AD-A105 480 ARMY INVENTORY RESEARCH OFFICE PHILADELPHIA PA F/G 5/1

TREATMENT OF SERVICEABLE RETURNS IN SUPPLY CONTROL STUDIES.(U)

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FINAL REPORT
IRO REPORT NO. 284

AD A105480

TREATMENT OF SERVICEABLE RETURNS IN SUPPLY CONTROL STUDIES

US ARMY DARCOM

U.S. ARMY

INVENTORY
RESEARCH
OFFICE

AUGUST 1981

ROOM 800
U.S. CUSTOM HOUSE
2nd and Chestnut Streets
Philadelphia Pa. 19106

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER IRO Report No. 284	2. GOVT ACCESSION NO. AD-A105	3. RECIPIENT'S CATALOG NUMBER 480
4. TITLE (and Subtitle) TREATMENT OF SERVICEABLE RETURNS IN SUPPLY CONTROL STUDIES		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) SALLY FRAZZA		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Inventory Research Office, ALMC Room 800, US Custom House 2nd & Chestnut Sts., Phila., PA 19106		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Materiel Development & Readiness Command 5001 Eisenhower Avenue Alexandria, VA 22333		12. REPORT DATE August 1981
		13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Information and data contained in this document are based on input available at the time of preparation. Because the results may be subject to change, this document should not be construed to represent the official position of the US Army Materiel Development & Readiness Command unless so stated.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Demand Forecasting
Supply Control
Inventory Models

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

Currently, because the forecast of serviceable returns is not trusted, the use of these returns as an offset to the demand forecast is limited. Various options for incorporating serviceable returns into the demand forecast were evaluated based on a cost/performance inventory measure. A forecast which offsets returns will cost less, but will also result in a lower supply performance. Our findings show that adjusting the demand forecast by returns has the same effect as not offsetting the demands with returns but lowering the

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) performance goal. In either case, the change in cost and the change in supply performance are virtually identical.

SUMMARY

1. Background

The Supply Control Study (SCS) is an application of the Commodity Command Standard System (CCSS) for which the average monthly demand (AMD) is computed for requirements forecasting. Data are passed from the demand, return, and disposal (DRD) process to the SCS, and the last two years of historical data are used to compute the AMD. Computation depends on item and CCSS parameters which vary by command, but essentially the AMD is the sum of recurring demand and a percentage of non-recurring demand, less serviceable returns.

2. Problem

The problem addressed in this report is determining the optimal treatment of serviceable returns in computing stock requirements. It appears obvious that serviceable returns should be accounted for in some way when determining requirements. Currently, because the forecast of these returns is not trusted, the serviceable return offset is limited to a maximum percentage of the total demand. This percentage tends to be set to a small value, and consequently there is a risk of overstatement of future requirements. A General Accounting Office (GAO) draft report estimates that had all the returned materiel been used to offset past demands in 1978, the Army could have avoided procurement and repair costs estimated at tens of millions of dollars [1].

3. Scope and Methods

This study is limited to serviceable returns for demand supported secondary items. Summary data were collected from two Materiel Readiness Commands (MRCs), Army Tank-Automotive Command (TACOM) and Army Missile Command (MICOM), to evaluate the magnitude of returns by calculating return/demand ratios by item. Similar statistics were compiled from the Inventory Research Office (IRO) demand-return history file for Army Troop Support & Aviation Materiel Readiness Command (TSARCOM) aviation items. Seasonal patterns, reasons for the returns, and spikes in the data were also investigated.

A new forecast evaluator based on a cost/performance inventory measure was used with the historical data to test various options for incorporating serviceable returns into the demand forecast.

4. Findings

Our statistics verify that return quantities are exceedingly large; in many instances returned quantities for an item exceed the item's average demand.

In addition, the behavior of returns is highly erratic, exhibiting large spikes and no visible trends over time. There is no apparent way to distinguish between returns which can be used to statistically forecast future returns and one time returns, which may occur for items undergoing a status change, or items coming from a closed installation.

Empirical work with a new forecast evaluator shows an imperceptible difference in cost/performance when serviceable returns are used to offset the demand forecast. This result holds regardless of the limit set on the percentage of demand forecast which can be offset by returns.

5. Conclusions

The enormous potential dollar savings cited by GAO is based on aggregate statistics, and assumes all serviceable returns can be used to satisfy future requirements. A returned quantity, in excess of the item's demand will not constitute savings against demand for another item. There is no guarantee that future demands will occur for an item with returns, and there is also no guarantee that returns imply a reduction in future demand.

Based on our empirical findings we conclude that using returns to offset demand history does not significantly improve the forecast of future net demands. A forecast which offsets returns will cost less, but will also result in a lower supply performance. Our findings show that adjusting the demand forecast by returns has the same effect as not offsetting the demands with returns but lowering the performance goal. In either case, the change in cost and the change in supply performance are virtually identical.

We are still interested in the reasons for high return quantities, specifically if reasons for the returns reveal their applicability to future demand. TACOM and TSARCOM have agreed to question their customers about reasons for unusually high turn-in quantities, and are currently collecting responses to questionnaires.

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CHAPTER I

SURVEYS OF RETURN DATA

1.1 Snapshot Return/Demand Ratios

IRO obtained data from TACOM and MICOM to make histograms of return/demand ratios. The data obtained were from the DRD Quarterly Budget Stratification Summary of September 1980. This file includes the recurring and non-recurring demand quantities and the serviceable and unserviceable return quantities. Figures used were from the prior fiscal year, since these were complete.

As of November 1980, the policy at TACOM was to include 100% of the non-recurring demand in their AMD computation. MICOM's policy was not to include any of the non-recurring demand, because they felt that coding errors overstate the recurring demand.

The maximum offset parameters for serviceable returns are 0 for TACOM and 20% for MICOM, which means that TACOM does not use serviceable returns and MICOM reduces demand quantities by at most 20%. These parameters can work at odds with the policies concerning non-recurring demand. MICOM is decreasing their AMD by excluding non-recurring demands, but increasing the AMD by having a small (20%) offset parameter. This is not a criticism, but added to point out the potential effect to the AMD of parameter juggling.

Table 1 contains some figures from the summary data we received from TACOM and MICOM to give an indication of the number of items studied and the demand and return quantities. Table 2 contains the percent of items in each ratio class. The ratio, R, equals the yearly return quantitiy divided by the yearly demand quantity. The six ratio classes are the following:

(1) $R \leq .1$
(2) $.1 < R \leq .5$
(3) $.5 < R \leq .75$
(4) $.75 < R \leq 1.$
(5) $1. < R \leq 5.$
(6) $5. < R$

Note that items in ratio classes 5 and 6 have more returns than demands.

Table 2 is based only on items with both demands and serviceable returns. Ratios for both TACOM and MICOM are based on a fraction of the total demand.

Although in practice MICOM does not include the non-recurring demand in their AMD computation, we did include it for our ratio computations. The effect is higher demand, hence conservative return/demand ratios.

Aggregate figures, such as those in Table 1, do not show the potential effect of returns on the AMD of an individual item. One item with a return quantity of 5 times the demand can swing the aggregate ratio way up. All of these returns should not, and are not used to offset the demand forecast. Table 2 results are indicative of the actual impact of returns. Although MICOM has lower aggregate ratios, they have more items in the higher ratio classes. Returns in these classes are less likely to be applicable to future demand.

TABLE 1

FIGURES FROM THE SUMMARY DATA

	TACOM		MICOM	
# ITEMS				
WITH DATA	35,158		25,936	
WITH DEMANDS ONLY	21,270	= 60%	15,907	= 61%
WITH RETURNS ONLY	974	= 3%	2,439	= 10%
WITH BOTH (ITEMS USED)	12,914	= 37%	7,590	= 29%
QUANTITIES (ALL ITEMS)				
RECURRING DEMAND	15,165,705		2,023,743	
NON-REC DEMAND	7,966,762		886,161	
TOTAL DEMAND	23,132,467		2,909,904	
SERVICEABLE RETURNS	1,677,808		172,766	
SERV-RETS/REC-DEMAND	11.1%		8.5%	
SERV-RETS/TOTAL DEMAND	7.3%		5.9%	
QUANTITIES (ITEMS USED)				
RECURRING DEMAND	11,912,078		1,377,146	
NON-REC DEMAND	5,406,423		489,063	
TOTAL DEMAND	17,318,501		1,866,209	
SERVICEABLE RETURNS	1,228,912		131,769	
SERV-RETS/REC-DEMAND	10.3%		9.6%	
SERV-RETS/TOTAL DEMAND	7.1%		7.1%	

TABLE 2

PERCENT OF ITEMS IN EACH RATIO CLASS

	TACOM	MICOM
$R \leq .1$	44	28
$.1 < R \leq .5$	33	40
$.5 < R \leq .75$	5	6
$.75 < R \leq 1$	5	10
$1 < R \leq 5$	10	13
$5 < R$	3	3
	100%	100%
# Items Used	12,914	7,590

1.2 Historical Return/Demand Ratios

The IRO demand history file of TSARCOM aviation items [2] was expanded to include serviceable returns. Program data are also included. The result is an 8 year history covering 1972 thru 1979, which contains 10,663 items which had both demands and returns during the 8 years.

The ratio analysis of the previous section was repeated for the 8 year data base of aviation items. The analysis was done separately for each two year period. Since only items with both demands and returns in the period were included, the number of items studied differs for each two year period.

The results are shown in Table 3, and are not inconsistent with the previous results for TACOM and MICOM. The results indicate a high percent of items with large ratios of return to demand.

Table 4 shows the percent yearly dollar return in each ratio class, with the total two year dollar return at the bottom, in millions. This result was not included for the snapshot data because the unit prices were not readily available.

The different time periods do not contain the same items, hence trends over the time period do not apply. The dollar return figures indicate that there was at least one huge return in 1972-73 which fell in the last ratio class.

Results for the other periods show similarities. The bulk of items fall consistently in the second ratio class. The overwhelming percentage of returns in the second and higher ratio classes indicate an inordinate quantity of returns, and for all the time periods at least 20% of the items have more returns than demands.

1.3 Seasonal View of the History Data

The remaining results are based on a random sample of 3627 items from the TSARCOM 8 year data base. Graph I and Table 5 display the data by quarter. The table is arranged by quarters across, so that each line is one year. Similar quarters for each year line up in columns. Two sets of column totals appear, the first for the entire 8 years, the second for the last 4 years only.

Graphs II thru V show returns for 1976 thru 1979 broken down by month. A potential problem with looking for trends in this data is the ambiguity surrounding the date. The date used is the document date from the DRD, which is the date the MRC receives report of excess from the customer. After this, a reply is established depending on the inventory position at the MRC. The receipt of materiel need not come in for 120 days from CONUS, 180 from Europe. Credit for returns is not received until after the materiel receipt has been recorded, which could be another 60-90 days later.

1.4 Reasons for the Returns

Presumably, the customer does not know at the time of reporting excess whether he will receive credit for a return, since credit depends on the inventory position at the MRC. A scan of 1000 advice codes on the 1979 DRD file revealed 16.5% for credit, 79% for no credit, and 4.5% with no code. Results tabulated in a report by the Defense Audit Service for all five Army MRCs for January 1 thru September 30, 1979 average about 55% for no credit [3]. At any rate, it does not seem likely that a large quantity of returns are motivated by the credit received for them.

Although advice codes exist to encompass many reasons for returns, the only codes in use are the excess codes: return of creditable excess and return of non-creditable excess. Currently an investigation is underway at TSARCOM and TACOM to question the field concerning their reasons for unusually high return quantities.

TABLE 3

PERCENT OF ITEMS IN EACH RATIO CLASS

	72-73	73-74	74-75	75-76	76-77	77-78	78-79
$R \leq .1$	12	9	9	9	10	15	19
$.1 < R \leq .5$	35	31	37	36	38	41	42
$.5 < R \leq .75$	10	10	10	10	10	10	8
$.75 < R \leq 1$	11	11	10	11	11	11	10
$1 < R \leq 5$	25	29	25	25	24	18	17
$5 < R$	7	10	9	9	7	5	4
	100%	100%	100%	100%	100%	100%	100%
# Items Used	6635	6332	5936	6151	6101	5084	4055

TABLE 4

PERCENT OF YEARLY $ RETURN IN EACH RATIO CLASS

	72-73	73-74	74-75	75-76	76-77	77-78	78-79
$R \leq .1$	3	6	5	8	7	13	19
$.1 < R \leq .5$	11	51	61	53	56	50	39
$.5 < R \leq .75$	2	15	9	7	10	8	10
$.75 < R \leq 1$	2	7	4	5	6	8	8
$1 < R \leq 5$	3	14	16	16	14	17	16
$5 < R$	79	7	5	11	7	4	8
	100%	100%	100%	100%	100%	100%	100%
Total $ return in millions	147.4	38.0	32.5	31.5	29.9	20.5	21.1

GRAPH I: QUARTERLY RETURNS IN THOUSANDS FOR SAMPLE OF 3627 ITEMS

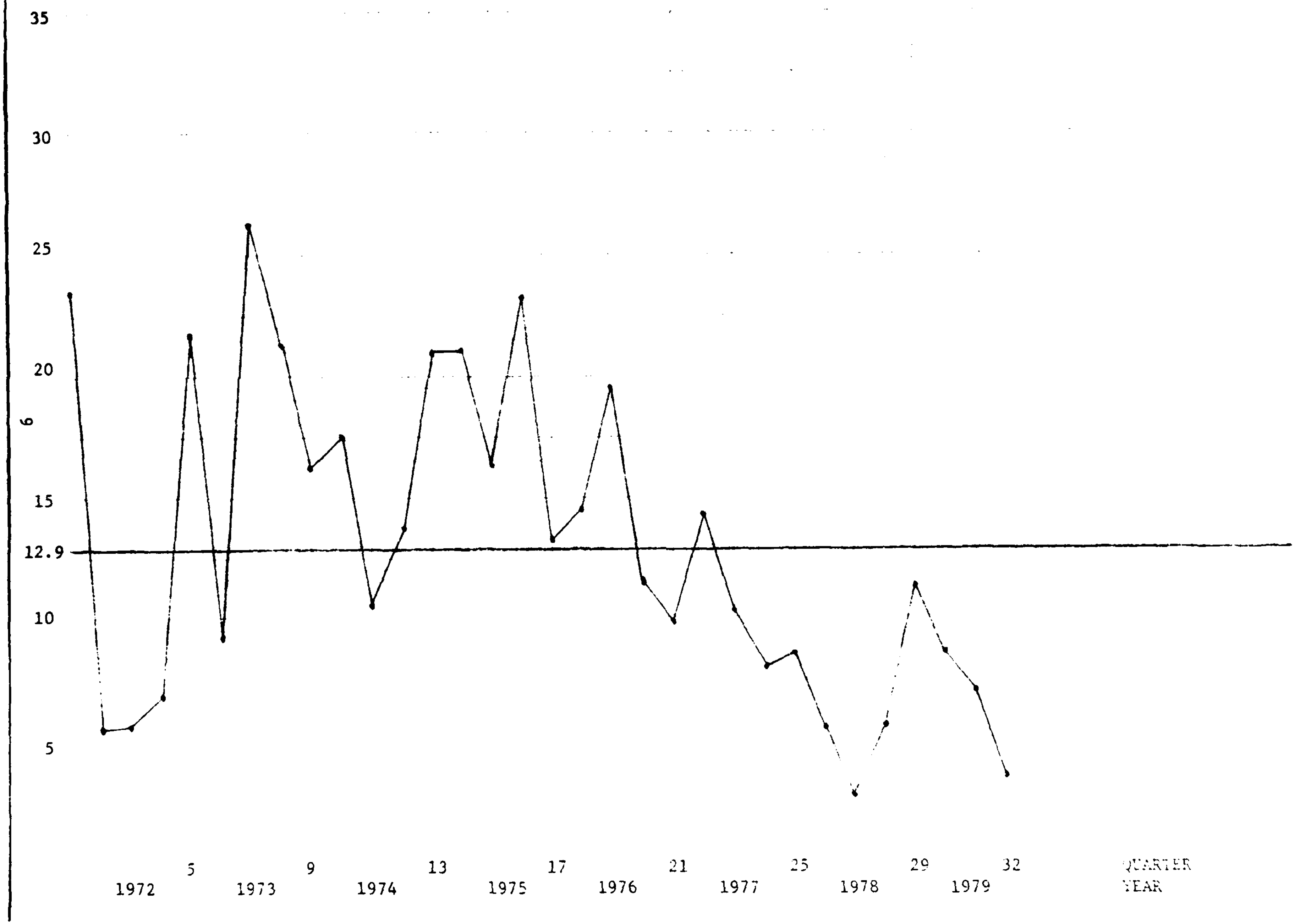


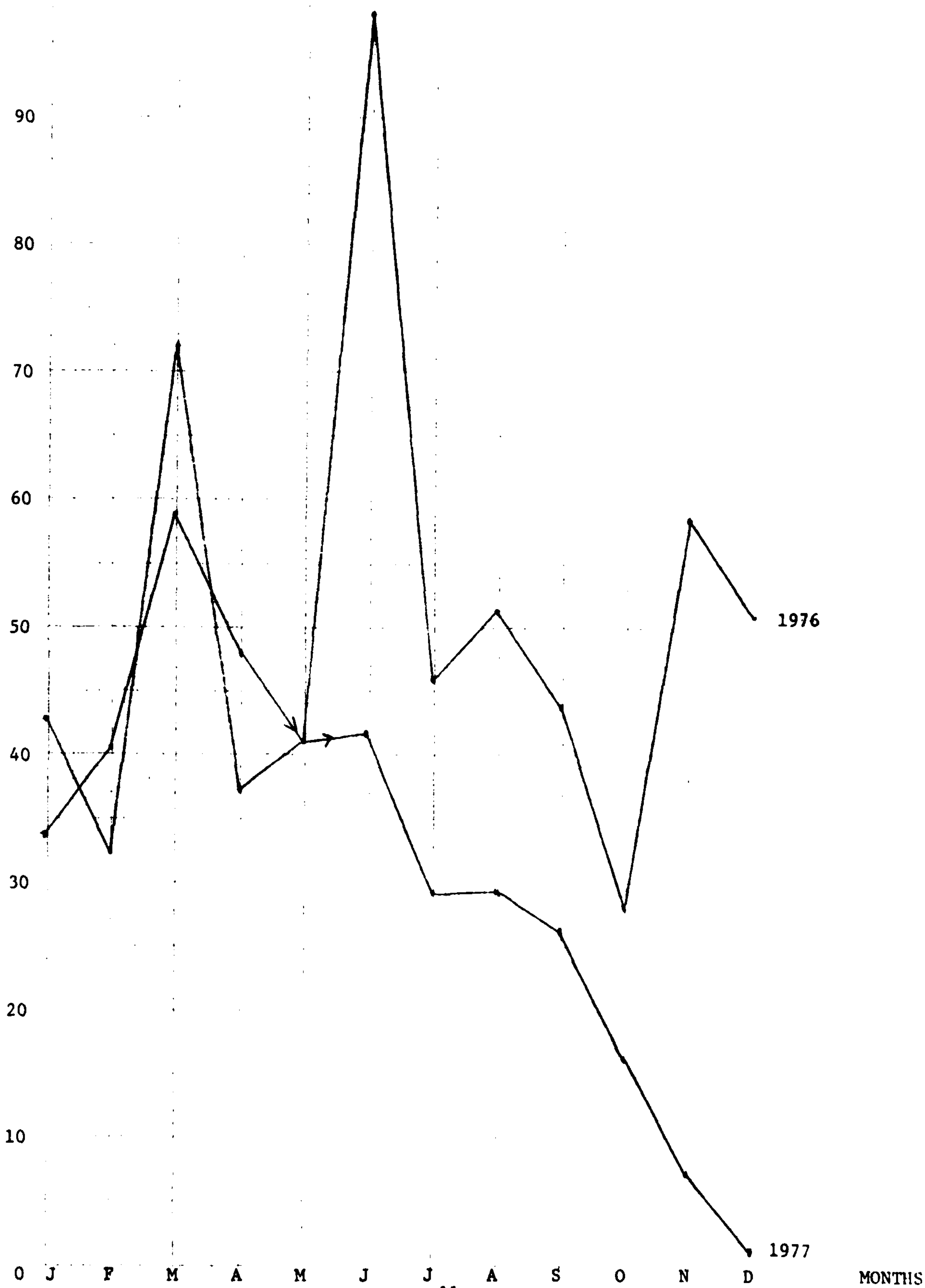
TABLE 5

QUARTERLY RETURNS FOR 32 QUARTERS (1972 - 1979) FOR SAMPLE OF 3627 ITEMS

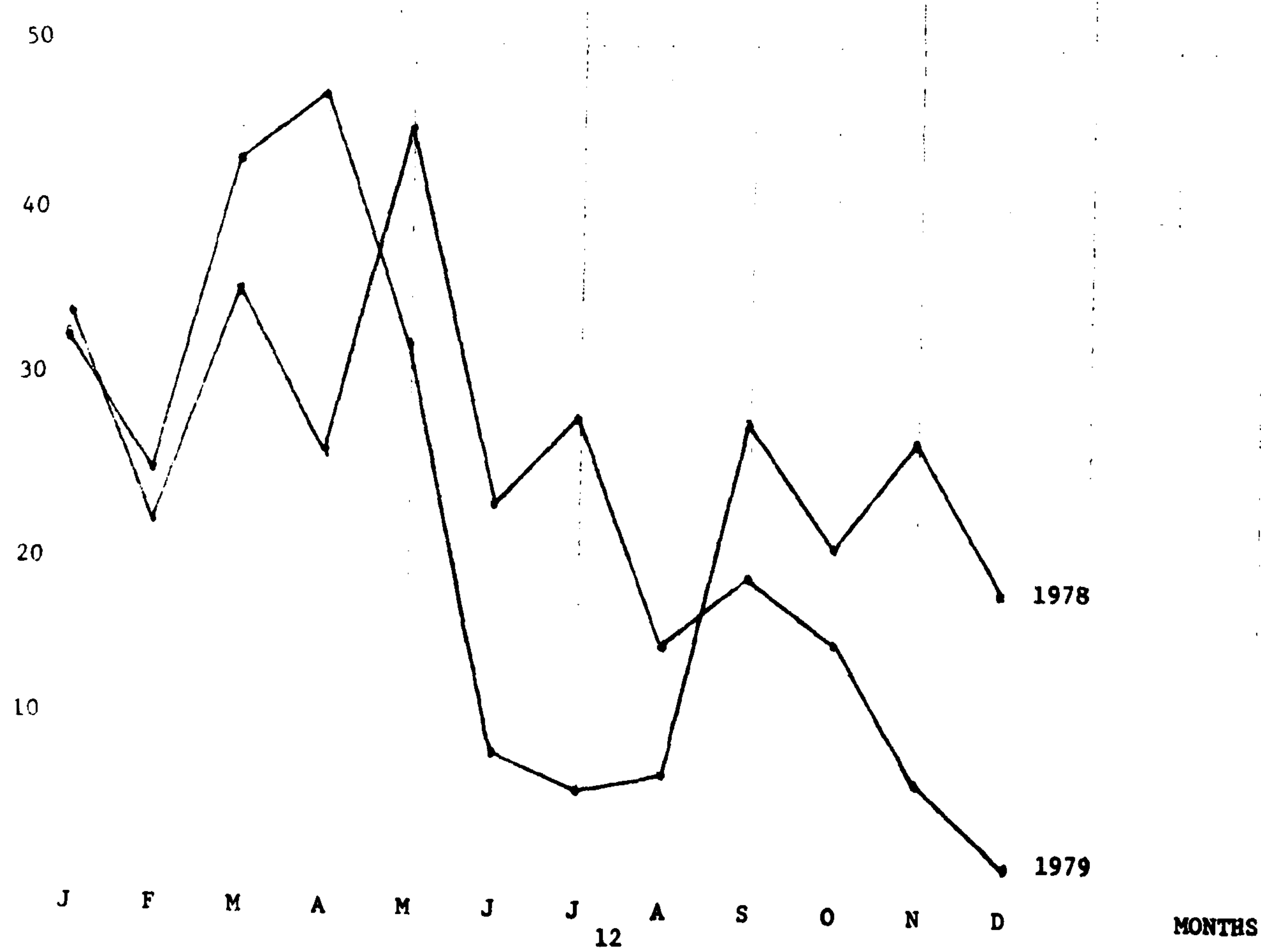
QTR	RETURNS	QTR	RETURNS	QTR	RETURNS	QTR	RETURNS
1	23,674	2	5,346	3	5,580	4	6,821
5	21,690	6	9,220	7	26,256	8	21,303
9	16,227	10	17,495	11	10,411	12	13,802
13	21,009	14	21,011	15	16,368	16	23,209
17	13,369	18	14,611	19	19,568	20	11,473
21	9,913	22	14,322	23	10,441	24	8,068
25	8,377	26	5,525	27	2,863	28	5,581
29	11,557	30	8,682	31	7,059	32	3,487
Grand Total	125,816		96,212		98,546		93,744
Total of last 4 qtrs	43,216		43,140		39,931		28,609

Note: The average quarterly return for the 8 yr period is 12,947 = 414,318/32

GRAPHS II & III: MONTHLY SERVICEABLE RETURNS IN HUNDREDS (AVSCOM DRD DATA)



GRAPHS IV & V: MONTHLY SERVICEABLE RETURNS IN HUNDREDS (AVSCOM DRD DATA)



1.5 Spikes in the Returns

We were deterred from developing a more sophisticated method for forecasting returns by the proliferation of spikes in the aviation data. Of the 3627 items, 94% of them showed at least one spike in the 8 year time period. A spike was defined as a quarterly return quantity greater than three standard deviations from the mean, where the mean was the average quarterly return quantity over 8 years. Of the spikes found, 40% were between three and four standard deviations, 30% were between four and five, and 30% were greater than five.

The same procedure run for the last two years of quarterly data, with the mean taken to be the average over the last two years, showed 34% of the items with at least one spike.

CHAPTER II

EVALUATION OF FORECASTS

2.1 Methodology

The 3627 item data base described in Chapter I was used to evaluate forecast methods. For each of the items in the data base a forecast and evaluation were made for each time period of available data. Statistics were accumulated over all the forecasts to determine cost and performance measures for a given forecast method. Cost/performance points determined for a few discrete safety levels were used to extrapolate costs for intermediate performance levels and the costs of achieving equal performance with alternative forecast methods were compared.

2.2 Forecast and Evaluation

The forecast algorithm used was the 1794, currently in use in the Army Inventory System [4]. A description of the model and error evaluation is included in Appendix A.

The forecast methods evaluated vary by the extent to which serviceable returns are used to offset the demand forecast. Each series to be forecast was adjusted quarterly.

Let D = demand in quarter

R = return in quarter

M = maximum offset parameter, $0 \leq M \leq 1$

Adjusted demand = D-min (R,M·D)

At the time of a demand from the adjusted series, a forecast was made for a procurement lead time (PLT). The "actual" series used to evaluate the forecast was D-R over the PLT. This value was constrained to be non-negative.

Also evaluated was a policy of using returns to offset the demand forecast only if the returns fell within a reasonable range of the average of returns for the item. For each quarter, the sample mean and standard deviation of returns were computed based on the preceding two years of data. If the quarterly returns exceeded three standard deviations of the mean, we call them spikes and they were ignored. Otherwise they were netted out to the applicable maximum percent (M·D).

2.3 Performance and Cost Measures

The performance measure is an estimate of the total number of requisitions not satisfied. Each time an underforecast is made the portion of requisitions in the period not satisfied by the forecast is accumulated and finally taken as a percentage of all the requisitions.

Let D_{ij} = demands

R_{ij} = returns

RQ_{ij} = demand requisitions

F_{ij} = forecast + safety level (See Appendix A)

A_{ij} = actual = max $(D_{ij} - R_{ij}, 0)$

For all variables, the subscripts i,j designate the i^{th} item, the j^{th} forecast period.

Then

$$\text{Poor performance} = \frac{\sum_i \left(\sum_j \frac{\max(A_{ij}-F_{ij},0) \cdot RQ_{ij}}{A_{ij}} \right)}{\sum_i \left(\sum_j RQ_{ij} \right)}$$

Another way of stating performance is that it is the underforecast weighted by requisitions. This equals the requisitions short when order sizes are sufficiently small so that the forecast satisfies the same proportion of requisitions as it does of demand. For example, assume demand is ten and the forecast is four. If the demand is five requisitions for two each then 60% of the requisitions are not satisfied. If the demand is two requisitions for five each then none of the requisitions are satisfied. In both cases the performance measure is 60%.

The cost was accumulated as the total dollars spent on forecast and safety level.

Let F_{ij} = forecast + safety level for i^{th} item, j^{th} forecast period

UP_i = unit price for i^{th} item

N_i = number of forecasts for i^{th} item.

Then

$$\text{Cost} = \sum_i \sum_j \frac{F_{ij} \cdot UP_i}{N_i}$$

2.4 Evaluation Technique

Evaluation was made by comparing the relative costs of various performance levels. The best forecast method is the one which will provide a given performance level for the least cost.

Our evaluation technique relies on determining the cost for any desired performance level. The safety level is included in our total forecast, F_{ij}, as a control knob to produce different performance levels for the same forecast method. Negative safety levels are included.

The safety level computation depends on the shortage cost parameter λ (lambda). The larger the λ value, the more cost attributed to requisitions short and the more safety level required to minimize the cost. In turn, the more safety level, the more dollars required. By varying λ we produce different sets of cost and performance measures. The details of the safety level computation and an alternate way of looking at the evaluation technique are included in Appendix B.

From the cost/performance points computed for a few discrete λ values, and hence safety levels, intermediate points can be extrapolated to draw a continuous curve of cost versus poor performance, and the cost of any performance level can be read off the curve. Curves closer to the axes indicate better performing forecast methods.

Previous work using this evaluation technique [5,6] compared the relative position of curves drawn for all the forecast methods to be evaluated. In this work, there was so little difference between different forecast methods that a more quantitative technique was employed. A continuous curve was drawn for the base forecast method of forecasting on demand alone (no use of return data). Discrete cost/performance points were generated for the alternate forecast methods, and the costs compared with the cost of achieving the same performance with the base.

2.5 Forecasts Evaluated

Six policies were tested against a base policy of forecasting using demands alone.

a. Net out a maximum of 80% demand.

b. Net out a maximum of 20% demand.

c. Net out a maximum of 100% demand, leaving at least 1 demand.

d. Same as a, excluding spikes.

e. Same as b, excluding spikes.

f. Same as c, excluding spikes.

These policies correspond to having a maximum offset parameter, M, of .80, .20, and 1. For M=1, a minimum of 1 demand was retained.

2.6 Results

Graph VI shows the results of six points for policy a. relative to a base of forecasting on demand alone. To quantify the graphical evaluation, a cost/performance curve continuous over the entire range of safety levels was drawn for the base. The costs of the alternate policies for a few discrete safety levels were compared with the base cost. The results range from .2% to 1.8% improvement in cost, as detailed in Table 6.

These cost differences are insignificant relative to the precision of the evaluation methodology. Two "equal" performance measures could differ by as much as .8% and could generate costs (for the same policy) which differ by as much as .3%. For linear curves in the range of error, the graphical evaluation could be off by over 1%.

GRAPH VI: COST/PERFORMANCE CURVE FOR BASE POLICY X's Indicate 1st 6 Points in Table 6

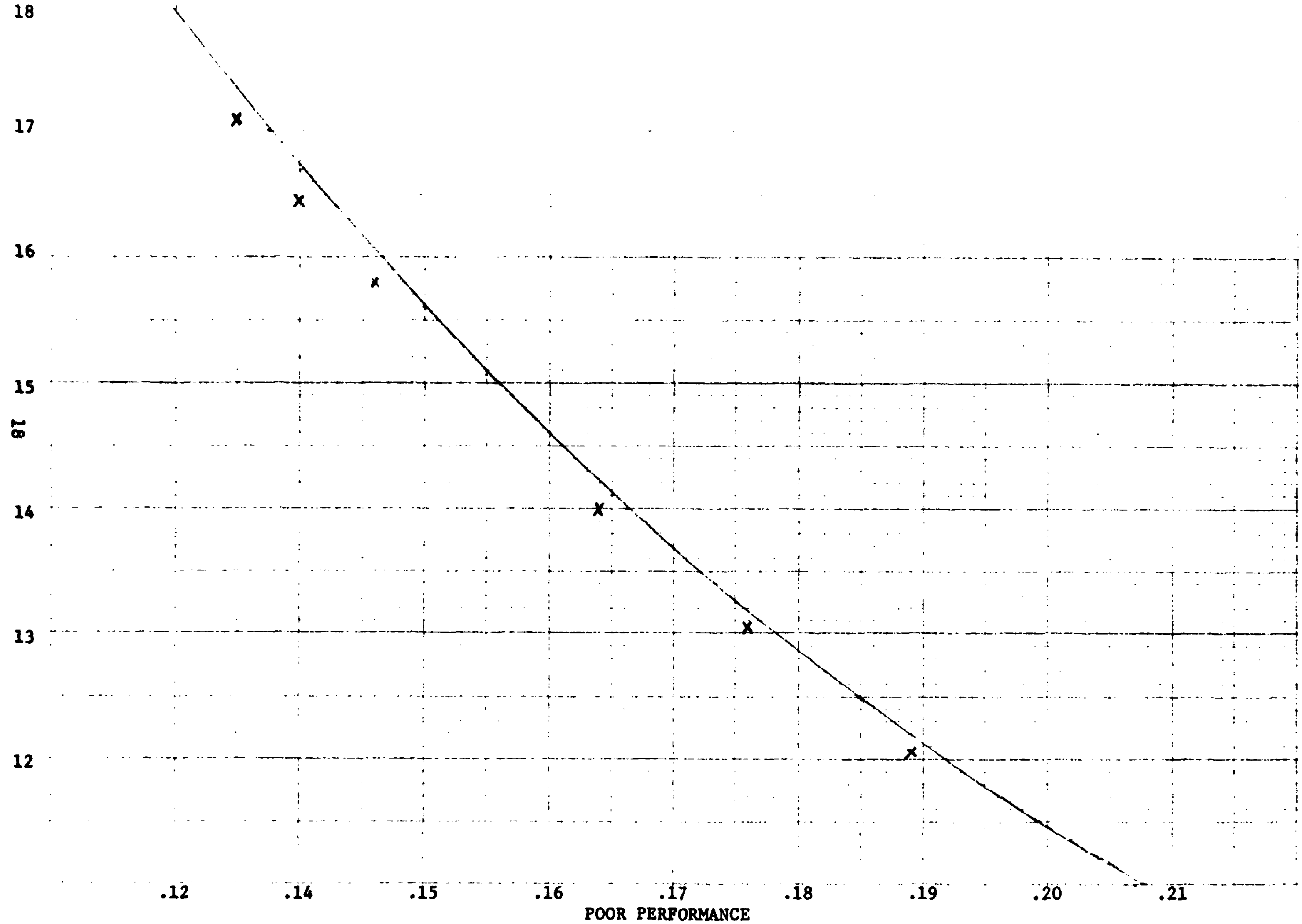


TABLE 6

COMPARISON OF COST OF POLICIES a, b, c

	Performance	Cost of Base	Cost to Net	% Savings
Policy a	.135	17.3	17.1	1.2
(M = .80)	.140	16.7	16.45	1.5
	.146	16.0	15.8	1.25
	.164	14.15	14.0	1.1
	.176	13.25	13.05	1.5
	.189	12.25	12.05	1.6
	.207	11.0	10.8	1.8
	.229	9.65	9.6	.5
	.248	8.75	8.6	1.7
	.276	7.65	7.55	1.3

Note: Policy a was tested for 10 performance levels.

	Performance	Cost of Base	Cost to Net	% Savings
Policy b	.298	7.0	6.9	1.4
(M = .20)	.216	10.4	10.3	1.0
	.195	11.8	11.7	.8
	.123	18.9	18.7	1.1
Policy c	.379	5.3	5.21	1.7
(M = 1.00)	.229	9.65	9.63	.2
	.164	14.15	14.05	.7
	.135	17.30	17.22	.5

TABLE 6 (CONT)

COMPARISON OF COSTS FOR POLICIES d, e, f (SPIKES EXCLUDED)

	Performance	Cost of Base	Cost to Net	% Savings
Policy d	.307	6.75	6.65	1.5
(M = .80)	.223	9.95	9.87	.8
	.202	11.30	11.13	1.5
	.131	17.80	17.65	1.7
Policy e	.296	7.05	6.97	1.1
(M = .20)	.214	10.53	10.43	.9
	.193	11.95	11.77	1.5
	.122	19.10	18.84	1.4
Policy f	.307	6.75	6.67	1.2
(M = 1.00)	.223	9.95	9.91	.4
	.202	11.30	11.18	1.1
	.131	17.80	17.74	.3

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APPENDIX A

FORECAST MODEL & ERROR EVALUATION

D_j = demand quantity for quarter j

R_j = return quantity for quarter j

H_j = program (flying hours) for quarter j

Q_i = forecast for quarter i

P_i = PLT forecast, starting in quarter i

PLT = procurement lead time in quarters

M = maximum offset parameter
(maximum percent by which demand may be offset by returns)

$$S_j = (D_j - \min (R_j, M \cdot D_j)$$

$$Q_i = \frac{\sum_{j=i-8}^{i-1} S_j}{\sum_{j=i-8}^{i-1} H_j}$$

$$P_i = \sum_{j=1}^{PLT} Q_i \cdot H_{i+j-1}$$

$DPLT_i$ = demand in PLT starting quarter i

$RPLT_i$ = return in PLT starting quarter i

Forecast = max (P_i,0) + variable safety level

Actual = max ($DPLT_i$ - $RPLT_i$,0)

Error = Forecast - Actual

APPENDIX B

SAFETY LEVEL COMPUTATION

The safety level computation is based on minimizing the following cost expression:

$$\text{Total Cost (TC)} = UP \cdot R + \frac{\lambda}{S} \sum_{X=R}^{\infty} (X-R)f(X)$$

where UP = unit price
R = stockage quantity
λ = cost of a shortage
S = order size
X = demand
f(X) = probability demand is X

By algebra:

$$TC(R-1) - TC(R) = -UP + \frac{\lambda}{S} \sum_{X=R}^{\infty} [(X-R-1)f(X) - (X-R)f(X)]$$

$$= -UP + \frac{\lambda}{S} \sum_{X=R}^{\infty} f(X)$$

$$= -UP + \frac{\lambda}{S}(1-F(R-1))$$

where F(X) = probability demand $\leq$ X

We want to find R such that

$$TC(R-1) - TC(R) \geq 0 \geq TC(R) - TC(R+1).$$

Substituting in our previous expression:

$$-UP + \frac{\lambda}{S}(1-F(R-1)) \geq 0 \geq -UP + \frac{\lambda}{S}(1-F(R))$$

$$1 - F(R-1) \geq \frac{UP \cdot S}{\lambda} \geq 1 - F(R)$$

To solve for R we use a binary search from - (PLT demand) to + (2 standard deviations of PLT demand). The PLT demand is the forecast described in

Appendix A (without the safety level).

Safety level = R - PLT demand

The R in this appendix is equivalent to the F_{ij} in the description of the cost and performance measures. Another way of viewing the evaluation is as the accumulation of the results of solving a succession of single period problems. Each problem corresponds to one forecast, and the results are summed over all the items (i's) and all the forecasts (j's).

Each problem is to find the stock level, R, such that the cost of procuring R units, (UP·R), plus the cost of shortages having procured R, $(\frac{\lambda}{S} \sum_{X=R}^{\infty} (X-R)f(X))$ is minimized. $\frac{\lambda}{S}$ represents the shortage cost in terms of units. $\sum_{X=R}^{\infty} (X-R)f(X)$ is an expression for the expected value of X-R when $X \geq R$, which is the expected value of units short. A negative binomial distribution of demand was assumed.

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