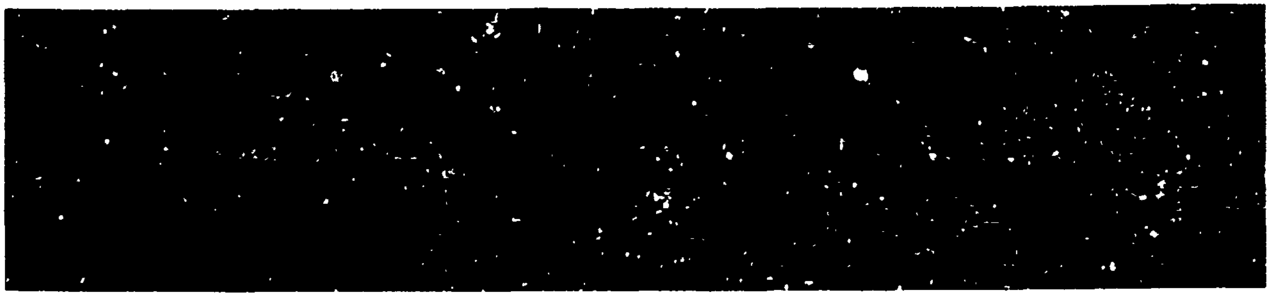

A Basis for Establishing Order Shipping Time (OST) Standards for the Direct Support System

by Leon N. Karadbil
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13. ABSTRACT

The Direct Support System (DSS) in Europe is designed to streamline the supply system (via removal of an echelon of supply) and improve its responsiveness. In concept, DSS would increase the percentage of customer requests that are immediately filled, and decrease the waiting time for those that are not. This reduction would be accomplished by reducing overall order shipping time (OST) from 80 to 45 days. Thus, a standard of 45 days OST has been established for DSS.

This report analyzes the performance and cost implications of several alternative interpretations of the 45-day standard, and establishes a basis for selecting an interpretation that is at once meaningful, attainable, and worth the cost. The RAC Supply Point Simulation Model (SPSM) was used to consider performance and cost sensitivities to various interpretations of the standard, i.e., 80 percent of fill accomplished in 45 days, 40 percent, etc.

It is demonstrated that adjustment of stockage quantities to realistically reflect the OST will yield the best supply performance. Fixed stockage quantities would cost less but, unless OST is actually shortened more than it has been to date, performance would thereby suffer. In either case, a suggested Army interpretation of the 45-day standard is advanced.

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FOREWORD

This report describes the use of RAC's Supply Point Simulation Model (SPSM) as an aid in determining appropriate and meaningful supply performance standards for Europe. The SPSM is especially well suited to such analyses. It yielded performance and cost results for this study, based upon a cross-section of possible assumptions concerning interpretation of the order shipping time standard. These results rapidly provided logical bases for decision. The effort was begun in Jan 71, and findings were reported to the Army the following May.

Lee S. Stoneback
Head, Logistics Department

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The draft document was reviewed by MG S. D. Smith, Jr (USA-Ret), Dr. R. G. Ruppenthal, Mr. C. J. Christianson, Mr. John R. Bossenga, and Mr. K. E. Geisinger, whose suggestions for revision were invaluable.

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RAC

SUMMARY

PROBLEM

For the Direct Support System (DSS) as configured in Europe, the problems addressed by this report are:

(1) to analyze the performance and cost implications of several possible interpretations of the delivery time [order shipping time (OST)] standard.

(2) to provide a basis for selection of an OST standard against which to measure DSS performance.

BACKGROUND

The DSS is designed to streamline the supply system and improve its responsiveness. The term "responsiveness" as used herein represents the compilation of all time-weighted measures of supply system effectiveness. These include immediate fills, fills via backorder releases, and fills resulting from receipts of non-stocked items due-in. Thus, the supply system could be 100 percent responsive only if all requisitions were filled immediately upon arrival at the proximate supply point. In concept, the DSS would increase the percentage of user requirements that are immediately filled and, more importantly, decrease the waiting time for those that are not. This would be accomplished by supplying repair parts directly from depots in the United States to customer units overseas. Such a revision of the supply system is expected to reduce OST. The projected reduction is from about 80 days to 45 days; therefore the standard, as specified by DSS procedures, is 45 days.

After the European test of the DSS had been underway for several months, disagreement arose concerning the meaning of the standard.

It could be interpreted as the time within which the maximum fill is achieved, an average time to fill, or the time to fill some specified percentage of requisitions submitted. RAC was requested to develop a means of selecting an appropriate interpretation of the standard.

APPROACH

The RAC Supply Point Simulation Model (SPSM) was used to compare the performance, workload, and cost implications of various interpretations of the standard. Performance is measured in terms of fill rates, parts shortages, duration of shortages, and zero balances with dues-out. Workload is measured by such terms as number of replenishment requisitions, frequency of reorders, and weight and cubic displacement of inventory on hand. The costs considered herein are the average inventory and pipeline investment costs.

The supply point represented in the model was a typical direct support unit (DSU). Replenishment requisitions and requests for parts not stocked at the DSU were filled from depots in the United States; the time required to complete that fill was selected probabilistically for each requisition from an appropriate distribution. The distributions used were developed from distributions whose shapes are equivalent to that of empirical OST data, but in which a specific cumulative percentage of completions occur within the standard time (e.g., 80 percent of fill within 45 days).

Stockage Levels

A requisitioning objective (RO) is the quantity authorized to be on hand and on-order. It is composed of a safety level (SL), an operating level (OL), and an OST quantity. The OST quantity is that portion of the stockage level normally consumed during the time required for supply replenishment. It is usually stated in days, but can be converted to quantity by multiplying by the daily consumption rate for the particular repair part.

Empirical OSTs are seldom used in developing stockage levels. To do so precisely could require the use of different numbers of days for each different repair part stocked. Even then replenishment time-variations would complicate the problem tremendously. Therefore, especially at DSU level, the Army has elected to use the same number of days of OST for stockage level computation for all repair parts stocked. Often, the selection of that number of days has been arbitrary, and does not represent real OST.

The OST stockage levels used in this evaluation were of two kinds, for each of the standards tested: (1) "fixed" OST level, equivalent to the standard [OST level = 45 days (or 35 days) consumption], and (2) "adjusted" OST level, equivalent to the average value of the specific OST distribution used in each model iteration [OST level = quantity consumed in the average number of OST days]. The adjusted level is used to more accurately reflect "real" OST, as used in the simulation. Clearly, if OST were 62 days, then stockage of 62 days' worth of assets will provide better performance than will stockage of 45 days' worth.

Rationale

By simulating system behavior assuming a number of different interpretations of the delivery time (OST) standard, it was possible to (1) determine the incremental improvements in performance, (2) compute the costs to attain them, and (3) establish a much-reduced range of alternatives that appears to be at once reasonable and worth the costs to attain.

FINDINGS

If the primary objective of the DSS system is improved performance, stockage levels adjusted to average OST are preferable. Interpretation of the standard can then be based upon what is achievable, rather than what is desirable, without seriously degrading performance.

If the primary objective is reduced cost, and if 60 percent of fill within 45 days is not achievable, fixed OST levels would be preferable because they would result in lower dollar investment—but at the expense of performance. Therefore, the use of fixed levels is not considered desirable. Use of adjusted levels instead will produce monetary savings if OST is rapid and better performance if OST is long.

Less than 60 percent of fill within 45 days results in apparently unacceptable performance; more than 80 percent (even if achievable) would probably not be worth the required resource expenditures. It is suggested, therefore, that the interpretation of the delivery time standard be somewhere between 60 and 80 percent of fill in 45 days, subject to Army discretion. Relative importance of cost and performance for these alternatives is described in this report.

A BASIS FOR ESTABLISHING ORDER SHIPPING TIME (OST) STANDARDS FOR THE DIRECT SUPPORT SYSTEM

4

RAC

ABBREVIATIONS

AMC	Army Materiel Command
CONUS	continental United States
DA	Department of Army
DSS	Direct Support System
DSU	direct support unit
EOQ	economic order quantity
FSN	Federal stock number
NICP	national inventory control point
OL	operating level
OST	order shipping time
RO	requisitioning objective
RP	reorder point
SL	safety level
SPSM	Supply Point Simulation Model
TODC	theater oriented depot complex

GLOSSARY

addition criterion. The minimum number of demands required in the base period for addition of an item to the stockage list at a supply point.

backorder. Same as due-out.

base period. That time period for which factors were determined for use in current planning and programming for overseas stockage, usually one year.

demand. A valid requirement for materiel placed on the supply system by an authorized customer. Demand is categorized as recurring or nonrecurring and is measured in terms of frequency or quantity.

Direct Support System. The supply concept in which a large portion of a DSU's repair parts requirements are met by direct supply from CONUS.

Direct Support System test. An ongoing test of the Direct Support concept, that began in Europe in July 1970.

direct support unit. A company of a maintenance battalion furnishing repair-parts and maintenance support to a user unit.

due-out. That portion of stock requisitioned which is not immediately available for supply and which will not be referred to a secondary source of supply but will be recorded as a commitment for future issue.

economic order quantity. A quantity of materiel established for each item based on a relationship of variable cost to hold assets vs variable cost to buy, resulting in an optimum order quantity at a minimum total cost.

holding cost factor. A factor used to determine the costs associated with the physical presence of materiel in inventory; generally expressed as an annual percentage of average inventory investment.

immediate fill. Same as initial fill.

initial fill. The percent of total demands (frequency or quantity) filled from available stock on hand at a supply point.

inventory investment. As used in this report, the aggregate dollar value of the average quantity of assets on hand at a supply point for each of the lines on its stockage list.

operating level. The quantity of materiel required to sustain operations in the interval between requisitions or the arrival of successive shipments.

order shipping time quantity. The portion of the requisitioning objective that represents the quantity of stock that will normally be consumed during the time elapsing between the initiation of stock replenishment action and the receipt of materiel.

performance. The degree of supply effectiveness provided, in terms of initial fill, backorders, shortages, and times. As used herein, performance is always considered relative to other factors, such as cost, and to other system configurations or policy alternatives.

pipeline. The channel of support or a specific portion thereof by means of which materiel flows from sources of procurement to points of use.

pipeline investment. The dollar value of assets required to fill the pipeline.

reorder point. That stock level at which stock replenishment requisitions are submitted.

replenishment requisition. A request for the quantity of materiel required to maintain a net asset position equal to the requisitioning objective. The net asset position is the sum of assets on hand and on order, less those due to customers.

requisitioning objective. The maximum quantity of materiel to be maintained on hand and on order to sustain current operations at a supply point. It consists of the sum of stocks represented by the safety level, operating level, and OST level.

responsiveness. The sum and substance of all time-weighted measures of supply system effectiveness.

retention criterion. The minimum number of demands required in the base period for retention of an item on the stockage list at a supply point, once it has been added.

review period. The time interval between reviews of demand history for the purpose of adding or deleting items from the stockage list.

safety level. The quantity of materiel, in addition to the operating level, required to be on hand to permit continuous operations in the event of minor interruption of normal replenishment or unpredictable fluctuations in demand.

stockage criteria. The rules that govern what items will be maintained on the stockage list at a supply point. They are composed of addition criteria and retention criteria.

stockage depth. The quantity of items stocked at a particular supply echelon, also expressed as days of supply.

supply point. An Army activity that provides materiel support to customer units and is dependent upon higher echelons for replenishment. Support includes the processing of requests and requisitions, record-keeping, issuance of supplies, and materiel storage.

Chapter 1

INTRODUCTION AND MODEL APPLICATION

BACKGROUND

The Army has specified a standard delivery time of 45 days for its Direct Support System (DSS)* in Europe. As with the choice of any standard, it fulfills two basic purposes: (1) it is an objective to be reached or surpassed, (2) it provides a gauge against which to measure actual performance. The 45 day delivery time was specified without further clarification, and was therefore open to a wide range of possible interpretations. Thus, the Army was faced with the problem of defining exactly what its interpretation should be.

This report addresses the selection and interpretation of a delivery time standard for the European theater. Performance and cost implications of its alternative interpretations are evaluated, in order to provide a logical basis for choice of an appropriate one.

The Army has had to reduce inventories and expenditures for its supply system because of funding constraints. Guided by Department of Army (DA) Circular 700-18, "Logistics Improvements,"[1] a support plan has been developed to streamline the supply system, with the objective of improving responsiveness while conserving resources. This plan, known formally as the Direct Support System, is currently undergoing test in Europe.[2]

Direct Support System

The DSS is the concept of supplying and replenishing repair parts to direct support units (DSUs) directly from a theater-oriented depot complex (TODC) in the continental United States (CONUS). By providing detailed supply management information from the DSUs to the item

*For an analysis of three supply systems, one of which is the DSS, see Ref. 3.

managers at the national inventory control points (NICPs), the DSS is intended to insure more rapid and accurate response to current or anticipated field requirements. Intensive management is applied to the relatively few very-frequently-demanded items that constitute the bulk of customer demands, thus assuring adequate stockage at the TODC to provide improved customer satisfaction. In addition, reduction of delivery time [also referred to as order shipping time (OST)] for CONUS supply of European customers is to be accomplished by eliminating one current supply echelon, the theater depot level. The OST reduction contemplated, from an average of approximately 80 days currently to a maximum of 45 days,* would result in savings in required inventory on hand and on order.

The DSS Test[2]

The European test of the DSS has been underway since July 1970. During the first In-Process Review of the test, conducted in December 1970, concern was expressed regarding the interpretation to be applied to certain goals and standards specified in the test plan. Of immediate interest was the delivery time (OST) standard, then set at 35 days, and later changed to 45 days, for fill from CONUS. Though specifically referred to in the test plan as a maximum, it had been variously interpreted to mean 100 percent of fill within that time, 80 percent, an average time to fill, etc. Further, a "requirement" to achieve a specified percentage of fill within so many days may either be not attainable, or may only be attainable through excessive cost.

RAC's Logistics Department is involved in the evaluation of the DSS test, and therefore has access to most test data. The monthly analyses thereof (as of December 1970) had indicated that considerably less than 100 percent of fill was actually occurring within the specified 45-day goal. Some deliveries had taken several months. Further, with

*Thirty-five days was specified by Ref. 2 for stockage list items, but this was amended by the March 1970 DSS In-Process Review[4] to 45 days. Also, the new standard for non-stocked items is 51 days. However, for the sake of simplicity of analytic comparisons, the OST for non-stocked items was not used herein. All lines in a given run were subjected to the same delivery lag time distribution.

only 6 months' experience so far accumulated on completed (delivered, or filled) requisitions, some replenishment times could be expected to take longer than 6 months.

APPROACH

In order to provide a sound basis for interpretation of the standard, RAC suggested application of its Supply Point Simulation Model (SPSM)[5] to the problem. This model provides a very rapid means of evaluating proposed changes, especially changes in supply policies and procedures, in terms of the supply performance implications as measured at one supply point.

Rationale

A delivery time (OST) standard for the DSS, to be meaningful, must be one that: (1) is possible to achieve, based on past experience and subsequent system improvements, and (2) is worth whatever additional costs are required to attain it. Delivery time (OST) affects all time-related measures of performance. Increases in OST will result in either increased number and duration of shortages, or a required increase in inventory and pipeline stockage investment. Conversely, although performance improves and asset investment decreases as OST becomes shorter, there is a cost to attain that improvement, e.g., premium transportation.

The simulations described herein encompassed a number of possible interpretations of the standard. That is, the percent of requisitions filled within the standard delivery time was varied from 100 to 20, in 20 percent increments. For each of these variations, the performance and cost implications were tabulated. Thus, it was determined approximately where the improvements wrought by possible decreases of OST become marginal, in terms of benefits vs costs. This is described fully in Chap. 2.

Operation of the SPSM

For this evaluation, the supply point used is the DSU. Its supply activities are simulated using detailed demand experience, and detailed distributions of actual resupply lag times for fill from CONUS supply sources. Stockage policies for the DSU are preset as model inputs.

The SPSM simulates demands for a single stock number at a time, then aggregates the individual results in a subsequent computer subroutine. In order to reduce computer time expenditures, the stock numbers demanded are grouped into classes of similar demand patterns. The classes are designated by ranges of demand frequencies.

Occurrences of demands during the simulation are governed by the Poisson distribution whose average is equal to the average demands per day actually experienced by items in each class. Quantity per demand is a truncated geometric function whose average is the average quantity per demand experienced. After simulation of supply activity for a particular class, results are aggregated for all classes by weighting according to the number of FSNs in each class. Average price, weight and space consumption (cube) data for each class are used to provide additional outputs.

INPUTS TO THE SIMULATIONS

Listed in Table 1 are the inputs used in this set of simulations. They are of two basic types: empirical data (demands, quantity demanded, OST, price, weight and cube), and system description (stockage policy, cost factors, length of simulation).

Demand History Data

In order to avoid biases due to seasonal variations in demand patterns, demand data for one year were used. Customer units' demands on the 3d Inf Div in Europe were used as the basic inputs to the several model runs. The user unit data covered all recurring demands for the period 10 Feb 70 to 9 Feb 71. The 3d Inf Div had been operating under DSS procedures since the test began in July 70, so these data include 7 months of DSS experience. Table 2 gives the detailed characteristics for each of the 29 demand classes into which these data were segregated.

OST Data

Although the simulations were begun in February 71, the OST data available included only those requisitions completed through December 70, i.e., 6 months' data.

At first, delivery time appeared to be much improved over that experienced prior to DSS. However, this improvement was illusory--as the test

Table 1

INPUT VALUES USED IN EVALUATING
DSS OST STANDARDS

Required input	Value used
<u>Empirical data</u>	
Demands per day	Poisson distribution having mean equal to average demands per day of lines in class
Quantity per demand	Truncated geometric distribution having mean equal to average quantity per demand of lines in class
Delivery time (OST)	Semi-log distribution having slope equivalent to empirical distribution, and intersecting the time standard (e.g., 45 days) at selected cumulative percentages of fill (e.g., 80 percent fill in 45 days)
Unit price	Average unit price of lines in class
<u>Stockage policy</u>	
Base period	1 year
Review period (frequency of review)	Annual
Safety level (SL)	15 days
OST level	35 days, 45 days, or average value of OST distribution used in simulation
Operating level (OL)	EOQ (a description of EOQ follows in section titled "Stockage Level")
Initial inventory	OL + OST
Stockage criteria:	
Addition criterion	6 demands/year
Retention criterion	3 demands/year
Weight and cube	Average weight and cube of lines in class
<u>Length of simulation</u>	5 years

Table 2

DEMAND CLASS CHARACTERISTICS

Class designation	Range of annual demands of included FSNs	Number of FSNs	Average unit characteristics of included FSNs				
			Demands per day[a]	Quantity per demand	Price (dollars)	Weight (lbs)	Cube (ft^3)
1	150-199[b]	40	.715	5.6	8.14	10.24	1.043
2	100-149	67	.452	6.3	4.14	3.54	.237
3	90-99	33	.367	4.6	4.29	1.85	.076
4	80-89	31	.333	2.5	6.50	3.58	.303
5	70-79	40	.288	6.2	7.64	5.98	.278
6	60-69	50	.249	6.9	7.22	4.44	.175
7	50-59	36	.214	4.7	10.44	6.56	.345
8	45-49	59	.183	4.1	11.00	4.61	.271
9	40-44	74	.162	4.3	10.33	7.54	.365
10	35-39	95	.144	8.0	18.67	9.26	.343
11	30-34	135	.123	5.6	8.79	5.73	.313
12	25-29	196	.105	5.3	12.05	8.17	.313
13	20-24	286	.085	5.8	12.97	5.32	.231
14	15-19	432	.066	6.0	15.79	10.72	.410
15	10-14	889	.046	5.5	16.05	11.13	.388
16	9	272	.035	4.5	25.65	12.30	.397
17	8	327	.031	4.9	11.72	5.28	.229
18	7	398	.027	5.2	16.40	7.11	.336
19	6	520	.023	8.0	41.67	11.90	.483
20	5	715	.019	4.8	17.58	4.66	.185

Table 2 (continued)

Class designation	Range of annual demands of included FSNs	Number of FSNs	Average unit characteristics of included FSNs				
			Demands per day[a]	Quantity per demand	Price (dollars)	Weight (lbs)	Cube (ft^3)
21	4^c	540	.016	6.3	20.08	4.22	.241
22	4^d	376	.016	1.1	20.10	7.72	.252
23	3^c	634	.012	9.9	9.58	4.53	.344
24	3^d	841	.012	1.1	29.78	13.73	.505
25	2^c	790	.008	14.5	8.49	4.67	.115
26	2^d	1839	.008	1.3	34.75	8.30	.356
27	1^c	1055	.004	24.6	13.29	1.92	.127
28	1^e	2081	.004	2.9	19.54	3.77	.285
29	1^f	4253	.004	1.0	37.27	11.55	.461
		17104					

[a]Assuming 257 working days per year.

[b]No FSNs in data base used were demanded more than 199 times.

[c]Quantity per year ≥ 6

[d]Quantity per year < 6

[e]Quantity per year: 2-5

[f]Quantity per year = 1

progressed, the OST appeared to increase. This was to be expected, as the OST data were only available for completed requisitions initiated on or after 1 July 1970. Those cases of especially long time-to-completion were only beginning to appear after 6 months. As the more difficult-to-fill requisitions were completed, average OST increased, as did elapsed time to complete a given percentage of requisitions.

To illustrate this point, consider the left-hand curve (labeled "A") in Fig. 1, a semi-logarithmic plot of cumulative OSTs for all requisitions submitted and completed between 1 July and 31 August 1970. Obviously, any requisition taking longer than 62 days could not have appeared in this distribution.

The curve labeled "B" includes one additional month of data. The apparent increase in OST is due to the increase in time since the test began. After 92 days of test experience, some of the more difficult-to-fill requisitions are appearing in the distribution.

This apparent tendency to increase will ultimately resolve into a representative distribution only after the test has been underway long enough to permit inclusion of the long delivery times. As of December 1970 it was clear that DSS had not yet been underway long enough, and it was impossible to predict how much longer would be required. Nevertheless after extensive discussions with personnel from the DSS test directorate of AMC, it was agreed that recognition of these inevitable long fill times was essential to an appropriate simulation.

Earlier OST experience. Two years' OST data for completed 4th Armd Div requisitions[6] appear as plot "C" in Fig. 1. These suggest that DSS test OST may ultimately approximate that of the older, longer period. This tendency appears to have been real. Table 3 provides distributions of OST by month of submission, for all DSS test requisitions completed as of July 1971 (after this reported evaluation was completed). The more recently that requisitions have been submitted, the shorter the time to completion for those completed. Conversely, more time has elapsed since August submissions, allowing inclusion of the longer delays. Other published RAC reports[7,8] tend to confirm that the distribution of delivery times that has developed for DSS is quite similar to earlier experience.

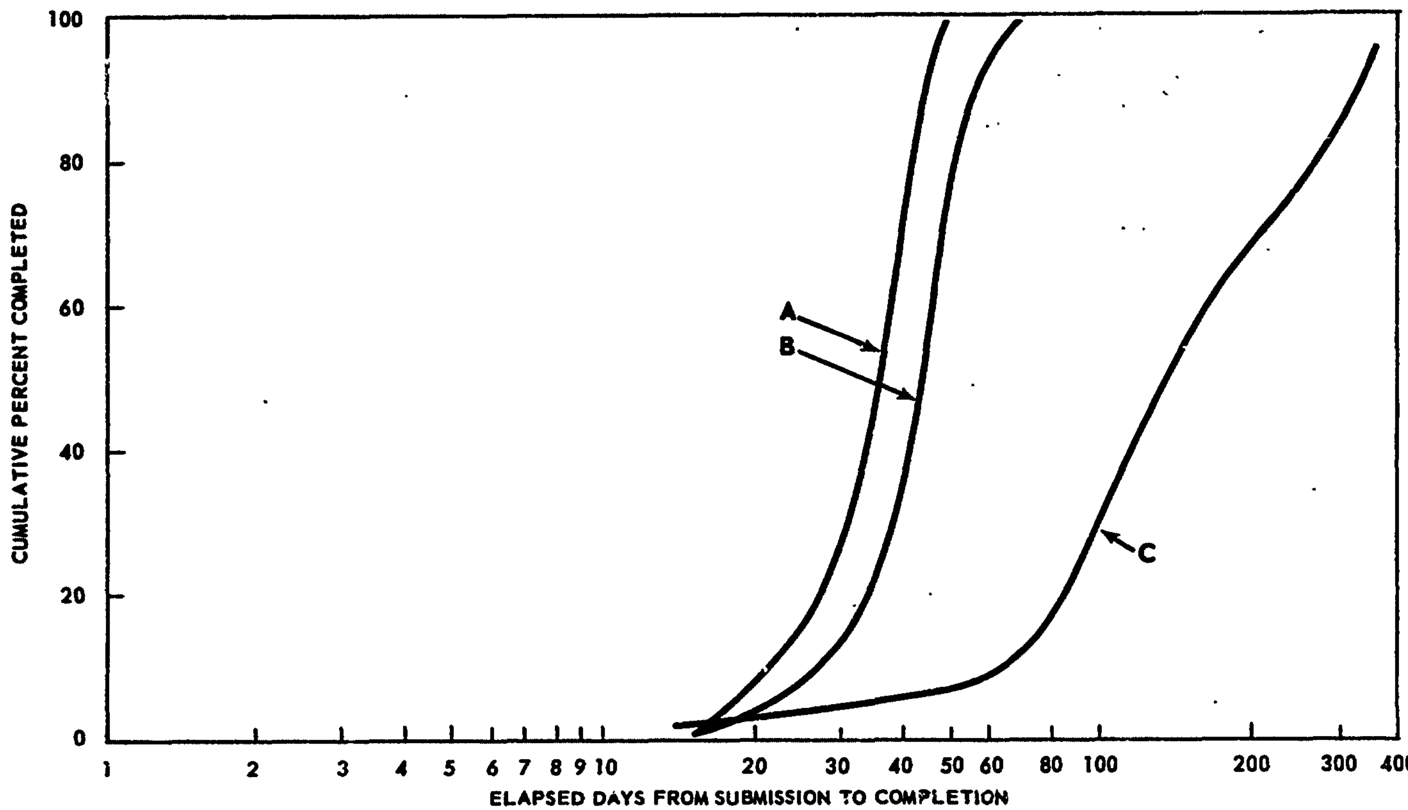

Fig. 1—DSS Test OST Compared with 2 Years' Earlier OST Experience

A. DSS test requisitions completed as of 31 Aug '70.
B. DSS test requisitions completed as of 30 Sep '70.
C. Completed 4th Arm Div requisitions, Jan '67–Jan '69.

Table 3

DELIVERY TIME DISTRIBUTIONS FOR COMPLETED DSS TEST REQUISITIONS FROM EUROPE

By Month of Submission

Time to fill (days)	Cumulative percent completed as of 31 July 1971, by month of submission										
	Aug '70	Sep	Oct	Nov	Dec	Jan '71	Feb	Mar	Apr	May	Jun
1-20	0	1	1	0	4	3	1	3	2	2	3
21-35	6	12	5	6	19	20	28	30	36	39	[illegible]
36-45	23	36	17	20	43	41	44	50	57	64	86
46-50	37	44	24	31	58	52	50	58	67	78	97
51-55	50	49	29	39	69	62	57	64	74	88	99
56-60	59	56	36	52	75	68	65	69	81	95	99
61-90	76	71	75	86	92	82	77	77	92	99	
91-120	80	88	90	93	96	87	82	81	93		
121-150	92	94	94	97	98	89	84	82	99		
> 150	100	100	100	100	100	100	100	100			
Total completed[a]	4629	6463	6757	8789	10,539	5329	5562	8672	3532	3190	1,875
Net submitted[b]	4706	6594	6931	9183	11,257	6303	6164	9889	4827	6501	15,028

[a]Number of requisitions completed, regardless of when completed, that were submitted in specified month, as of 31 July 71.

[b]Total requisitions submitted less cancellations.

Extrapolation technique. The following technique was used to extrapolate from the older data to a set of distributions to be used in the simulations:

1. A straight-line approximation of the distribution of the older OST data was developed.

2. In recognition of general improvements in routine supply responsiveness due to automation at lower levels of the system, the median (50th percentile) of the older data was shifted to the left (decreased) by 30 days. Hereafter, this distribution is referred to as the "base" delivery time, and is used as a baseline for other simulations. It is plotted on Fig. 2.

3. For the simulation of a DSS that will provide 100 percent of deliveries within the standard time (in this case 45 days), a straight line having the slope of the "base" OST distribution is positioned so that 100 percent of deliveries occur within 45 days. Various other points in the resulting distribution are read off (as indicated by the dashed lines in Fig. 2), providing the OST distribution required for input to the SPSM.

Distributions for other percentages of fill within the standard are similarly derived. A sufficient number of these were developed to provide a spectrum of times. Their data points, given in Table 4, were used as input to the 24 model runs described in this report.

SIMULATIONS USED

Each simulation for the 45-day standard was repeated using the 35-day standard. In each set, it was assumed that delivery was accomplished within the standard time for a specific percentage of submitted requisitions (i.e., 100, 80, 60, 40, and 20 percent). Simulations using "base" OSTs, as derived from the two years' data, were run to provide a baseline.

Stockage Levels

The stockage level, sometimes referred to as the stockage depth, is the quantity of parts to be stocked of a particular stock number. It is usually stated in terms of a requisitioning objective (RO), which is the quantity authorized to be on hand and on-order. The RO is composed of a safety level (SL), an operating level (OL), and an OST

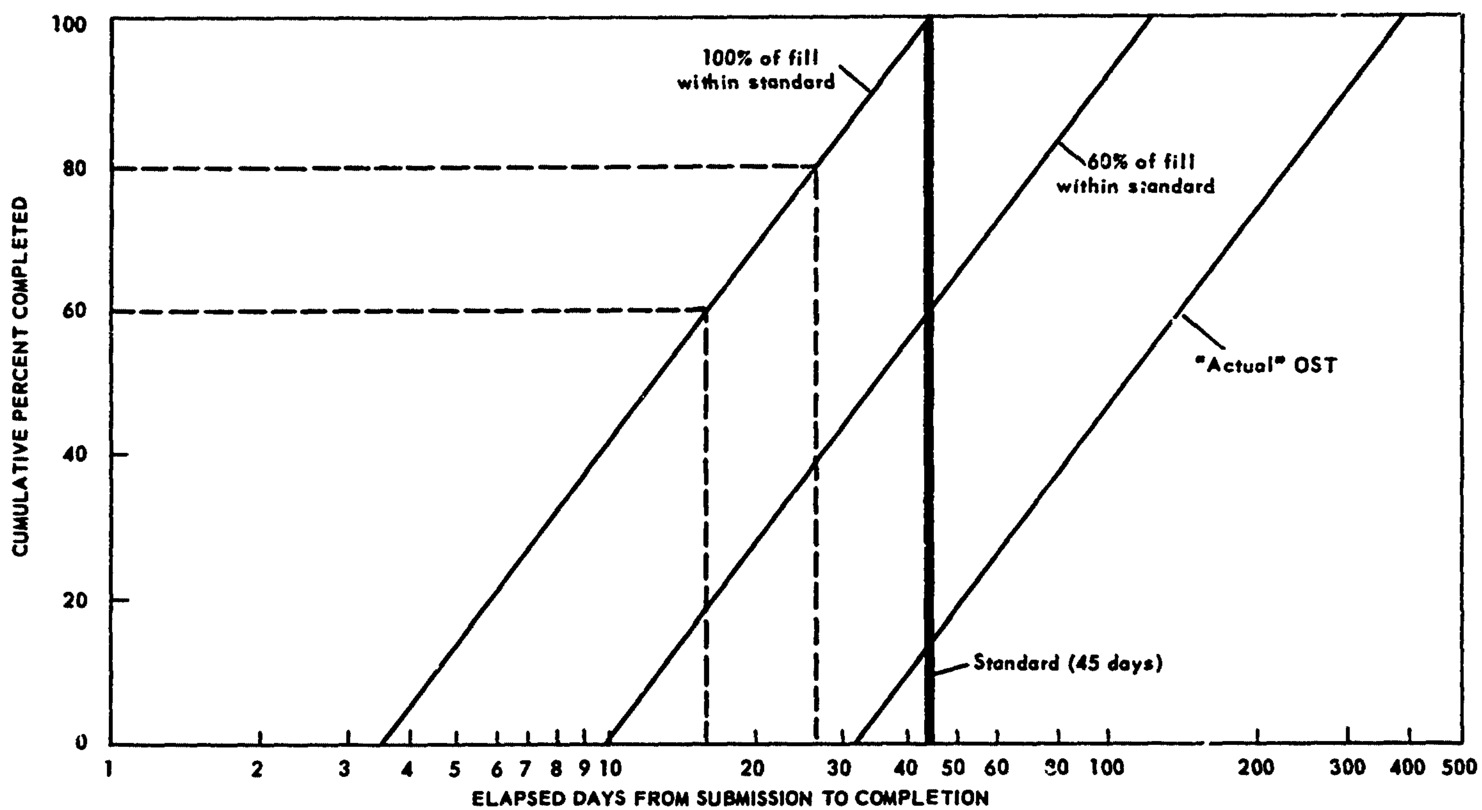

Fig. 2—Illustration of Technique Used To Derive OST Distributions

Table 4

OST DISTRIBUTIONS DERIVED FOR SPSM INPUT

Standard time to fill	Interpretation: Percent filled within standard time	Average[a] OST (days)	Days to fill indicated percentages of requisitions submitted: 20	40	60	80	100
35 days	100	13.4	5	8	13	21	35
	80	22.0	8	13	21	35	58
	60	36.3	13	21	35	58	96
	40	60.1	21	35	58	96	160
	20	100.5	35	58	96	160	272
45 days	100	16.9	6	10	16	27	45
	80	28.1	10	16	27	45	75
	60	46.8	16	27	45	75	126
	40	78.3	27	45	75	126	210
	20	130.7	45	75	126	210	350
"base"	-	150.8	54	86	145	242	400

[a]These averages are computed by a subroutine of the SPSM, from the distributions used as input.

quantity. The OST quantity is that portion of the RO normally consumed while awaiting replenishment from the supplier. The OST level is usually stated in days, which may be converted to quantity by multiplying by the daily consumption rate of the particular repair part.

To develop a precise OST level for a particular part, its daily consumption would be multiplied by the exact number of days required to obtain replenishment. Since that number of days varies from part to part, and even from time to time for the same stock number, real OSTs are seldom used in computing stockage level quantities. Instead, a fixed number of days' stockage is generally used as the OST quantity for all items stocked. This is especially true at the DSU level and below, as varying the OST days for each different item would cause complications too great to be handled at those levels.

As a consequence, the OST days used in level computations often do not reflect empirical OST at all. Instead, they are arbitrary choices that are either (a) too short, resulting in frequent and long-lasting zero balances and poor supply performance; or (b) too long, resulting in accumulation of excess assets.

For this evaluation, two types of OST levels have been used: (1) "fixed," the quantity consumed during the number of days in the <u>standard</u>, i.e., 35 or 45 days' worth of stockage, (2) "adjusted," the quantity consumed during the <u>average number of days of the OST distribution assumed</u> for the particular simulation being run. The former is past Army policy for DSUs. The latter is current policy for those units where the required capability to determine real OST exists. The "adjusted" OST stockage level will result in greater stockage depth for longer order shipping times.

The remaining components of the stockage levels used in the simulations described herein are as follows:

Safety level (SL) = 15 days' consumption

Operating level (OL) = economic order quantity (EOQ)

The EOQ is computed using the quantity demanded in a year (Q) and the unit price of the part (P) according to the following formula:

$$EOQ = 7\sqrt{\frac{Q}{P}}$$

then the OL is equal to the EOQ, unless EOQ > $\frac{Q}{3}$, in which case, OL = $\frac{Q}{3}$ or $\frac{EOQ}{3}$, whichever is larger.

The variations provided by two standards, fixed and "adjusted" OST levels, and the six assumptions regarding percent of fill completed within the standard, resulted in 24 separate simulations. These are outlined in Table 5.

Table 5

MATRIX OF SIMULATIONS

Delivery time standard (days)	Type of OST stockage level	Interpretation					
		Percent delivered within standard time					
		20	40	60	80	100	"base"
35	fixed[a]						
35	adjusted[b]						
45	fixed[c]						
45	adjusted[d]						

[a]Fixed OST at 35 days, SL = 15 days, reorder point (RP) = SL + OST = 50 days.

[b]Adjusted levels with 35-day standard. Mean values of appropriate OST distributions are used for OST level, and are as follows:

Interpretation	Adjusted OST (mean of OST distribution)
Percent completed within standard (35 days)	
20	101
40	60
60	36
80	22
100	13
"base"	151

[c]Fixed OST at 45 days, RP = 60 days.

[d]Adjusted levels with 45-day standard. As in footnote b:

Interpretation	Adjusted OST (mean of OST distribution)
Percent completed within standard (45 days)	
20	131
40	78
60	47
80	28
100	17
"base"	151

Chapter 2

SIMULATION RESULTS

The SPSM provides three types of output measures: performance, workload, and costs. Though approximately 40 such measures are contained in model output as currently configured, only those that vary as a function of delivery time (OST) variations are of any concern here. Each is duscussed in detail below.

PERFORMANCE

Initial Fill

Initial fill is measured two ways: as the percent of total requisitions, and as the percent of quantity requisitioned, that is filled from assets on hand at the supply point. High initial fill is therefore desirable, as few pieces of equipment will be out of commission awaiting parts. But it may be costly; large inventories of parts on hand and on order may be required to attain such fill.

Consider Table 6, which gives initial fill statistics for number of requests and quantity requested, as functions of variations in the OST distribution. Based on model results, when 100 percent fill occurs within 35 or 45 days, only 79 percent of requisitions received, and 73 percent of the quantity requisitioned, will receive initial (i.e., immediate) fill. But as OST is increased (as percent of fill within the standard time decreases) a marked degradation occurs in initial fill. For example, only about half of the requisitions and quantity requested receive initial fill if only 40 percent of the total requisitions to CONUS are completed within the 35- or 45-day standard. That is, the longer it takes to receive replenishment from CONUS, the poorer the system performance.

Table 6

INITIAL FILL PERFORMANCE, FIXED OST STOCK LEVELS

OST standard	Initial fill of	Interpretation of standard					
		Percent delivered within standard time					
		100	80	60	40	20	"base"
35 days	demands	79	77	69	54	32	14
45 days		79	76	68	50	24	18
35 days	quantity	73	71	64	50	29	13
45 days		73	71	63	47	23	16

RAC

Effect of "Adjusted" OST Levels. When the OST portion of the stockage level is "adjusted" to reflect more realistically the OST simulated, considerably better initial fill can result. Table 7 shows the initial fill performance with adjusted OST. Except for the cases in which 80 and 100 percent are filled within the standard, the adjusted OST stockage level provides better performance than the fixed. Naturally, there is a price to pay for this performance, as more assets will be required.

Differences in initial fill between fixed and adjusted OST are illustrated in Figs. 3 and 4.

Shortages

Parts shortages are roughly equivalent to those requisitions not filled initially. Of greater importance than the occurrence of a shortage is its duration. Table 8 gives the shortage statistics provided by the model. Note that parts shortages and part-days of shortage both increase as OST is increased, even where the OST stockage level is adjusted. Thus the adjustment in some cases has little discernable effect on average shortage duration (Table 8), though absolute numbers of parts shortages are markedly decreased. Thus, it is possible to reduce the number of parts shortages expected by a realistic adjustment of OST stockage levels. However, once a shortage exists, its duration is primarily a function of, and controlled by, delivery time. Figure 5 gives a graphic presentation of this phenomenon for number of parts short, Fig. 6 for duration of shortages.

Zero Balances and Dues-Out

The frequently-used percent of stocked items at zero balance (having no assets on hand) is a misleading performance measure. The existence of a zero balance is only undesirable when a demand encounters that zero balance, i.e., when there is an unfulfilled requirement. Over time, these unfulfilled needs may be measured by the time at zero balance and the percent of that time for which dues-out are recorded. These two measures are shown in Table 9. Table 9 suggests that demands upon the DSU may be encountering zero balance there up to 60 percent of the time, and that up to 96 percent of these cases have dues-out recorded during the zero balance time.

Table 7

INITIAL FILL PERFORMANCE, ADJUSTED OST STOCK LEVELS

Delivery time standard	Initial fill of	Interpretation of standard: Percent delivered within standard time 100	80	60	40	20	"base"
35 days	demands	75	74	70	67	64	62
45 days		74	72	70	67	62	62
35 days	quantity	69	67	65	62	59	59
45 days		71	67	64	63	60	59

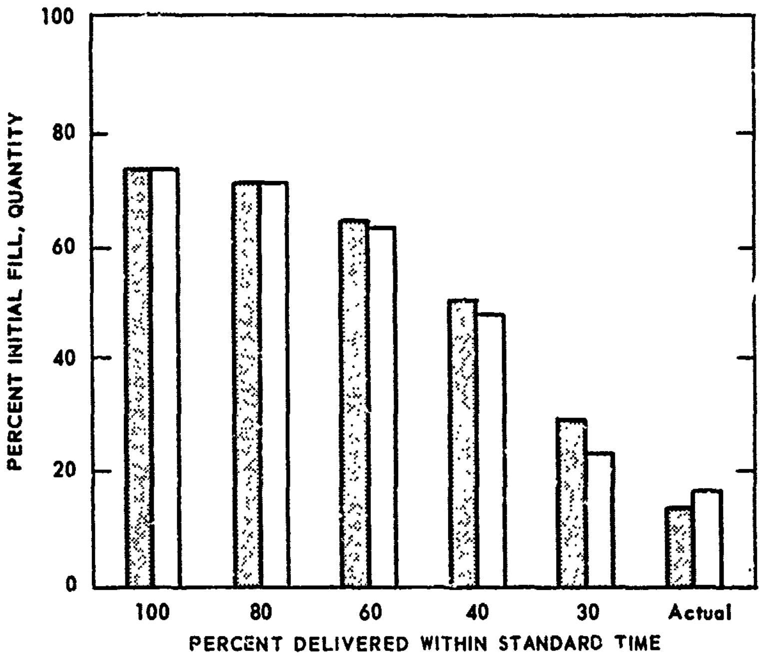

Fig. 3—DSU Initial Fill, OST Quantity Fixed at 35 and 45 Days, Respectively

Standard: 35 days 45 days

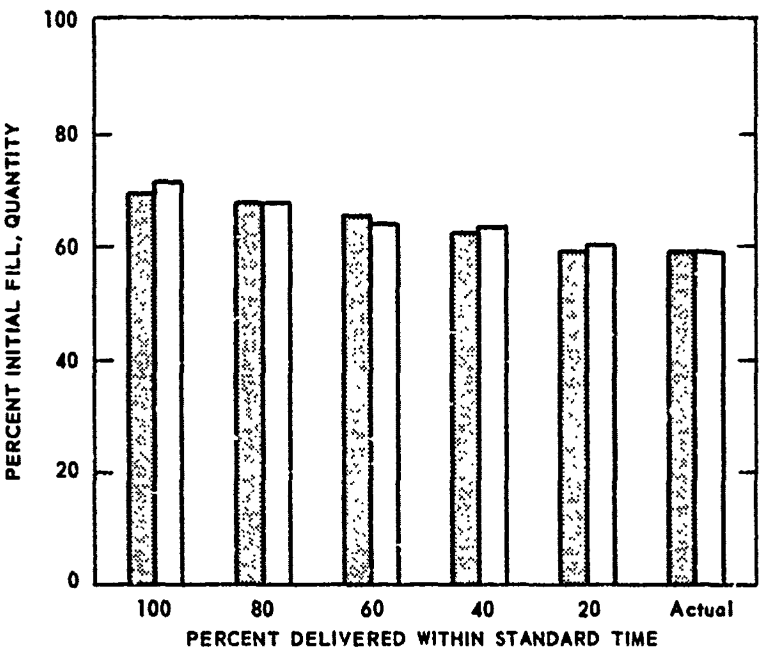

Fig. 4—DSU Initial Fill, OST Quantity Adjusted To Reflect Average OST for the Time Distribution Used

Standard: 35 days 45 days

Table 8

SHORTAGE STATISTICS

Delivery time standard (days)	OST stockage level type	Interpretation of standard: percent of requests delivered within standard time: 100	80	60	40	20	"base"
Number of parts short per year (thousands)							
35	fixed	166	176	221	300	415	525
45		162	179	206	308	445	488
35	adjusted	189	200	214	228	230	253
45		191	200	219	226	247	253
Part-days of shortage (millions)							
35	fixed	2.54	4.24	7.57	14.78	31.80	61.33
45		3.19	5.53	9.03	19.04	40.76	51.19
35	adjusted	2.86	4.61	7.52	12.37	19.73	28.60
45		3.57	5.54	9.90	15.56	25.91	28.60
Average duration of shortages (days)							
35	fixed	15	24	34	49	77	117
45		20	31	44	62	72	105
35	adjusted	15	23	35	54	86	113
45		19	28	45	69	105	113

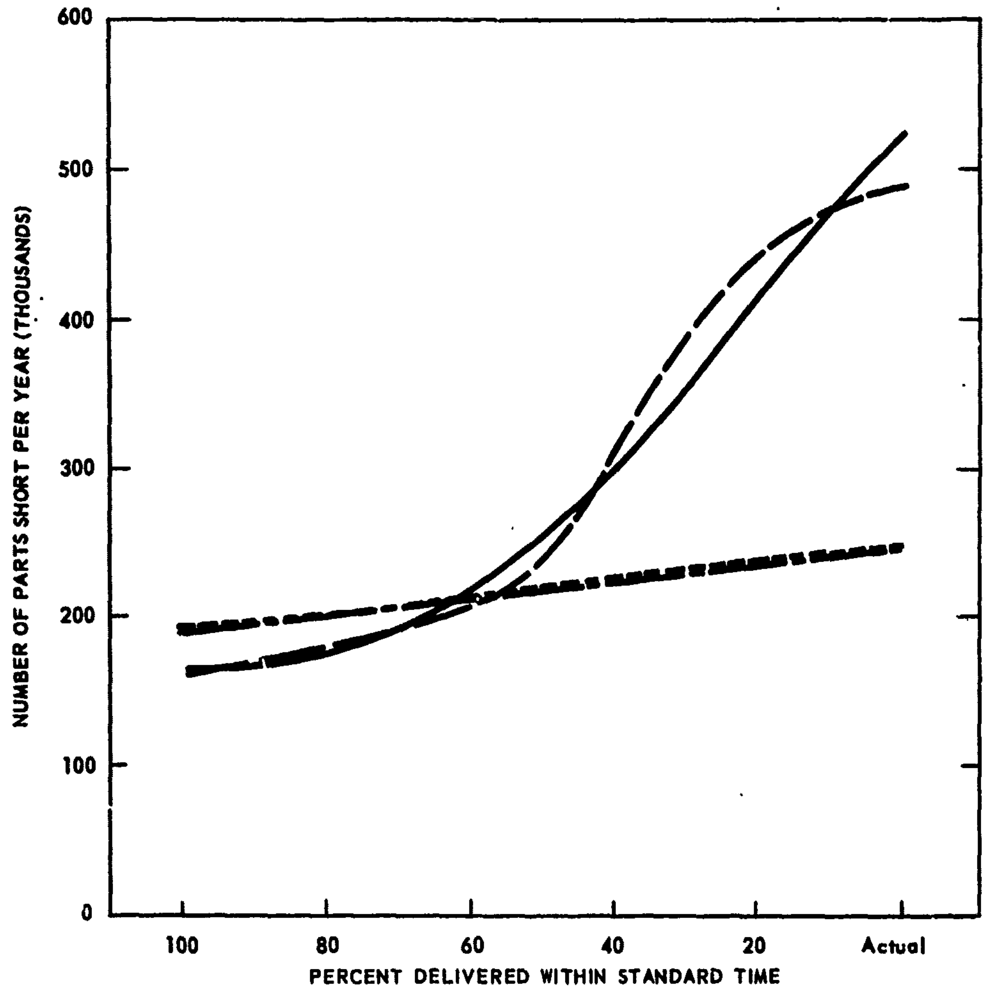

Fig. 5—Number of Parts Short per Year as Affected by OST

Fixed OST stock levels: ——— 35 days — — 45 days

Adjusted OST stock levels: ---- 35 days ——–45 days

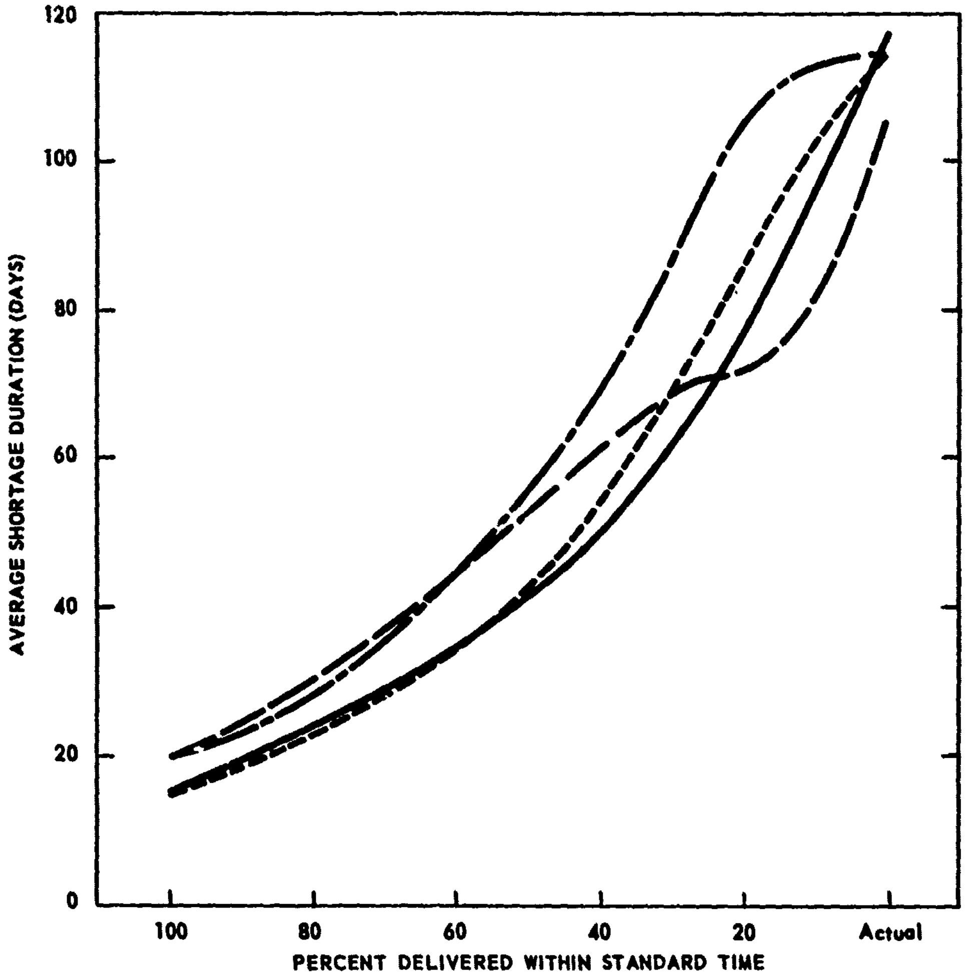

Fig. 6—Average Duration of Shortages as Affected by OST Achieved

Fixed OST stock levels: ——— 35 days — — 45 days
Adjusted OST stock levels: - - - 35 days —-—-45 days

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Table 9

ZERO BALANCES AND DUES-OUT

Delivery time standard (days)	Type of OST stockage level	Interpretation of standard — Percent delivered within standard time					
		100	80	60	40	20	"base"
Percent of time at zero balance							
35	fixed	2	4	10	22	41	60
45		3	6	13	26	50	58
35	adjusted	4	7	9	14	18	20
45		6	8	11	15	23	20
Percent of zero balance time during which dues-out are recorded							
35	fixed	89	91	93	94	96	96
45		88	88	89	92	94	94
35	adjusted	90	83	94	84	90	94
45		89	84	89	85	89	94

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By combining the two sections of Table 9, insight may be gained regarding the effects of long delivery time, as shown in Fig. 7. Once again it is clear that (a) performance is degraded substantially if fewer than 60 percent of the requisitions are completed within the standard time and (b) adjusted OST stockage levels can have a markedly beneficial effect if long delivery time is experienced.

WORKLOAD

Workload statistics normally derived from the SPSM simulation include such measures as the number of requisitions processed, average quantity per demand received or replenishment order sent, and number of replenishment orders per year. However, in this series of simulations, the input values that control the above measures are fixed, thus the results are quite stable across all runs. Therefore the following numbers are not given as a table. Demands received are controlled by the distributions for each class; a DSU receives about 105,000 demands per year for an average quantity of 6 per demand (regardless of the delivery time distribution). Similarly, since average replenishment order size and frequency are overwhelmingly controlled by the EOQ operating level, the number of annual orders hardly varies from the average 35,250, and the quantity per order averages 17.

<u>Workload Imposed by Inventory</u>

In lieu of major variations in the more conventional workload measures described above, the only remaining factor affecting workload is average inventory. Asset quantities on hand affect workload to the extent that they occupy space, consume load-carrying capacity, require accountability, and require control of issues and receipts. Thus it is of interest to examine the average quantities on hand as a function of delivery lag time.

Figure 8 is a plot of the weight and space consumption (cube) of the average quantities on hand, for each percent of fill within the standards. Note that the addition of more intransit assets by adjustment of OST stockage levels results in maintenance of relatively stable on-hand asset levels, regardless of delivery time. The rather severe drop in inventory in going from 60 to 40 percent fill within the standard reconfirms the degradation in fill performance for the same interval.

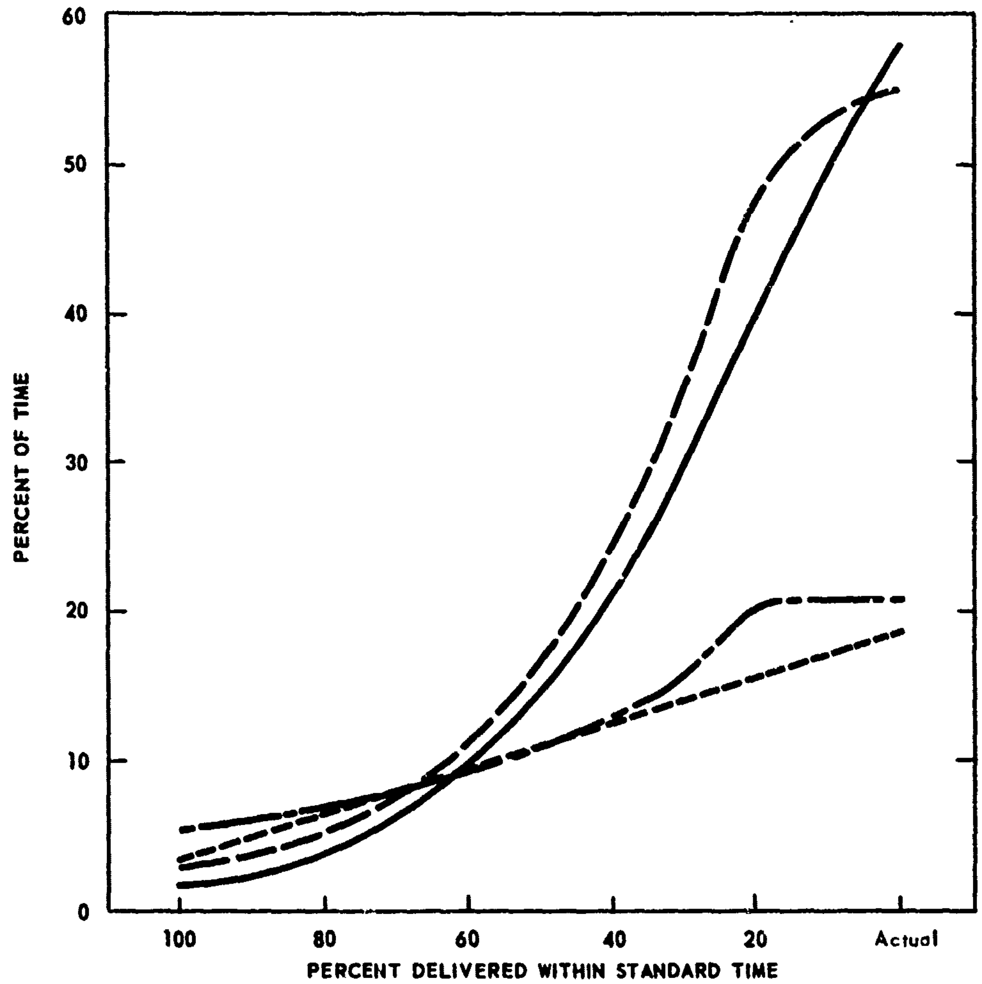

Fig. 7—Percent of Time at Zero Balance with Recorded Due-outs

Fixed OST stock levels: ——— 35 days — — 45 days

Adjusted OST stock levels: - - - - 35 days -——- 45 days

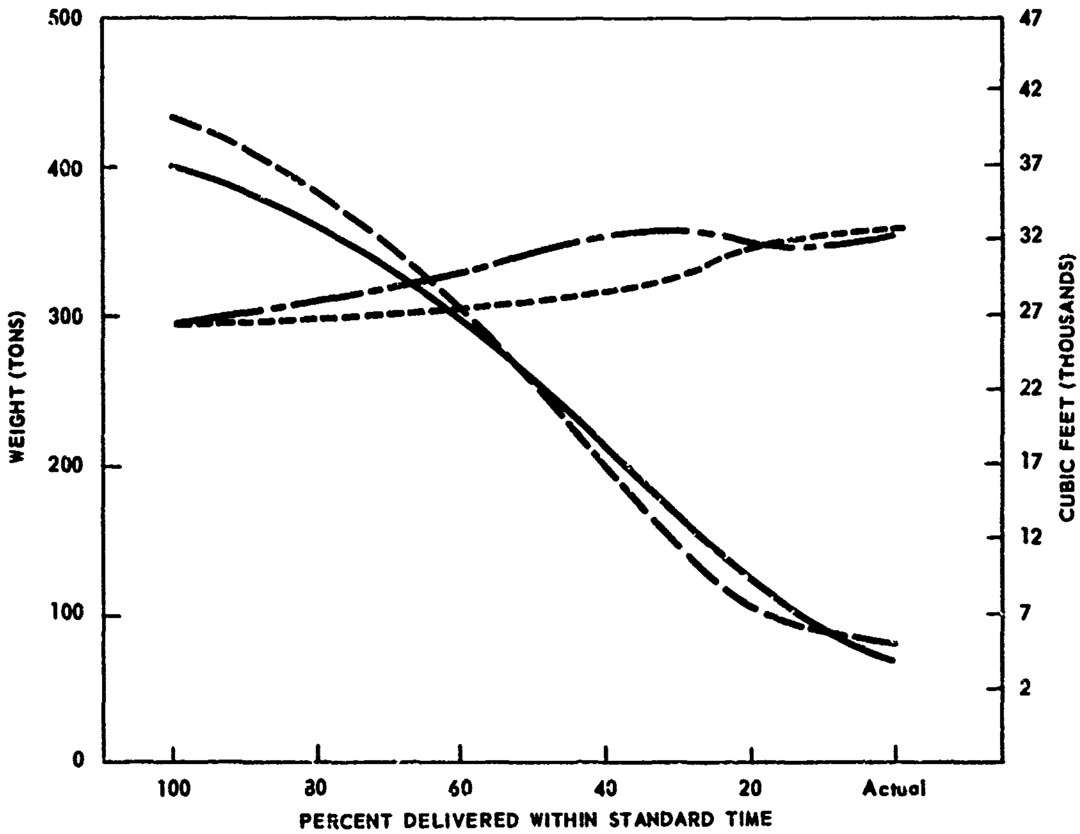

Fig. 8—Weight and Cube of Average Inventory on Hand at DSU

Fixed OST stock levels: ——— 35 days ——— 45 days

Adjusted OST stock levels: — — — 35 days —·—·— 45 days

COSTS

Inventory Investment

As with the workload measures, the cost measures normally associated with SPSM simulation output are inapplicable in this particular analysis. Costs associated with requisition processing, transportation, storage, and ordering are constant for all simulations. Therefore, inventory investment is used as the primary cost measure of varying delivery time. Though by no means a measure of total system cost, inventory investment does provide a readily available means of comparison.

Figure 9 plots dollar value of average inventory on hand as a function of OST. As with the weight and cube in Fig. 8, inventory value drops markedly when less than 60 percent fill within the standard is experienced (unless the stockage levels are adjusted to accommodate the longer fill times).

Pipeline Investment

Table 10 gives pipeline investment requirements of the adjusted OST levels used in the simulations. Pipeline cost as used here considers only the dollar value of intransit assets. It does not include the value of any assets on hand. Naturally, pipeline investment required increases considerably as delivery time increases. Thus, it is advantageous to strive for lasting reductions in OST.

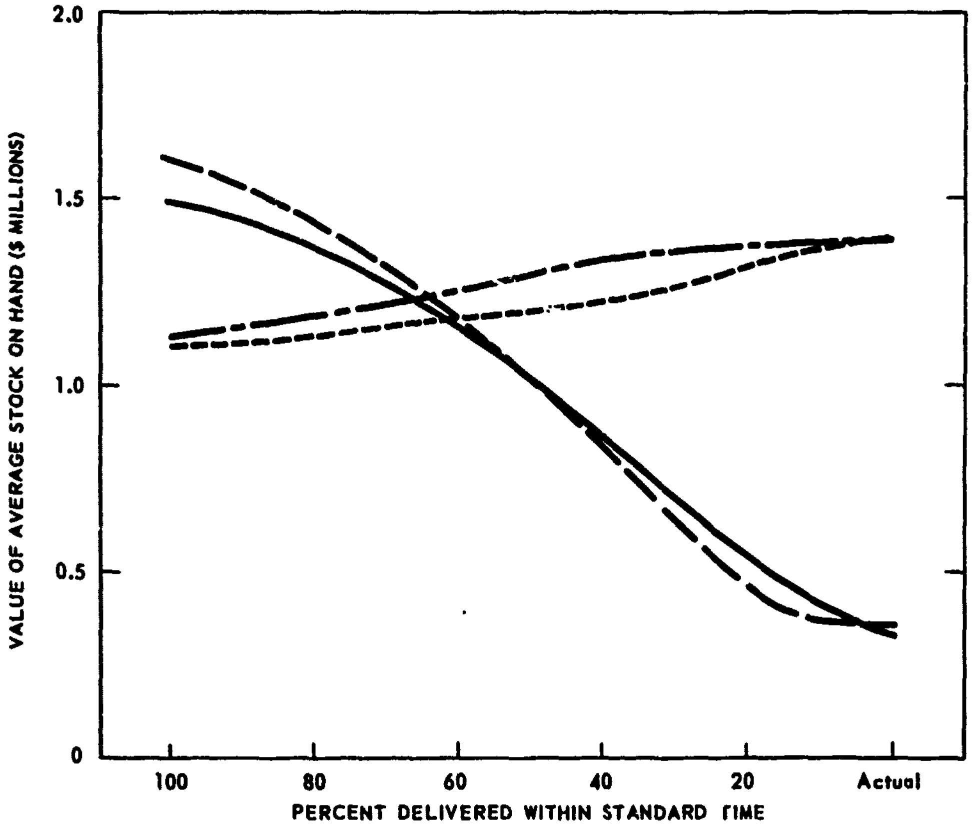

Fig. 9—DSU Inventory Value

Fixed OST stock levels: 35 days 45 days

Adjusted OST stock levels: 35 days 45 days

Table 10

INTRANSIT PIPELINE INVESTMENT
REQUIRED BY ADJUSTED STOCKAGE LEVELS

Percent filled within standard time	35-day standard		45-day standard	
	Adjusted OST[a] level (days)	Pipeline cost ($thous)	Adjusted OST[b] level (days)	Pipeline cost ($thous)
100	13	334	17	436
80	22	565	28	719
60	36	924	47	1206
40	60	1541	78	2002
20	101	2593	131	3363
"base"	151	3876	151	3876

[a]Fixed OST level of 35 days requires $898 thousand pipeline investment.

[b]Fixed OST level of 45 days requires $1155 thousand pipeline investment.

Chapter 3

SELECTION OF THE STANDARD

Ultimately, the interpretation of the 45-day standard will involve a tradeoff between performance achieved and the cost to attain it. By simulating DSU supply operations for different percentages of fill achieved within that standard, certain performance measures appeared to be most sensitive to the differences. These were dollar value of average inventory on hand, percent initial fill, number of parts short (annually), and percent of time at zero balance with recorded dues-out. These results are summarized in this chapter.

PERFORMANCE AND COST RELATIONSHIPS

Since the standard OST for fill from CONUS has been reset at 45 days, results herein are summarized only for the 45-day analysis. They are categorized two ways: (1) a fixed OST stockage level of 45 days, for each delivery time distribution used in the simulation, and (2) OST levels adjusted to reflect the average value of the delivery time distribution used. Fixed levels have been used extensively in the past. This often-conscious disregard of actual OST was perpetuated primarily because adjustment of OST level would mean increased fund commitments for the longer pipeline required. Cognizant of that fact, the Army has instructed all supply points (DSU and above) to use variable OST levels when computing requirements.[1] Such variability is generally based on experience for lines of like materiel category.

Performance vs Cost, Fixed Stockage Levels

The results of using a fixed OST of 45 days in computing stockage levels are shown in Table 11. For required total (pipeline plus inventory) investment and initial fill performance, the percent

Table 11

PERFORMANCE AND COST IMPLICATIONS OF 45-DAY STANDARD FOR FILL

OST STOCKAGE LEVELS FIXED AT 45 DAYS

Interpretation	Total investment required		Quantity initial fill		Annual parts short		Zero balance with recorded dues-out	
Cumulative percent filled within 45 days	$millions	Percent increase	Percent	Percent increase	Number (thous)	Percent decrease	Percent of days	Percent decrease
100	2.759		73		162		3	
		7		3		9		40
80	2.589		71		179		5	
		11		13		13		58
60	2.330		63		206		12	
		18		34		33		50
40	1.976		47		308		24	
		23		104		31		49
20	1.610		23		445		47	
		6		44		9		15
"base"	1.523		16		488		55	

increase derived is given for each 20 percent increment of increase in percent of requisitions completed within 45 days. For example, in improving responsiveness from 20 to 40 percent of requisitions filled within 45 days, a 23 percent increase in total investment is required, and an improvement of 104 percent in initial fill is derived. Percentage decreases in number of parts short and zero balances with dues-out are also given. In the above example, a decrease of 31 percent in parts short, and a decrease of 49 percent in time at zero balance with due-outs may be derived. The improvement in performance resulting from this 20 percent gain in response cannot overshadow the more important fact that very likely overall performance may still be unacceptably low. Perhaps the initial fill goal, for example, should be higher than 47 percent.

It is important, then, to consider the costs vs gains for 60 percent or more completions within the standard. In gaining the interval from 60 to 80 percent fill, an 11 percent increase in total investment "buys" 13 percent better initial fill, 13 percent fewer parts short, and a full 58 percent improvement (i.e., reduction) in average duration of zero balances. If the required reduction in actual delivery time can be achieved, it may well be worth the cost. Note that pipeline investment is fixed ($1.155 million, footnote b, Table 10), as the OST level is fixed at 45 days.

Performance vs Cost, Adjusted Stockage Levels

The percentage improvement in performance that may be derived from each (20 percentile) increment in responsiveness, assuming adjusted stockage levels, is given in Table 12.

Required total investment is least for 100 percent of fill within the standard time. The average value of the OST distribution that provides 100 percent fill within 45 days is only 17 days. The use of 17 days of pipeline results in fewer average assets on hand, thus lower inventory investment. Pipeline cost is similarly reduced as was shown in Table 10. That is, the faster the delivery time, the fewer on hand and intransit assets are required.

When Tables 11 and 12 are compared, it is clear that either fixed or adjusted levels will result in roughly equivalent performance if

Table 12

PERFORMANCE AND COST IMPLICATIONS OF 45-DAY STANDARD FOR FILL OST STOCKAGE LEVELS ADJUSTED TO MEAN VALUE OF OST

Interpretation	Total investment required		Quantity initial fill		Annual parts short		Zero balance with recorded dues-out	
Cumulative percent filled within 45 days	$millions	Percent decrease	Percent	Percent increase	Number (thous)	Percent decrease	Percent of days	Percent decrease
100	1.548		71		191		5	
80	1.903	19	67	6	200	5	7	29
60	2.454	22	64	5	219	9	10	30
40	3.346	27	63	2	226	3	13	23
20	4.704	29	60	5	247	9	20	35
"base"	5.274	11	59	2	253	2	19	5

60 percent or more of submitted requests can be filled within 45 days. The total cost advantage, however, is clearly a function of delivery time distribution assumed. Assuming very rapid fill (greater than 60 percent fill within 45 days), adjusted levels actually cost less than fixed. However, if that kind of rapid response cannot be achieved, then serious consideration must be given to the choice of a standard and to the selection of fixed vs adjusted stockage levels.

Where good performance is the primary objective, the adjusted levels have the advantage. Selection of the standard then becomes a question of what is achievable, as opposed to what is desirable. When cost is the primary consideration, and in the event that 60 percent or more is not achievable within 45 days, the fixed levels would be preferable. Average on hand inventory is lower, as would be inventory intransit. Naturally, decreased asset availability would have adverse effects on performance.

FINDING

In summary, every effort should be made to insure that at least 60 percent of requests submitted are filled within 45 days. In any case, stockage levels should be adjusted to reflect actual delivery time, now specified by policy.[1] This will result in monetary savings if delivery time is rapid and better performance if delivery time is poor. The standard itself can be selected on the basis of comparative data presented in Tables 11 and 12. It is suggested that less than 60 percent fill within 45 days may result in unacceptably poor performance; further, more than 80 percent, even if achievable, is probably not worth the mammoth task of maintaining such responsiveness over the long run.

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