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PERFORMANCE STANDARDS FOR DEPOT INITIAL FILL RATES



FINAL REPORT
MAY 1972

BY
ALAN J. KAPLAN

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TABLE OF CONTENTS

	<u>Page</u>
TABLE OF CONTENTS.....	i
ABSTRACT.....	ii
SUMMARY	i
1. Background.....	iii
2. Objectives.....	iii
3. Scope.....	iii
4. Methodology.....	iv
5. Results.....	iv
MAIN REPORT	
1.1 Simulation Design.....	1
1.2 Factors Investigated.....	4
1.3 Investigation Scheme (Experimental Design)...	6
1.4 Results.. ..	8
1.5 Analysis.....	11
1.6 Supplementary.....	13
APPENDIX.....	15
BIBLIOGRAPHY.....	18
DISTRIBUTION.....	19

ABSTRACT

For each customer a national inventory control point will have a preferred depot from which to supply him. Stock distribution effectiveness as discussed here measures the extent to which stock is available at the preferred depot when needed. The major variables affecting stock distribution effectiveness are identified, their impact measured, and performance estimates are made for representative values of these variables. These estimates can be used as performance standards. The major research tool is a simulation.

SUMMARY

1. Background

In the past few years, increased attention has been focused on that aspect of NICP supply support effectiveness relating to the satisfaction of the customer from the depot oriented to that customer. This saves both time and transportation money. The importance of the time saving has been highlighted by recent experience with the Direct Supply Support Test (DSST).

At the request of AMC Directorate of Distribution and Transportation (AMCSU-M) routine measurement of the extent to which customers are satisfied from the correct depot is being implemented under MILSTEP. At the same time, AMC Inventory Research Office was asked to undertake this study to determine what performance could be expected under various conditions, and in particular under the current environment.

2. Objectives

The specific objectives of this effort were:

- a. To identify those factors which affect stock distribution effectiveness, and estimate their relative significance.
- b. To obtain representative values for the "key factors".
- c. To develop performance standards based on the representative values obtained.

3. Scope

The results of this study apply to NICP managed secondary items.

The results obtained do not take into account the potential impact of special management actions such as described in [2]. On

the other hand, they assume a basically stable demand pattern subject only to random fluctuations. In this sense, they are standards rather than predictions of performance.

4. Methodology

A simulation was developed and served as the primary investigation tool. Demands on each depot were generated using a random number generator. For the most part, standard statistical techniques were used to estimate and control the variability of simulation output, i.e., to insure that results reported were not due to the particular set of random numbers generated.

Analytical methods for projecting performance were briefly examined. Two simple models were developed, but neither worked well; i.e., they were unable to project performance consistent with the simulation results.

5. Results

Distribution effectiveness is defined here as the ratio of total demand satisfied from the correct depot, to total demand satisfied by the NICP from all depots. The ratio is expressed as a percent. Requisitions placed on backorder before being filled are not considered in developing the ratio. The "correct" depot is the depot designated for support of the customer whose demand is received.

The key factors affecting distribution effectiveness as defined are

(1) Number of depots at which stock for an item is stored; increase in number degrades distribution effectiveness.

(2) NICP Target Stock Availability: increase in NICP stock

availability improves distribution effectiveness (and visa versa).

(3) Variability of demand during the procurement lead time:
increase of variability degrades distribution effectiveness (and visa versa).

(4) Distribution of demand among depots; i.e., if each depot accounts for about the same proportion of total demand, distribution effectiveness tends to be lower than if demand is concentrated at one depot.

Since distribution effectiveness as measured in this report considered only demand satisfied without first being placed on backorder, it was not obvious before the simulation work that factors 2 and 3 would affect distribution effectiveness.

For representative values of the Key factors, distribution effectiveness was found to be 74% if stock is stored at 3 depots, and 67% if stock is stored at 4 depots.

MAIN REPORT

1.1 Simulation Design

The following processes were simulated: receipt of demand; selection of depot to fill demand or placement of demand on backorder if necessary; comparison of assets to reorder point; determination of amount to order and how to allocate stock amongst depots; receipt of stock due-in; and application to any existing backorders; also, performance statistics were accumulated. The simulation is run for one item at a time.

The simulation was run in both 3 depot and 4 depot mode; i.e., assuming an item is stocked at 3 depots serving 3 customer areas, or at 4 depots serving 4 customer areas. Change of mode required a minor modification of the computer program.

Demand is generated independently by random number generator for each customer area.* The NICP satisfies the demand from the area oriented depot to the extent possible. If part or all of a requisition cannot be filled from the correct depot, a search routine is utilized as follows:

3 Depot Mode: depots are identified as East, Central, West. Demand from the East, if not satisfied there, is satisfied from Central if possible and from West as a last resort. Similarly the search pattern in response for demands from the West is West, Central, then East. For demands from the Central area, the search pattern is Central, East, then West.

*Stuttering Poisson demand was generated.

4 Depot Mode: depots are identified as East, Central-1, Central-2, West. Search patterns are:

<u>Demand Area</u>	<u>Order of Search</u>
East	East, Central-1, Central-2, West
Central-1	Central-1, Central-2, East, West
Central-2	Central-2, Central-1, West, East
West	West, Central-2, Central-1, East

Some attempt is made in the issue process to avoid partial fills; i.e., if demand cannot be satisfied even in part from the local depot, the search is first confined to those depots with assets at least equal to the requirement. Thus East demand would be satisfied in total from West depot if there were no East assets, and assets in Central depot did not equal the requisition amount. A modified simulation was also run in which no special effort was made to avoid partial fills (current policy). It was clear that stock distribution effectiveness was completely insensitive to which way the simulation was run. Current policy of course reduces waiting time and transportation mileage, but causes extra shipments.

The NICP reorder point and reorder quantity were input to the simulation and were determined using the MIT model [1]. If a demand dropped assets below the reorder point, the reorder point deficit plus the procurement cycle quantity were ordered. Procured stock was allocated to the depots on a straight percent basis without regard to the relative asset position at each depot at time of order. For example, if 25% of future demand was expected to originate in the

area served by East depot, East depot would always be allocated 25% of stock placed on order.

Stock received from procurement was treated as if it arrived at each depot at the same time. Backorders would then be satisfied from the local depot to the extent possible. If, after this process, there were still backorders remaining at some depots, and assets available at other depots, the same search process as already described for demand satisfaction was used to satisfy the backorders.

In the real world, application of stock received from procurement to clear up outstanding backorders is much more complex than the procedure just described. For example, the age and priority of backorders is considered in the real world. However, it is not believed the simplification adopted should significantly affect distribution effectiveness as measured. For the same reason, the complexities of reparable item management were not simulated.

In all other respects the simulation is intended to reflect current AMC policies.

Measurement. The simulation measured units of demands filled or backordered, rather than number of requisitions. (One requisition possibly being for many units). This was intended to simplify the computer program. Experience with other simulations indicates that the fill rates for requisitions for an item is equivalent to fill rate for units, provided partial fills are not counted in measuring fill rates for requisitions. In any event, since the measure of interest was a ratio of fill rates - fill from correct depot to total NICP fill - use of units is a reasonable simplification and all results are considered to approximate closely the results which would have been obtained from requisition measurement.

1.2 Factors Investigated

Two sets of variables were defined:

<u>Set I</u>	<u>Set II</u>
1. NICP Reorder Point	NICP Target Stock Availability
2. NICP Procurement Cycle Quantity	NICP Procurement Cycle (Months)
3. Procurement Lead Time	Same
4. Number of depots	Same
5. Average Order Size	Same
6. Fraction of demand expected from each area	Same
7. Total NICP demand	Coefficient of variation of NICP Lead Time demand*

Set I constitutes the variables actually input to the simulation for an item being simulated. Set II is an equivalent set in the sense that given values for all set II variables, values for set I variables can be determined. For example, the MIT model [1] was used to translate target availability into a reorder quantity. Details on the entire process of going from set II to set I are given in the Appendix.

The reason for constructing set II relates to objective (a) of this study: identification of the Key variables. The point is best explained by example. It was believed that if average order size, for instance, were changed significantly, and all other variables in set I were held constant, stock distribution

*This variable is defined as the ratio of lead time standard deviation of demand to mean lead time demand.

effectiveness as observed in the simulation might also change significantly; in other words, average order size would be indicated as a Key variable. On the other hand, it was believed if average order size were changed, and all the other variables in set II were held constant, expected stock distribution effectiveness would not be changed. Using set II, the average order size - as well as some other variables - could be considered as irrelevant to expected performance, provided a subset of set II variables were known; this subset would represent a limited manageable set of Key variables. These beliefs were based on analytical understanding* and constituted part of a hypothesis to be tested by experimentation using the simulation.

*Some of this analytical understanding became clear only after some preliminary experimentation.

1.3 Investigation Scheme (Experimental Design)

A "base" case was defined as follows:

1. NICP Target Stock Availability: 85%
2. NICP Procurement Cycle: 6 Months
3. Procurement Lead Time: 9 Months
4. Number of Depots: 3
5. Average Order Size: 100
6. Distribution of Demand: Central - 37% East - 28%
West - 35%
7. Coefficient of variation of Lead Time Demand: 50%

All values chosen are representative values for NICP managed secondary items. In particular, the distribution of demand figures were furnished by AMCSU-M. The coefficient of variation percent was developed by Martin Cohen, AMC Inventory Research Office, as a by product of Project #194, "NICP Safety Levels for Intensive Managed Items." (Data base of that project was not limited to intensive managed items). Number of CONUS depots storing the same item typically is 3 or 4, depending on NICP and item.

The investigation scheme was basically to vary the value for one variable at a time and compare resulting simulated performance to that of the base case as an indication of the variable's significance. The value changes made were always large.

One exception to this general approach was that Procurement Lead Time and Procurement Cycle were changed together in a

series of 4 simulation runs:

Procurement Lead Time		Reorder Cycle
(a)	6	1
(b)	6	12
(c)	18	1
(d)	18	12

It was thought that possibly the relationship between Procurement Lead Time and Procurement Cycle was more important than the value for either of them alone.

1.4 Results

The performance statistic measured was the ratio of requisitions filled from the correct depot to total requisitions filled.* Only requisitions satisfied without first being put on backorder were considered. For example, if

100 requisitions are received

85 requisitions are initially filled** by inventory control point (ICP)

70 requisitions are initially filled by NICP from closest depot used to stock item

then

$$\text{stock distribution effectiveness} = \frac{70}{85} = 82\%$$

Note that in the above example, 15 requisitions out of 100 would not be filled because of unavailability of stock in the wholesale system; of the remaining 85, 15 could not be filled from the closest depot because the stock was not well located. Now 15/85 or 18% is the difference between 100% and stock distribution effectiveness as measured.

The simulation results are shown in Table 1. Under the column labelled "Variable Changed", each run is identified by how it differs from the base case described in section 1.3. For example, in run 2 the average order size is 10 rather than 100 as in the base case. Abbreviations used are

* Note qualification discussed at end of section 1.1.

**Initial fill denotes that stock was available to satisfy requisition when it was received.

Ord Size	-	Average Order Size
Procy	-	Procurement cycle months
PLT	-	Procurement Lead Time months
Coef of Var	-	Coefficient of variation of lead time demand
Disn	-	Distribution of demand by depot
NICP Tar	-	Initial fill rate target at National Inventory Control Point

The standard deviation %'s shown in Table 1 indicate the variability of the stock distribution effectiveness result reported. In any simulation with random variables the output depends in part on chance (e.g. what demands are generated by the random number generation). However, it is unlikely that, if the simulation were rerun many times, the answers obtained would differ from the result shown by more than two Standard Deviations.

The Appendix describes calculation of the standard deviation.

<u>Run #</u>	<u>Variable Changed</u>	<u>Distribution Effectiveness</u>	<u>Standard Deviation</u>
1	Base Case	73.9%	0.5%
2	Ord Size = 10	73.9%	0.6%
3	Procy = 1 PLT = 6	73.8%	0.6%
4	Procy = 1 PLT = 18	73.0%	0.8%
5	Procy = 12 PLT = 6	76.6%	0.7%
6	Procy = 12 PLT = 18	73.6%	0.8%
7	Coef of Var = .25	82.4%	0.7%
8	Disn Central 10% East 70% West 20%	79.5%	0.6%
9	NICP Tar = 95%	78.8%	0.5%
10	NICP Tar = 75%	69.4%	0.6%
11	# Depots = 4 Disn Central-1 18.5% Central-2 18.5% West 35% East 28%	67.0%	0.5%

TABLE 1

1.5 Analysis

The results in Table 1 for the most significant variables, the "Key variables", are summarized below.

<u>Run</u>	<u>Variable Examined</u>	<u>Change in Performance From Base Case</u>
7	Coefficient of Variation	+8.5%
8	Distribution of Demand	+5.6%
9	NICP Target Availability	+4.9%
10	NICP Target Availability	-4.5%
11	Number of Depots	-6.9%

TABLE 2

Run 7:

We see that decreasing the variability of demand (i.e., decreasing the coefficient of variation) increased depot effectiveness 8.5%. This occurred even though the NICP safety level was reduced along with the variability of demand, keeping NICP availability at about 85%.

Run 8:

The base case distribution of demand was quite symmetrical; i.e., about 1/3 at each depot. In case 8 demand was asymmetrical with a predominance at the East depot, and depot effectiveness increased. Increasing asymmetry, i.e., concentrating the demand at one depot, has the same kind of effect as reducing the number of depots.

Run 9, 10:

Despite the way stock distribution effectiveness was defined (Section 1.4), effectiveness still increases with NICP availability.

In run 9 NICP Target was 95%, in run 7 it was 75% (it was 85% in the base case).

Run 11:

If there is only 1 depot, stock distribution effectiveness must be 100%. As the number of depots increases, it becomes harder to correctly allocate stock. Increasing the number of depots by 1 reduced depot effectiveness about 7%.

While not listed as key variables, there was one case where changing the procurement lead time and procurement cycle had some effect on depot effectiveness (run 5). In this run, the ratio of procurement cycle to lead time was 2 (12 months to 6 months). This kind of ratio is characteristic of Low Dollar Value items.

1.6 Supplementary Results

4-Depot Case. Since many items are stored at 4 depots, additional runs were made for the 4 depot case. Recall (run 11, Table 1) that the 4 depot case was run with item parameters set as in the base case (section 1.3), except that 4 depots were identified with expected distribution of demand as follows:

East	-	28%
Central 1-		18.5%
Central 2-		18.5%
West	-	35%

In run 11 target availability was 85%. Additional runs were made with targets availabilities of 75% and 95% giving

Target Availability	Dis'n Effectiveness	Comparable 3 Depot Run
95%	73.4%	78.8%
85%	67.0%	73.9%
75%	62.9%	69.4%

Coefficient of Variation. Referring to Table 2, the impact of coefficient of variation on distribution effectiveness was particularly large. An additional run was made giving:

Coefficient of Variation	Distribut	ctiveness
.50 (base case)		
.25 (run #7)		
.35 (supplementary run)		78.4%

The supplementary run confirms the importance of this variable, which is not under NICP control.

Stock Allocation Policy. As stated in section 1.1, current AMC policy is to allocate procurement due-in to depots in most cases without regard to assets at the depots at the time of buy. To see the affect of considering assets, the base case was rerun using the following policy:

Let R = NICKP reorder quantity

Q = NICKP procurement cycle quantity

P_i = Proportion of demand expected on depot i

A = NICKP assets at time of buy of NICKP (equals sum of depot assets)

A_i = Assets at time of buy located at depot i or due-in to depot i

Then

$$\text{Buy} = R + Q - A$$

$$\text{Allocation of due-in to depot } i = P_i \times (R+Q) - A_i$$

Note: $\sum_i P_i \times (R+Q) = R+Q$ and $\sum_i A_i = A$.

Results of using modified policy were:

	Stock Dis'n Effectiveness	Standard Deviation
Current Policy (Base Case)	73.9%	0.5%
Modified Policy	70.3%	0.6%

The current policy is clearly better for the case run. This suggests that careful testing should be accomplished before any more "sophisticated" policy is adopted.

APPENDIX

This Appendix contains the technical backup to the report.

Equivalence of Set I and Set II Variables. (Section 1.2)

Given variables of set II, we show how to derive the variables in set I.

Let

R = NICP Reorder Point

Q = NICP Procurement Cycle Quantity

PLT = Procurement Lead Time (Months)

D = Demand in Procurement Lead Time (Quantity)

λ = Demand in Procurement Lead Time (Frequency)

S = Average Order Size

α = Target Availability

C = Coefficient of Variation of Lead Time Demand

Demand was assumed in the simulation to have a Stuttering Poisson distribution. For the Stuttering Poisson [3],

$$(1) \quad D = \lambda * S$$

$$(2) \quad \text{Variance} = (2S-1)\lambda * S$$

Hence

$$(3) \quad C = \frac{\sqrt{(2S-1)\lambda * S}}{\lambda * S} \approx \sqrt{\frac{(2S-1)}{\lambda * S}}$$

Inspection of (3) shows C to be a monotonic decreasing function of λ . Hence, give S,C (set II), it is easy to find λ and, then, using (1), to get D (set I).

*See last paragraph of reference in particular, noting $S = 1/(1-p)$ where p is the geometric distribution parameter.

Given D, annual demand (set I) = $\frac{D}{PLT} * 12$. Also, Procurement Cycle Quantity (set I) is simply Procurement Cycle Months (set II) * D/PLT.

R is found using the MIT Model [2] with inputs C, α , D, PLT, and Q. This completes the derivation of the set I variables.

Calculation of Simulation Outputs. (Section 1.4)

We give procedure used to derive output results shown in Table 1.

Let

- n = number of years for which simulation was run
(excluding 5 year warmup)
- t = length of a simulation period (simulation is divided into n/t periods for purposes of accumulating performance statistics)
- j = subscript denoting period
- D_j = total initial fill by correct depot in period j
- N_j = total initial fill by NICP in period j
 $(N_j = D_j + \text{those demands initially filled by other than correct depot})$
- DE = Stock Distribution Effectiveness
- $E()$ = expected value of random variable specified
- $\sigma()$ = standard deviation of random variable specified
- $\hat{E}(), \hat{\sigma}()$ = estimate of mean, standard deviation based on simulation output
- \hat{DE} = simulation estimate of DE

Two alternative definitions were considered for DE

(1)
$$DE = \frac{E(D_j)}{E(N_j)}$$

(1')
$$DE = E \left(\frac{D_j}{N_j} \right)$$

Definition (1) was chosen because it is independent of (t), and because of the context in which the simulation results are to be used. We are interested in overall effectiveness over a group of items. This means we are interested in total fill from correct depot compared to total NICP fill, not the average of the observed ratios by item. The former corresponds most closely to measure (1) and the latter to (1').

It was not possible to estimate $\sigma(\hat{DE})$ directly from the simulation outputs available. However, there is good reason to claim that

$$(2) \quad \sigma(\hat{DE}) = \sigma\left(\frac{\hat{E}(D_j)}{\hat{E}(N_j)}\right) < \frac{\sigma[\hat{E}(D_j)]}{E(N_j)}$$

and the right hand term of (2) can be estimated. The inequality has intuitive appeal and it was verified by simulation (of the base case) that

$$(3) \quad \hat{\sigma}\left(\frac{D_j}{N_j}\right) < \frac{\hat{\sigma}(D_j)}{\hat{E}(N_j)}$$

This makes sense since D_j and N_j are positively correlated.

Therefore, $\hat{\sigma}[\hat{E}(D_j)/\hat{E}(N_j)]$ was used as the estimator for DE, recognizing it as an upper bound.

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