUALS 5
LET LOCATION(VESSEL) = AE. SAN. FRAN. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 1 AND OLD LOCATION EQUALS 6
LET LOCATION(VESSEL) = AE. TID. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 1 AND OLD LOCATION EQUALS 7
LET LOCATION(VESSEL) = AE. BATH. STL. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 1 AND OLD LOCATION EQUALS 8
LET LOCATION(VESSEL) = AE. DIPLO
ELSE IF TYPE(VESSEL) EQUALS 2 AND OLD LOCATION EQUALS 1
LET LOCATION(VESSEL) = AOR. ALAM. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 2 AND OLD LOCATION EQUALS 4
LET LOCATION(VESSEL) = AOR. NSC. DAK. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 2 AND OLD LOCATION EQUALS 5
LET LOCATION(VESSEL) = AOR. TID. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 2 AND OLD LOCATION EQUALS 7
LET LOCATION(VESSEL) = AOR. BATH. STL. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 2 AND OLD LOCATION EQUALS 8
LET LOCATION(VESSEL) = AOR. DIPLO
ELSE IF TYPE(VESSEL) EQUALS 3 AND OLD LOCATION EQUALS 1
LET LOCATION(VESSEL) = AFS. ALAM. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 3 AND OLD LOCATION EQUALS 4
LET LOCATION(VESSEL) = AFS. NSC. DAK. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 3 AND OLD LOCATION EQUALS 5
LET LOCATION(VESSEL) = AFS. TID. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 3 AND OLD LOCATION EQUALS 7
LET LOCATION(VESSEL) = AFS. BATH. STL. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 3 AND OLD LOCATION EQUALS 8
LET LOCATION(VESSEL) = AFS. DIPLO
ELSE IF TYPE(VESSEL) EQUALS 3 AND OLD LOCATION EQUALS 9
LET LOCATION(VESSEL) = AFS. PTA. P. PORT CHANGE
ELSE IF TYPE(VESSEL) EQUALS 4 AND OLD_LOCATION EQUALS 1
LET LOCATION(VESSEL) = MOS.ALM.PORT.CHANGE
ELSE IF TYPE(VESSEL) EQUALS 4 AND OLD_LOCATION EQUALS 5
LET LOCATION(VESSEL) = MOS.SAN.FRM.PORT.CHANGE
ELSE IF TYPE(VESSEL) EQUALS 4 AND OLD_LOCATION EQUALS 6
LET LOCATION(VESSEL) = MOS.TOP.PORT.CHANGE
ELSE IF TYPE(VESSEL) EQUALS 4 AND OLD_LOCATION EQUALS 3
LET LOCATION(VESSEL) = MOS.DEPLOY
ELSE IF TYPE(VESSEL) EQUALS 4 AND OLD_LOCATION EQUALS 10
LET LOCATION(VESSEL) = MOS.T.1.PORT.CHANGE
ELSE IF TYPE(VESSEL) EQUALS 4 AND OLD_LOCATION EQUALS 11
LET LOCATION(VESSEL) = MOS.MERI.PORT.CHANGE
ELSE IF TYPE(VESSEL) EQUALS 5 AND OLD_LOCATION EQUALS 1
LET LOCATION(VESSEL) = AR.ALM.PORT.CHANGE
ELSE IF TYPE(VESSEL) EQUALS 5 AND OLD_LOCATION EQUALS 2
LET LOCATION(VESSEL) = AR.MARE.ISL.PORT.CHANGE
ELSE IF TYPE(VESSEL) EQUALS 5 AND OLD_LOCATION EQUALS 4
LET LOCATION(VESSEL) = AR.NSC.DAK.PORT.CHANGE
ELSE IF TYPE(VESSEL) EQUALS 5 AND OLD_LOCATION EQUALS 8
LET LOCATION(VESSEL) = AR.DEPLOY
ELSE REGARDLESS

REMOVE THIS VESSEL FROM SHIP.QUEUE(OLD_LOCATION)
FILE THIS VESSEL IN SHIP.QUEUE(LOCATION(VESSEL))

THIS SECTION THEN SCHEDULES THE NEXT PORT CHANGE FOR THIS VESSEL.

IF LOCATION(VESSEL) EQUALS 1 SCHEDULE 1 CHANGE,LOCATION
GIVEN VESSEL IN ALM.SHIP.INTER.DEPARTURE.DAYS
ELSE IF LOCATION(VESSEL) EQUALS 2 SCHEDULE 1 CHANGE,LOCATION
GIVEN VESSEL IN MARE.ISLAND.SHIP.INTER.DEPARTURE.DAYS
ELSE IF LOCATION(VESSEL) EQUALS 3 SCHEDULE 1 CHANGE,LOCATION
EVENT READY FOR SHIPMENT GIVEN REQ
DEFINE REQ AS AN INTEGER VARIABLE

THE SHIPPING DESTINATION IS FOUND AND TIME, WEIGHT, AND
VOLUME STATISTICS ARE COMPUTED

LET PORT = LOCATION(OWNER(REQ))
LET REQUISITION = REQ
FILE REQUISITION IN THE SHIPPING QUEUE(PORT)
LET TIME READY FOR SHIP(REQ) = TIME
ADD QUANTITY(REQ) = WEIGHT(REQ) TO WT SHIPPED(PORT)
ADD QUANTITY(REQ) = VOLUME(REQ) TO VOL SHIPPED(PORT)
RETURN
END
GIVEN VESSEL IN EXPONENTIAL. F(16.3333, 1) DAYS
ELSE
   IF LOCATION(VESSEL) EQUALS 4 SCHEDULE A CHANGE LOCATION
   GIVEN VESSEL IN UNIFORM. F(9.85, 1) DAYS
ELSE
   IF LOCATION(VESEL) EQUALS 6 SCHEDULE A CHANGE LOCATION
   GIVEN VESSEL IN SCHEDULED DEPARTURE DAYS
ELSE
   IF LOCATION(VESEL) EQUALS 7 SCHEDULE A CHANGE LOCATION
   GIVEN VESSEL IN SCHEDULED DEPARTURE DAYS
ELSE
   IF LOCATION(VESEL) EQUALS 8 SCHEDULE A CHANGE LOCATION
   GIVEN VESSEL IN 7 DAYS
ELSE
   IF LOCATION(VESEL) EQUALS 9 SCHEDULE A CHANGE LOCATION
   GIVEN VESSEL IN 7 DAYS
ELSE
   IF LOCATION(VESEL) EQUALS 10 SCHEDULE A CHANGE LOCATION
   GIVEN VESSEL IN UNIFORM. F(3.75, 1) DAYS
ELSE
   IF LOCATION(VESEL) EQUALS 11 SCHEDULE A CHANGE LOCATION
   GIVEN VESSEL IN 44 DAYS
ELSE
   SCHEDULE A CHANGE LOCATION
   GIVEN VESSEL IN 44 DAYS

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REGARDLESS

MATERIAL IS REMOVED FROM THE VESSEL'S OLD LOCATION QUEUE
AND ADDED TO THE VESSEL'S CURRENT LOCATION QUEUE

FOR EACH REQUISITION IN SHIPPING.QUEUE(OLD.LOCATION)
WITH OWNER(REQUISITION) = VESSEL ON THIS
REMOVE THIS REQUISITION FROM SHIPPING.QUEUE(OLD.LOCATION)
FILE THIS REQUISITION IN SHIPPING.QUEUE(LOCATION, VESSEL)
SUBTRACT QUANTITY(REQUISITION) * WEIGHT(REQUISITION)
FROM WT.SHIPPED(OLD. LOCATION)
SUBTRACT QUANTITY(REQUISITION) * VOLUME(REQUISITION)
FROM VOL.SHIPPED(OLD. LOCATION)
ADD QUANTITY(REQUISITION) * WEIGHT(REQUISITION) TO
WT.SHIPPED(LOCATION, VESSEL)
ADD QUANTITY(REQUISITION) * VOLUME(REQUISITION) TO
VOL.SHIPPED(LOCATION, VESSEL)

LOOP
RETURN
END
EVENT SHIPMENT TO GIVEN DESTINATION

DEFINE DESTINATION AS AN INTEGER VARIABLE
IF N.SHIPPING QUEUE(DESTINATION) EQUALS 0
   GO TO 'FIRST'
ELSE
   'SHIP'

STATISTICS ARE COMPUTED

ADD 1 TO NR.TRUCKS(DESTINATION)
LET WT.FINAL.SHIPPED(DESTINATION) = WT.SHIPPED(DESTINATION)
LET VOL.FINAL.SHIPPED(DESTINATION) = VOL.SHIPPED(DESTINATION)
LET TOT.REQ(DESTINATION) = N.SHIPPING QUEUE(DESTINATION)
LET WT.SHIPPED(DESTINATION) = 0
LET VOL.SHIPPED(DESTINATION) = 0
FOR EACH REQUISITION IN SHIPPING QUEUE(DESTINATION) DO THIS
   IF PRIORITY(REQUISITION) = 1 LET 1.WAIT.TIME = TIME.V - TIME.READY.FOR.SHIP(REQUISITION)
ELSE
   IF PRIORITY(REQUISITION) = 2 LET 2.WAIT.TIME = TIME.V - TIME.READY.FOR.SHIP(REQUISITION)
   ELSE
   LET 3.WAIT.TIME = TIME.V - TIME.READY.FOR.SHIP(REQUISITION)
   END IF
   REGARDLESS
   REMOVE THE REQUISITION FROM SHIPPING QUEUE(DESTINATION)
   DESTROY REQUISITION
END LOOP
'FIRST'

THE NEXT SHIPMENT FOR THIS PORT IS COMPUTED
AND SCHEDULED

IF TIME.V = INT.F(TIME.V)
SCHEDULE A SHIPMENT TO GIVEN DESTINATION IN 1. DAY
ALWAYS
RETURN
END
EVENT STOP SIMULATION
LET LINES.V = 48
LET PAGE.V = 1
BEGIN REPORT ON A NEW PAGE
BEGIN HEADING
PRINT 5 LINES WITH PAGE.V AS FOLLOWS
SIMULATION RESULTS
PAGE NO. 44

IF PAGE IS FIRST:
PRINT 23 LINES AS FOLLOWS
THE EXECUTION TIME PARAMETER FOR THIS MODEL WAS 3.25 DAYS. THE FOLLOWING
SECTION IDENTIFIES ALL CODES USED IN THE MAIN PROGRAM AND THE RESULTS SECTION:

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REGARLESS OF HEADING
SKIP 17 OUTPUT LINES
PRINT 8 LINES THUS

THE FOLLOWING STATISTICS REPRESENT LOST TIME FOR
ISSUE GROUP CRe REQUISITION WHILE IN THE SHIPPING QUEUE:

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<th>MEAN</th>
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<th>STD DEV</th>
<th>MAX</th>
<th>MIN</th>
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A.A.10-20A-TM-54-894
STEP VARIATION
PRINT 1 LINE WITH MEAN, 1. WAIT, TIME, VAR, 1. WAIT, TIME, SD, 1. WAIT, TIME, 
MAX, 1. WAIT, TIME, MIN, 1. WAIT, TIME AS FOLLOWS

**********  **********  **********  **********  **********

PRINT 6 LINES THUS

THE FOLLOWING STATISTICS REPRESENT LOST TIME FOR
ISSUE GROUP TWO REQUESTIONS WHILE IN THE SHIPPING QUEUE:

MEAN VARIANCE STD DEV MAX MIN
PRINT 1 LINE WITH MEAN, 2. WAIT, TIME, VAR, 2. WAIT, TIME, SD, 2. WAIT, TIME, 
MAX, 2. WAIT, TIME, MIN, 2. WAIT, TIME AS FOLLOWS

**********  **********  **********  **********  **********

PRINT 6 LINES THUS

THE FOLLOWING STATISTICS REPRESENT LOST TIME FOR
ISSUE GROUP THREE REQUESTIONS WHILE IN THE SHIPPING QUEUE:

MEAN VARIANCE STD DEV MAX MIN
PRINT 1 LINE WITH MEAN, 3. WAIT, TIME, VAR, 3. WAIT, TIME, SD, 3. WAIT, TIME, 
MAX, 3. WAIT, TIME, MIN, 3. WAIT, TIME AS FOLLOWS

**********  **********  **********  **********  **********

PRINT 6 LINES THUS

THE FOLLOWING STATISTICS REPRESENT WEIGHT SHIPPED TO
VARIOUS DESTINATIONS:

DESTINATION MEAN STD, DEV, WT, SHIPPED WT, SHIPPED WT, SHIPPED WT, SHIPPED
FOR EACH PORT PRINT 1 LINE WITH PORT,
M,WT,FNIAL(PORT),V,WT,FNIAL(PORT),MAX,WT,FNIAL(PORT),MIN,WT,FNIAL(PORT),
F,TOTAL,RECEIVED(PORT) AS FOLLOWS

**********  **********  **********  **********  **********  **********  **********  **********

SKIP 9 OUTPUT LINES
PRINT 1 LINES THUS

THE SHIP, ITS FINAL PORT, THE TOTAL NUMBER OF REQUESTIONS
SHIPPED AND THE TOTAL NUMBER OF MOVES FOLLOWS:

SHIP PORT NR, REQ NR, MOVES
FOR EACH SHIP PRINT 1 LINE WITH SHIP, LOCATION(SHIP), 
T,SHIPPED(SHIP),T,CHANGE(SHIP) AS FOLLOWS

**********  **********  **********
PRINT 6 LINES THUS

THE SHIP CLASS AND ASSOCIATED NUMBER OF MOVES FOLLOWS:

CLASS    NR. MOVES

FOR I = 1 TO 5
    PRINT 1 LINE WITH I, CHANGE(I) AS FOLLOWS
    ***
    SKIP 5 OUTPUT LINES
PRINT 6 LINES THUS

THE NUMBER OF SHIPMENTS PER PORT FOLLOWS:

PORT    SHIPMENTS

FOR J = 1 TO 12
    PRINT 1 LINE WITH J, NR. TRUCKS(J) AS FOLLOWS
    ****
END**REPORT
STOP
END
APPENDIX E

CASE II

EVENT SHIPMENT TO GIVEN DESTINATION
DEFINE DESTINATION AS AN INTEGER VARIABLE
IF N*SHIPPING QUEUE(DESTINATION) EQUALS 0
  GO TO 'FIRST'

DECISION RULES FOR CASE II

IF INT(F(TIME.V/7)) EQUALS TIME.V/7,
  GO TO 'SHIP'
ELSE
  GC TO 'FIRST'
ELSE
  'SHIP'

STATISTICS ARE COMPUTED

ADD 1 TO N*TRUCKS(DESTINATION)
LET WT.FINAL.*SHIPPED(DESTINATION) = WT.*SHIPPED(DESTINATION)
LET VCL.FINAL.*SHIPPED(DESTINATION) = VCL.*SHIPPED(DESTINATION)
LET TOT.*REQUISITION = N.*SHIPPING QUEUE(DESTINATION)
LET WT.*SHIPPED(DESTINATION) = 0
LET VCL.*SHIPPED(DESTINATION) = 0
FOR EACH REQUISITION IN SHIPING QUEUE(DESTINATION)
  IF PRIORITY(REQUISITION) = 1 LET 1.*WAIT.TIME = TIME.V
    - TIME.READY.FOR.SHIP(REQUISITION)
  ELSE
    IF PRIORITY(REQUISITION) = 2 LET 2.*WAIT.TIME = TIME.V
      - TIME.READY.FOR.SHIP(REQUISITION)
  ELSE
    IF 3.*WAIT.TIME = TIME.V - TIME.READY.FOR.SHIP(REQUISITION)
      REGARDLESS
      ADD 1 TO *SHIPPED主人(REQUISITION))
      REMOVE THE REQUISITION FROM SHIPING QUEUE(DESTINATION)
      DESTROY REQUISITION
    LOOP
  'FIRST'

THE NEXT SHIPMENT FOR THIS DESTINATION IS COMPUTED
AND SCHEDULED

IF TIME.V = INT(F(TIME.V))
SCHEDULE A SHIPMENT TO GIVEN DESTINATION IN 1. DAY
ALWAYS
RETURN
END


APPENDIX F

CASE III

EVENT READY FOR SHIPMENT GIVEN REQ
DEFINE REQ AS AN INTEGER VARIABLE
THE SHIPMENT DESTINATION IS FOUND AND TIME, WEIGHT, AND
VOLUME STATISTICS ARE COMPUTED
LET PORT = LOCATION(OWNER(REQ))
LET REQUISITION = REQ
FILE REQUISITION IN THE SHIPping QUEUE(PORT)
LET TIME(READY, PORT, SHIP(REQ)) = TIME
ADD QUANTITY(REQ) * WEIGHT(REQ) TO WT_SHIPPED(PORT)
ADD QUANTITY(REQ) * VOLUME(REQ) TO VOL_SHIPPED(PORT)

DECISION RULES FOR CASE III

IF PRIORITY(REQ) EQUALS 1 SCHEDULE A SHIPMENT TO GIVEN
PORT NOW
ALWAYS
RETURN
END
APPENDIX G

CASE IV

EVENT SHIPMENT TO GIVEN DESTINATION
DEFINE DESTINATION AS AN INTEGER VARIABLE
IF N.SHIPPING.QUEUE(DESTINATION) EQUALS 0
   GO TO "FIRST"

DECISION RULES FOR CASE II
IF INT.(TIME.V/V) EQUALS TIME.V/V,
   GO TO "SHIP"
ELSE
DECISION RULES FOR CASE IV
FOR EACH REQUISITION IN SHIPPS.QUEUE(DESTINATION)
   WITH PRIORITY(REQUISITION) < 3, FIND THE FIRST CASE
   IF NONE, GO TO FIRST
ELSE
   "SHIP"

STATISTICS ARE COMPUTED
ADD 1 TO NR.TRUCKS(DESTINATION)
LET WT.FINAL.SHIPPED(DESTINATION) = WT.SHIPPED(DESTINATION)
LET VOL.FINAL.SHIPPED(DESTINATION) = VOL.SHIPPED(DESTINATION)
LET WT.SHIPPED(DESTINATION) = 0
LET VOL.SHIPPED(DESTINATION) = 0
FOR EACH REQUISITION IN SHIPPS.QUEUE(DESTINATION)
   DO THIS
   IF PRIORITY(REQUISITION) = 1 LET 1.WAIT.TIME = TIME.V
       - TIME.READY.FOR.Ship(REQUISITION)
   ELSE IF PRIORITY(REQUISITION) = 2 LET 2.WAIT.TIME = TIME.V
       - TIME.READY.FOR.Ship(REQUISITION)
   ELSE LET 3.WAIT.TIME = TIME.V = TIME.READY.FOR.Ship(REQUISITION)
   REGARDLESS
   IF 1.WAIT.TIME < 2.WAIT.TIME
   ELSE
   REMOVE THE REQUISITION FROM SHIPPS.QUEUE(DESTINATION)
   DESTROY REQUISITION
   LOOP "FIRST"
THE NEXT SHIPMENT FOR THIS DESTINATION IS COMPUTED
AND SCHEDULED
IF TIME.V = INT.(TIME.V)
SCHEDULE A SHIPMENT TO GIVEN DESTINATION IN 1. DAY
ALWAYS
RETURN
END
### APPENDIX H

**DETAILED RESULTS CASE I**

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LIST OF REFERENCES


8. Hernandez, E. R. Jr.; and Gallitz, R. J., An Analysis of the Oakland Naval Supply Center's Bay Area Local Delivery System, Naval Postgraduate School, Monterey,


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