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RETAIL STOCKAGE POLICY UNDER BUDGET CONSTRAINTS.(U)
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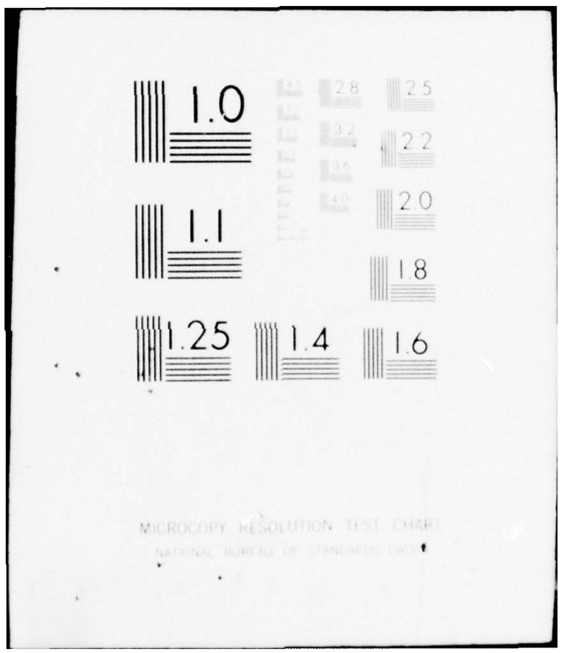
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FINAL REPORT
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RETAIL STOCKAGE POLICY UNDER BUDGET CONSTRAINTS

US ARMY
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INVENTORY
RESEARCH
OFFICE

June 1977

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

RETAIL STOCKAGE POLICY UNDER BUDGET CONSTRAINTS

FINAL REPORT

BY

ALAN J. KAPLAN

JUNE 1977

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

Retail level units are subject to budgetary constraints when they order support items. At the same time, the stockage policies under which they operate do not attempt to relate stockage quantities to funds available. This study found that cutting reorder points was substantially more cost/effective than cutting operating levels in that there is a smaller impact on fill rates for each dollar cut. Modifying stockage list retention criteria worked very well for one DSU unit, and very poorly for another, and therefore could not be recommended generally despite its potential.

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(ABSTRACT CONT)

In doing the study a Budget/Performance Evaluator (B/PE) was programmed. This is a computer program which can project budgetary requirements and fill rates for any retail unit, using input data about each item managed and the stockage policies to be followed. The input data is the same data needed for day to day management of the items. The B/PE differs from comparable programs already available in that it was designed to be accurate over the short term (e.g. 3 to 6 months).

SUMMARY

Retail level units are subject to budgetary constraints when they order support items. At the same time, the stockage policies under which they operate do not attempt to relate stockage quantities to funds available. Headquarters, Department of the Army requested that this study be performed to find out how to best modify current stockage policies when necessary to conserve funds.

It was found that cutting reorder points was substantially more cost/effective than cutting operating levels in that there is a smaller impact on fill rates for each dollar cut. The explanation is that under the Economic Order Quantity rules followed by Direct Support Units, operating levels days are already small on the higher dollar items where most of the dollar savings must be obtained.

It was also found that high priority items could be exempted from cuts in stockage levels without seriously impacting on the total savings which could be achieved.

In doing the study a Budget/Performance Evaluator (B/PE) was programmed. This is a computer program which can project budgetary requirements and fill rates for any retail unit, using input data about each item managed and the stockage policies to be followed. The input data is the same data needed for day to day management of the items. The B/PE differs from comparable programs already available in that it was designed to be accurate over the short term (e.g. 3 to 6 months).

The B/PE may have future use to provide tailored guidance to specific units. For example, it was found that modifying stockage list retention criteria worked very well for one DSU unit, and very poorly for another, and therefore could not be recommended generally despite its potential.

ACKNOWLEDGEMENT

Mr. Walter Belknap was project sponsor. He played the major role in problem definition, provided guidance as questions arose during the research, and assisted in the presentation of results. Mr. Thomas Beck was mainly responsible for the data base used, for transmitting it to us, and for guiding us in its use. Irving Klinger answered many of our questions concerning the details of the retail inventory systems. Mark Prestoy developed a computer simulation used. Robert Schraidt, COL Hugh Scott, Dennis Zimmerman, Richard McNertney, Martin Cohen, Bernard Rosenman, Donald Orr, Steven Gajdalo and W. Karl Kruse were all of assistance in various aspects of the work.

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CHAPTER I

INTRODUCTION

1.1 Background

Retail level units of the US Army order supply items (e.g., repair parts) subject to budgetary constraints. At the same time, the stockage policies under which they operate, in AR 710-2, do not attempt to relate stockage quantities to funds available, nor is there a systematic way prescribed to modify these stockage policies when necessary to conserve money. In the past, guidance given by Headquarters, Department of the Army to the Major Commands during periods of fiscal constraint has not been specifically designed to minimize impact on supply performance or operational readiness.

The US Navy does have a sophisticated mechanism available for resetting policy parameters of major field supply units to adjust to available funds both on an annual and on a quarterly basis [3, 5, 8]. Use of this mechanism by field units is not mandatory. For the annual resettings, a flow of information is involved:

DATA

UNIT — EVALUATION AGENCY

PARAMETER SETTINGS

The evaluation agency is the Naval Fleet Materiel Support Office. Some 30 Navy field units have a capability to do their own analysis for quarterly adjustments, employing a simplified version of the computer program used by Navy Fleet Materiel Support Office.

1.2 Objectives

The immediate objective of the effort described in this report was to develop an effective policy for modifying retail stockage quantities to conserve funds. If successful, the policy would be implemented in AR 710-2. It should not require significant new capabilities at the retail level, nor rely on a flow of information as depicted for the Navy.

The criteria for a successful policy is one which conserves funds with the least possible degradation of supply performance tempered by item priority.

1.3 Approach

A performance/budget evaluation was developed and programmed. Given information about the items managed by a retail unit, the evaluator can project the consequences of alternative methods for modifying stockage policies in terms of conservation of funds and degradation in supply performance.

Data for two representative units was run through the evaluator, and based on the results obtained, it was possible to reach some general conclusions.

The evaluator is also suitable for use as an operational tool, on an ad hoc basis, or as part of a system such as the Navy has.

1.4 Scope

The effort described focused on Class IX items of supply, repair parts and components, as managed by the Direct Support Unit level of Supply. Class IX items managed under the numerical stockage objective concept were excluded from the analysis.

The emphasis was on shorter term funding problems of three to six months. In other words, it was oriented to the unit which was experiencing fiscal difficulties in its current budget year, but expected to be able to resume normal operations when the next budget year began.

1.5 Performance Measures

Supply performance at retail level, consistent with common practice and AR 710-2, is measured in terms of initial fill (cf AR 710-2), defined as:

$$\frac{\text{total valid requisitions filled without backorders}}{\text{total valid requisitions received}}$$

In order that supply performance at the DSU level might better relate to operational readiness of end items in the field, the research sponsor directed that impact on initial fill be considered separately for items in each priority class. An item's priority class is defined in terms of the average MILSTRIP issue priority designator (AR 725-50) for all requisitions received for that item, as depicted below.

AVERAGE ISSUE PRIORITY DESIGNATOR	PRIORITY CLASS
1.0 - 3.5	I
3.6 - 8.5	II
8.6 - 15.0	III

Such a definition of priority class has been used in the SAILS system, and makes sense. Nevertheless, to our knowledge, the concept is not supported by any study. Therefore, as a side effort we did some evaluation of the concept, and this is reported in Appendix D.

1.6 Policies

Policy modifications considered included: cuts in operating levels, cuts in reorder points, and increases in retain criteria. The policy modifications were considered independently, and in combination; e.g., cut both reorder point and operating level.

Cutting operating levels reduces the amount ordered at one time. This can reduce the total amount ordered during the budget year, but this is not inevitable; it may only have the effect of increasing the order frequency, i.e. two orders for 10 units each instead of one order for 20 units. Cutting reorder points postpones ordering; if, as a result, assets have not fallen to the newly lowered reorder point by year's end, money is saved. Raising the retain criteria reduces the number of items qualifying for stockage.

Direct support units, unless "specifically directed by Department of the Army" use the fixed days of supply policy for reorder points, and fixed addition/retention criteria for qualifying items for stockage (AR 710-2). Operating levels for most items are to be based on Economic Order

Quantities. It was agreed with the research sponsor that policy modifications to save money should be kept at the same level of sophistication. In particular, a % cut in reorder points or operating levels had to be the same % for all items in the same priority class, but could differ between classes. Likewise, if the retain criteria were raised, it had to be by the same amount for all items in the same priority class.

There are a number of approaches to conserving funds other than modifying stockage policies. Some are noted here for interest. The most basic approach is to reduce the need for parts. Training patterns can be altered or maintenance practices modified, with less essential maintenance deferred as it might be in wartime. Alternatively, the DSU might stop satisfying low priority requisitions or funding priorities could be changed to make more money available.

1.7 Budget/Performance Evaluator

The evaluator is a sophisticated computer program which utilizes mathematical inventory theory and information about a particular item to project what will happen to that item, in terms of expenditures and initial fill, if a particular supply policy modification is implemented.

The evaluator can accept information about each item a unit manages, make its projections for each item, and then aggregate, to give the relationship between policy, expenditures and performance for the unit as a whole. Computer running cost on a CDC6500 at Picatinny Arsenal averaged $3 per policy evaluated per 1000 items. The program is approximately 500 Fortran lines.

Information necessary about each item is its: asset position; unit price; order and ship time; average monthly demand; number of requisitions in past year; current stockage classification (stocked or non-stocked); code to indicate whether its operating level is calculated by Economic Order Quantity or as fixed days of supply; Material Category code, for those units for which addition/retention criteria depend on this. The unit's addition/retention criteria, number of safety level days and, where applicable, operating level days is also needed.

The mathematical inventory theory used by the evaluator is described in Appendix A. A computer simulation used to validate the evaluator, and the results obtained, are described in Appendix B. While the evaluator gives only approximately correct answers, it was found these approximations are quite good.

The mathematical theory incorporated in the evaluator differs in two basic respects from a similar tool used by the Navy [3], and one used at the wholesale level within the Army [10]. Most importantly, the other programs use "steady state" theory; this projects what will happen over the long run. To get short term projections, the long run projections are factored to account for the time differences. The mathematical theory developed here is oriented to the shorter term time frame, and is more accurate for such time frames.

Also, this evaluator is able to more accurately project the impact on supply performance of requisition quantities for more than one unit. For example, in the other two evaluators it is assumed that orders are always placed when stock is at the reorder point. What can happen in the real world is that the reorder point is, say, 10, and assets are 12, and then a single requisition for 6 units drops assets down to 6.

CHAPTER II

DATA BASE

2.1 Basic Data

Data on two representative DSUs was provided by the RIMSTOP Working Group. Pertinent facts are summarized in Figures 2.1 and 2.2. It is clear that the two DSUs are dissimilar in all respects: functions, management parameters, catalog characteristics, average item characteristics.

Figure 2.2 shows that the % of total demand, in dollar terms, accounted for by all stocked items was only 25% at Ft. Carson and 52% at 3rd Infantry Div. The Ft. Carson figure may reflect the exclusion of all reparables, including stock fund, from the automated NCR records at that DSU. Even the 52% of 3rd Infantry Div. imposes an important limit on the usefulness of stockage policy modifications, since they have no effect on the dollars needed to satisfy demands for non-stocked items.

2.2 Demand and Order and Ship Time Variability

It was assumed that demand had a Stuttering Poisson probability distribution. This distribution has been found suitable in a number of studies such as those done by Research Analysis Corporation [9] and M.I.T. [4]. In any event, it is unlikely that a more accurate distribution can be found or that the final results are very sensitive to the distribution assumed. For the Stuttering Poisson, demand variability is determined by a theoretical relationship from the AYD (average yearly demand) and AYF (average yearly frequency).

An alternative method of computing demand variability was also considered. An empirical formula is used at wholesale level to relate demand variability to demand frequency, [2]. This formula, with one adjustment, compares reasonably well to results found for the overseas depot level [1]. The adjustment is to use the values specified for demand frequency of 5-8 for frequencies 1-8. This adjusted formula gives higher estimates of demand variability than those found theoretically using the Stuttering Poisson assumptions. Results using these higher estimates were obtained, but it was found that the conclusions were the same (results are reproduced in Appendix C).

Order and ship time mean and variance were computed by the RIMSTOP Group from the actual experience of the DSUs. It happened that the means were greater than the means upon which the DSU reorder points were based. In this study we assumed the latter were correct. We used the coefficients of variation (standard derivation $\div$ mean) found empirically, which were 1.50 for Ft. Carson and 0.97 for 3rd Infantry Division.

2.3 Editing

There was some editing which had to be done before using the data. Some items were excluded from analysis because of lack of unit price, or because the reported AYD was less than the AYF. There were discrepancies between the stockage code of an item and its AYF; i.e., some items coded as stocked had too few requisitions to qualify and visa versa. In developing Figure 2.2, we included those items which were coded stocked and had an AYF at least as great as the retention criteria; as well as those items which were not coded stocked but had experienced a number of demands at least as great as the addition criteria. However, when running the Budget/Performance Evaluator we did not include any items not actually coded as stocked.

We learned from the RIMSTOP people that an item's recorded AYD and AYF may reflect a different cut off date than the other elements. This could account for the discrepancies found between the stockage codes and reported demand frequencies. It may also account for discrepancies found between the reorder point and reorder quantity levels reported for the units, and those found by utilizing the appropriate computation rules; e.g., for Ft. Carson we would multiply the AYD by 35/365 to get the reorder point, and round, and get a different answer than the reported reorder point.

In the analysis, the computed rather than the reported stockage levels were used as input to the Budget/Performance Evaluator. If, as a result, assets were below the reorder point, they were reset to reorder point + 1/2 operating level. If assets exceeded twice the requirements objective, they were reset to that number. For 3rd Infantry Division, the assets reported were a roll up of assets of A Company and forward companies, but forward company assets were limited, and there were actually fewer occasions when assets exceeded the requirements objective than for Ft. Carson (29% vs 39%).

2.4 Impact of APA Secondary Items

While APA (appropriations account) secondary items are not subject to budget constraints at the present time, they were included in the 3rd Infantry Division data base. Of the 3630 APA items, however, 2698 were excluded for lack of unit price. The remaining items, of which 161 were stocked, had a very small impact on the average dollar value of demand of items run through the Budget/Performance Evaluator.

DATA BASES*

	620TH SUPPLY COMPANY	3RD INFANTRY DIV DSU
LOCATION	FT. CARSON	GERMANY
TYPE	NON-DIVISIONAL DSU	DIVISIONAL DSU
ORDER SHIP TIME	30 DAYS	65 DAYS
SAFETY LEVEL	5 DAYS	15 DAYS
OP LEVEL	EOQ	*EOQ/15 DAYS
ADDITION/RETENTION		
MATCAT H, J		3-1
	6-3	
ALL OTHER		6-3

*There is a code in item's record which indicates which to use.

FIGURE 2.1

DATA BASE (CONT'D)

CATALOG CHARACTERISTICS	FT. CARSON	3RD INF DIV
# ITEMS	9182	19,052
# DEMAND SUPPORTED	1417 (15%)	3708 (15%)
TOTAL $ MONTHLY DEMAND	$169,924	$419,776
$ AMD, DEMAND SUPPORTED	$35,682 (21%)	$207,885 (50%)
($ AMD, ALL STOCKED)	($42,471)(25%)	($216,358)(52%)
"AVERAGE ITEM" YEARLY DEMAND CHARACTERISTICS (DEMAND SUPPORTED)		
$ VALUE	$302.	$673.
NO. OF UNITS	64.	145
NO. OF REQUISITIONS	13.	23

FIGURE 2.2

CHAPTER III

RESULTS

3.1 Basic Findings

Figures 3.1 thru 3.4 show the projected impact on dollars saved and decrease in initial fill of alternative modifications of supply policies. "ROWP" is reorder point and "OP Level" is operating level. The "horizon" is the number of months until the end of the budget year. Dollars saved relates to the % decrease in the dollar value of funding needed over this horizon.

The saving is, for the most part, for budgeting purposes only, since at the end of the year inventory levels will be below normal causing an increased funding requirement for the ensuing year. Not all the dollars saved will have to be made up, however, since at least some of the materiel is likely to turn out not to have been needed.

In measuring fill, only requisitions for items which would have been stocked under the unmodified baseline policy were considered. The term "demand satisfaction" (AR 710-2) might have been more appropriate than fill rate, but it could be ambiguous in interpreting the results for the modified retention policy. The decrease in fill reflects the impact on fill both during the remainder of the budget year, and immediately after. For example, suppose Order and Ship Time is one month. Then regardless of what is ordered at the end of the budget year, it will not be received until a month later. Initial fill during the first month of the new year will reflect the low inventory levels created by the previous austerity, and hence initial fill will be degraded. By the same logic, if a money saving policy is instituted, its impact on fill will not be felt for the first month.

The effectiveness ratio is a convenient way to summarize impact of a policy. It is the percent decrease in dollar requirements for each percent decrease in initial fill. Clearly, the higher, the better.

3.2 Conclusions

Cutting reorder points is more effective than cutting operating levels. Modifying retain criteria works well on some units (cf 3rd Infantry Division), but poorly on others (cf Ft. Carson). Combining policies does not offer special advantages, but is an effective way of augmenting the savings achievable by using only one type of policy modification. For example, for Ft. Carson (Fig 3.3), the effectiveness ratio of the combined policy is not any higher, in fact lower, than the simple policy of cutting reorder points. However, it does permit additional savings at an effectiveness ratio which lies between the ratios of the two policies being combined; i.e., the ratio 8.8 lies between 10.4 and 7.9.

In general, the policies are more effective over the 3-month horizon than the 6-month horizon. There is good reason to believe this reflects a general rule: the shorter the time horizon, the more effective changes in supply levels can be.

The actual % dollar savings for a given cut in operating level is remarkably consistent between Ft. Carson and 3rd Infantry Division; e.g., 12.8% vs 12.7% for the 3-month horizon. This is not true for cuts in ROWP, nor is this surprising. Cutting a 35 day ROWP (Ft. Carson) cannot generate the same savings as the same % cut in an 80 day ROWP (3rd Infantry Division). What if we try to relate the % savings to the number of days cut in ROWP?

Figure 3.5 gives the answer. For each one day cut in the ROWP at 3rd Infantry Division, the % dollar savings is 1.00% if the total cut is 25% of the ROWP and 0.97 if the total cut is 50% of the ROWP. Averaging over both units, we get 0.91% and 0.87%. Averaging these numbers we get 0.90%. As an approximation, over a 3-month horizon, we may expect to save 0.90% of our projected dollar expenditures, for each one day cut from the ROWP, or 9% for each 10 days. Over a 6-month horizon, the saving is 4.8% for each 10 days.

3.3 Explanations

Why does cutting ROWPs work better than cutting operating levels? The following hypothetical example illustrates what is happening.

Suppose we have two 3rd Infantry Div. items which differ only in unit price. In particular, we have the following:

Item	$ AMD	Days ROWP	Days OP Level
1	$ 50	80	104
2	$1000	80	23

ROWP and OP Level days are the true days of supply which 3rd Infantry Div. would have for items with the Average Monthly Demand in dollars indicated.

If we cut ROWP by 25%, we cut 20 days of supply from both items for a dollar reduction in supply levels of (20/30) x ($50) + (20/30) x ($1000) or $700. If we cut operating level by 50%, we reduce levels by 52 days and 11.5 days respectively for a total dollar reduction of $470. In general, the impact on days of supply is greater, but the impact on dollars is smaller.

Reducing days of supply in the operating level degrades performance because it increases exposure to stockout. If any item is ordered three times a year, there are at most three times when stock can run out. If it is ordered six times, there are six separate stockouts possible.

Why did modifying the retain criteria work well for 3rd Infantry Div. and poorly for Ft. Carson? Additional data analysis provided the answer. Following are the statistics on the items with AYFs of 3, 4 and 5, i.e., those items which would be retained on the stockage list if retention criteria were 3, but would not be retained if retention were raised to 6*:

	% Items	% Requisitions	$ Dollars
Carson	27.0%	13.5%	17.2%
3rd Infantry	17.5%	4.4%	14.5%

*For 3rd Infantry Div., MATCAT H, J items, items with AYFs of 1, 2 and 3 were included since addition/retention criteria was 3-1 for MATCAT H, J items.

The %'s shown relate the designated items to all stocked items. Dollars % is % of total dollar value of demand accounted for by these items. As would be expected, since these items are slow movers, they account for a smaller % of requisitions, than the % of items which they constitute. Note, however, that at Carson they account for 13.5% of requisitions, but only 4.4% at 3rd Infantry Division. Thus, the potential impact on supply performance was much smaller at 3rd Infantry Division even though the potential savings were comparable as indicated by % of dollars accounted for.

There was some concern that the effectiveness of changing retention criterion at 3rd Infantry Division might have been due to elimination of MATCAT H, J items which normally have addition-retention criteria of 3-1. A run was made in which retention criteria were doubled, instead of adding 3: for non-MATCAT H, J items retention went from 3 to 6 and for MATCAT H, J from 1 to 2. Results differed by at most 0.1% from those reported in Figures 3.1 and 3.2.

3.4 Impact of Priority

The distribution of items by priority class is as follows:

PRIORITY CLASS	% ITEMS		% $ AMD	
	3RD INF	CARSON	3RD INF	CARSON
1	1.2%	4.7%	12.2%	4.2%
1 + 2	9.1%	36.7%	29.8%	72.6%

The results for 3rd Infantry Division are quite plausible in that they show that essential items account for more than a proportionate share of dollar demanded (e.g. 1.2% of items accounting for 12.2% of $AMD). This implies that essential items tend to be higher unit price items. The Carson figures,s seem out of line and are suspect.

It seems clear that priority class I items should be excluded from budget cuts, since they are very essential, and they account for less than 15% of total dollars. Exclusion of priority class II is marginal, even for 3rd Infantry Division.

Runs were made using the 3rd Infantry Division data, repeating the analysis of Figures 3.1 thru 3.4 but excluding all priority class I items, and then excluding all priority class I and II items. These runs are found in Appendix C. The conclusions stated earlier remain valid for these new runs.

3.5 Recommendations

It is recommended that guidance for reacting to fund shortages be incorporated in AR 710-2 or otherwise promulgated to the retail inventory manager. This guidance should state that cuts in reorder points up to 50% should be implemented before across the board cuts in operating levels. The guidance should give the approximate savings of reorder point cuts as 9% of normal expenditures on stocked items for each 10 days cut in ROW P over a 3-month period, and 5% over a 6-month period. The guidance should advise that priority class I items, where identified, be excluded from cuts.

Consideration should be given to further use of the budget/performance evaluator. Advantages of using the evaluator as an operational tool on selected units would include more precise estimates of budgeting impacts and, possibly, recommended changes in stockage criteria.

In any event, the evaluator should be used if there are major changes in baseline supply policies, to reevaluate the guidance given here. If more sophisticated policies for reacting to budget cuts become feasible, varying the response by item, the evaluator could be used to investigate these policies.

3RD INFANTRY DIVISION : 3 MONTH HORIZON

POLICY	DOLLARS SAVED (b)	DECREASE IN FILL (c)	EFFECTIVENESS RATIO* (b) (c)
(BASE)		(83.4)	
CUT ROWP 25%	19.9%	1.9%	10.5
CUT ROWP 50%	38.8%	3.9%	9.9
CUT OP LEVEL 50%	12.8%	1.9%	6.7
ADD 3 TO RETAIN CRITERIA	9.4%	0.5%	18.8
ADD 3 + CUT ROWP 25%	26.9%	2.3%	11.7
ADD 3 + CUT ROWP 50%	43.8%	4.3%	10.2

*Highest ratios represent most cost/effective policies

FIGURE 3.1

3RD INFANTRY DIVISION : 6 MONTH HORIZON

POLICY	DOLLARS SAVED (b)	DECREASE IN FILL (c)	EFFECTIVENESS RATIO* (b) ÷ (c)
(BASE)		(83.2%)	
CUT ROWP 25%	10.6%	2.2%	4.8
CUT ROWP 50%	21.2%	5.1%	4.2
CUT OP LEVEL 50%	6.9%	2.5%	2.8
ADD 3 TO RETAIN CRITERIA	6.9%	1.0%	6.9
ADD 3 + CUT ROWP 25%	16.1%	3.1%	5.2
ADD 3 + CUT ROWP 50%	25.4%	6.0%	4.2

FIGURE 3.2

FT CARSON: 3 MONTH HORIZON

POLICY	DOLLARS SAVED (b)	DECREASE IN FILL (c)	EFFECTIVENESS RATIO* (b) ÷ (c)
(BASE)		(90.9%)	
CUT ROWP 25%	7.4%	0.6%	12.3
CUT ROWP 50%	13.5%	1.3%	10.4
CUT OP LEVEL 50%	12.7%	1.6%	7.9
ADD 3 TO RETAIN CRITERIA	10.1%	2.0%	5.1
CUT ROWP 50% + CUT OP LEVEL 50%	24.7%	2.8%	8.8

FIGURE 3.3

FT CARSON: 6 MONTH HORIZON

POLICY	DOLLARS SAVED (b)	DECREASE IN FILL (c)	EFFECTIVENESS RATIO* (b) ÷ (c)
(BASE)		(89.9%)	
CUT ROWP 25%	4.0%	0.7%	5.7
CUT ROWP 50%	7.4%	1.7%	4.4
CUT OP LEVEL 50%	7.2%	2.4%	3.0
ADD 3 TO RETAIN CRITERIA	6.5%	3.6%	1.8
CUT ROWP 50% + CUT OP LEVEL 50%	14.3%	4.2%	3.4

FIGURE 3.4

SAVINGS PER DAY CUT IN ROW P: 3 MONTH HORIZON

UNIT	% CUT	DOLLAR SAVINGS
3RD INFANTRY DIVISION	25%	1.00%
	50%	0.97%
CARSON	25%	0.85%
	50%	0.77%
AVERAGE	25%	0.92%
	50%	0.87%
	-	0.90%

SAVINGS PER DAY CUT IN ROW P: 6 MONTH HORIZON

3RD INFANTRY DIVISION	25%	0.53%
	50%	0.53%
CARSON	25%	0.46%
	50%	0.42%
AVERAGE	25%	0.49%
	50%	0.48%
	-	0.48%

FIGURE 3.5

APPENDIX A

BUDGET PERFORMANCE EVALUATOR

A.1 Introduction

The motivation behind the B/PE was discussed in Chapter I. The program was developed by a series of iterations between design stage and validation stage, starting with a simple approach and adding refinements as necessary to achieve an acceptable degree of accuracy. While each refinement has its logical basis, its ultimate justification is that it works.

The reader should read as background to this Appendix the work by Silver [11]*.

Following is some standard notation used throughout the Appendix. Additional notation is introduced in many of the sections.

A.2 Common Notation

- CA - current assets, i.e. assets on hand and on order at time projection is made
- D - demand during rest of year
- EA - assets at end of year
- Q - reorder quantity
- R - reorder point
- s - requisition size
- u - deficit or undershoot, comparable to z in Silver's notation [11]
- OST - order and ship time
- λ - demand frequency
- Pr( ) - probability of event in parens
- Ex( ) - expected value of variable in parens
- σ^2( ) - variance of variable in parens
- γ( ) - coefficient of variation of variable in parens (i.e., $\gamma(x) = \sigma(x)/Ex(x)$)

*In that article, expressions for π_M and π_X (p 9-1) should correctly have a denominator of $(M-R)/P + 1-P$.

A.3 Basic Approach: Expected Amount Bought

It is simple enough to compute the probability that at least something will be bought. If we knew the ending asset position, given that there is at least one buy, we could back out the actual quantity bought. Algebraically, letting:

$$P1 \equiv Pr\ (D \geq CA-R)$$

$$E1 \equiv Ex\ (EA \mid D \geq CA-R)$$

$$D1 \equiv Ex\ (D \mid D \geq CA-R)$$

Then

(A.3.1) $$Ex(BUY) = P1 \times [E1 - CA + D1]$$

D1 and P1 are readily calculated. Our approach to calculating E1 takes note of the observation that when there are non-unit requisition sizes, the probability distribution on inventory position has a "spike" at R+Q[11]. We estimate this spike, and also the average ending inventory if it is not at R+Q.

Spike probability. The sample space for demand is the set of nonnegative integers. Divide this space as follows:

←(CA-R-1)→	← Ex(u) + 1→	←(Q-1) →	←Ex(u) + 1→	←(Q-1)→	
0	x_1	y_1	x_2	y_2	.....

For example, D falls into the interval labelled y_1 if D is in the interval [CA-R-1 + Ex(u) + 1 + 1, CA-R-1 + Ex(u) + 1 + Q-1]. Then we set:

(A.3.2) $$Pr(EA=R+Q \mid D \geq CA-R) \quad \sum_{i=1}^{\infty} Pr(D \text{ is in } X_i \mid D \geq CA-R)$$

This approximation was suggested by two observations. If Ex(u) = 0, i.e. all requisitions are for 1 unit, then (A.3.2) would hold exactly. Also if we define D_t to be demand over some period t, and EA_t to be ending assets after t, then we have using our approach:

$$\text{(A.3.3)} \qquad \lim_{t\to\infty} \Pr(EA_t = R+Q) = \lim_{t\to\infty} \sum_{i=1}^{\infty} \Pr(D_t \text{ is in } X_i)$$

Now the L.H.S. of (A.3.3) is the projected steady state probability of ending assets being R+Q. For "well behaved" distributions* the R.H.S. of (A3.3) is equal to [Ex(u) + 1]/[Ex(u) + 1 + Q - 1]. This in turn is equivalent to the steady state probability of a spike derived by Silver, [11, p. 94]. The equivalence is found by noting Ex(u) = Ex(s) - 1 (See Silver's expression 3b, p. 94), and Ex(s) = 1/p in Silver's notation. Hence our approach gives the correct answers over the short term for unit req sizes and over the long term for non-unit req sizes. This is the basis for trying it for non-unit order sizes over the short term.

Average Asset Position. Initially, it was assumed that if ending assets were not R+Q, they would be on average R + [(Q-1) + (1)]/2. It was found necessary, however, to adopt an approach consistent with the approach for finding the spike probability. For interval y_i, an equivalence was made between demand position and asset position:

y_i:	demand	1	2.......	Q-1
	assets	Q-1	Q-2	1

For example, if demand were equal to (CA-R) + (Ex(u)+1) + 3, this was equated to an asset position above R of Q-3; i.e. we had 3 demands after being at a spike. To approximate the probability of being at any particular demand position, we computed the probability (f_1), given a buy, of being at the first demand position in a y_i interval, and the probability (f_2) of being at the last position, and used interpolation for the other y_i interval positions. Hence, average ending assets, given there is a buy, and

---

*For example, unimodal functions such that the probability of being in any given interval goes to 0 as $t\to\infty$

given we are not at R+Q, is

$$\text{(A3.4)} \qquad \underset{\text{(above R)}}{\text{Avg Assets}^{*}} = \frac{\sum_{x=1}^{Q-1} (Q-x)\left[f_1 + \frac{x-1}{Q-2}(f_2-f_1)\right]}{\sum_{x=1}^{Q-1} f_1 \times \left[\frac{x-1}{Q-2}\right](f_2-f_1)}$$

Numerator equals $[f_1 + f_2/2](Q)(Q-1)/3$

Denominator equals $(1/2)(Q-1)(f_1 + f_2)$

Truncation: In the computer program, calculations were truncated after the interval y_3. Equation (A3.4) is then the average assets given demand falls in y_i, $i = 1 -> 3$; and this should be a reasonable approximation of average assets given demand fulls in y_i, $i = 1 -> \infty$ Similarly, we might have set the spike probability to:

$$\frac{\sum_{i=1}^{3} \Pr(D \text{ is in } x_i \mid D \geq CA-R)}{\sum_{i=1}^{3} \Pr(D \text{ is in } x_i \text{ or } y_i \mid D \geq CA-R)}$$

Label the numerator of that expression NUM and the denominator DEN. As a possible refinement, we set the spike probability to

$$\text{(A3.5)} \qquad \Pr(EA=R+Q \mid D \geq CA-R) =$$

$$\frac{NUM}{\Pr(D \geq CA-R)} + \frac{\Pr(D > CA-R)-DEN}{\Pr(D \geq CA-R)} \cdot \frac{Ex(u)+1}{Q+Ex(u)}$$

In other words, we used the steady state spike probability as representative of the probability of being at R+Q, given that there were more than 3 buys.

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*Formula incorporated in program was inadvertently, a little different: it gave f_2 too much weight and f_1 not enough.

Average Order Size Adjustment. One last refinement was useful. While in steady state $Ex(u) = Ex(s)-1$, we are really concerned with $Ex(u)$ given $D \geq (CA-R)$. Therefore, we really should use in calculating A3.2 and A3.5 $Ex(s)$ given $D \geq (CA-R)$. This last was approximated. The approach was as follows:

Let

$$Ex(D) = Ex(\lambda)\ Ex(s)$$

$$Ex(D|D \geq K) = Ex(\lambda_K)Ex(s_K)$$

where λ_K and s_K are the demand frequency, req size given $D \geq K$.

Set $FRAC = \gamma(s)/[\gamma(s) + \gamma(\lambda)]$

$$RATIO = Ex(D|D \geq K)/Ex(D)$$

Then, we assume

$$\frac{Ex(s_K)}{Ex(s)} = RATIO^{FRAC}$$

$$\frac{Ex(\lambda_K)}{Ex(\lambda)} = RATIO^{1 - FRAC}$$

Note, then, that

$$\frac{Ex(s_K)Ex(\lambda_K)}{Ex(s)Ex(\lambda)} = RATIO^{FRAC + 1 - FRAC} = RATIO$$

We are assuming in the above that if most potential demand variability is due to variability in req size, (FRAC is closer to 1), then most actual availability is due to req size, and vice versa.

Non-Stocked Items. For items not stocked as a result of raising the retention criteria, amount bought equals amount backordered by year's end, since material is bought only to satisfy due out. Thus, amount bought $= Ex(D-CA|D \geq CA) \cdot Pr(D \geq CA)$.

A4 Basic Approach: Expected Backorders

We assume all assets constituting starting asset position are on hand, since any backorders occurring because they are not will be unaffected by whatever policy we adopt. At the same time, we are concerned with all other backorders through the end of the year + one order and ship time (OST) since it will take us one OST to recover from any drawdown of assets existing at the end of the year.

We divide the backorders of interest into two components:

(a) Those which will eventually be elimінted by stock ordered before year end.

(b) Those which will not.

This distinction will become clearer when the methods of calculation are given.

For non-stocked items we need not make this distinction. Letting D_{OST} be demand thru the rest of the year plus an OST thereafter, we simply calculate $Ex(D_{OST} - CA | D_{OST} \geq CA) \cdot Pr(D_{OST} \geq CA)$.

On an individual item basis calculation is done in terms of units backordered, and then divided by average requisition size to get expected requisitions backordered. For some justification of this formula, see Kaplan [6].

Calculation of Component (a) of Backorders. Let I_B be the steady state value of an item's "initial backorder %," i.e. (100% - initial fill %). It is the expected value of the percent of all demands not satisfied from stock. Equivalently, it is the expected value of the percent of all stock ordered, which upon arrival, will be used to eliminate backorders rather than be held in inventory. We approximate component (a) as (IB) · (Expected Amount Bought).

To calculate IB, we note IB = 100 - FDSWB as defined by Silver [11]. Silver gives an exact formula for FDSWB which is too time consuming to use on a large number of items. We approximate his formula.

Silver actually gives two formulas for FDSWB, the first assuming unit demands (i.e. no undershoots), and the second, relaxing this assumption, the more general formula.

Let $S(x,y) = (FDSWB) \cdot (y)$ for $R = x$, $Q = y$, unit req sizes.

Then Silver's general formula is algebraically equivalent to:

$$FDSWB = \frac{1}{Q + E(u)} \left\{ \sum_{u=o}^{R} Pr(u)\ S(R-u,\ Q + u) + Pr(u>R)\ S(o,R+Q) \right\}$$

We simplify to the extent of defining $u_2 = Ex(u|u \leq R)$ and replacing:

$$\sum_{u=o}^{R} Pr(u) \cdot S(R-u,Q+u) \text{ with } Pr(u \leq R) \cdot S(R-u_2,\ Q+u_2)y$$

<u>Calculation of Component (b) of Backorders</u>. To calculate component (b), we assume all stock during the year is already on hand at the end of the year - backorders incurred because stock is not on hand are already accounted for in component (a). Basically,

Letting $B_2 \equiv$ component (b) backorders

$d_2 \equiv$ demand in OST

ENDIN $\equiv$ inventory at end of year

(A.4.1) Then $B_2 = Ex(d_2 - ENDIN|d_2 \geq ENDIN) \cdot Pr(d_2 \geq ENDIN)$

The problem of course is that ENDIN is a random variable with a probability distribution. It is not feasible to consider all possible values, nor was it found sufficient to use equation (A.4.1) with just Ex(ENDIN). The following scheme evolved through trial and error:

set HIASS = R + 3 * AMD

if CA $\leq$ HIASS

set $ENDIN_1 = Ex\ (ENDIN|D \geq CA-R)$

$ENDIN_2 = Ex\ (ENDIN|D \leq CA-R)$

If $CA > HIASS$

set $ENDIN_1 = Ex(ENDIN | D \geq CA\text{-}R)$

$ENDIN_2 = Ex(ENDIN | D < CA\text{-}R,\ D \geq CA\text{-}HIASS)$

$ENDIN_3 = Ex(ENDIN | D < CA\text{-}HIASS)$

Then

$$B_2 = \sum_i Ex(d_2 - ENDIN_i | d_2 \geq ENDIN_i) Pr(d_2 \geq ENDIN_i) \cdot Pr(ENDIN_i)$$

where $Pr(ENDIN_i)$ denotes the probability that D will be such that the conditional for $ENDIN_i$ will be satisfied, e.g. $Pr(ENDIN_1) = Pr(d \geq CA\text{-}R)$.

Netting Out. Following the arguments used in Kaplan [7], it may be shown that a fill rate can be computed as readily by looking at those backorders which will be eliminated by buys placed over a fixed period, as it can be by looking at those backorders which are actually incurred in a fixed period. In other words, to compute a 3 month fill rate for the baseline policy, we only need be concerned with component "(a)" of back-orders. Component (b) for the baseline policy is used only to calculate the asset drawdown impact of the other policies, by subtracting component (b) for baseline from component (b) of each policy modification.

A.5 Additional Issues

OST Variability. It was assumed orders do not cross; i.e, stock for a given item is received in the sequence in which it is ordered. Let OST_i and $Pr(OST_i)$ denote possible OST values and their probabilities. Without crossing, expected backorders (B) is:

(A.5.1) $$E(B) = \sum_i E(B | OST_i)\ Pr(OST_i)$$

Equation (5.1) would clearly be true if B only represented backorders at the end of one OST. It may also be shown to be correct where B represents total backorders incurred by an item, over time, perhaps involving multiple orders and OSTs. The argument is analogous to one used by Kaplan in his paper on Impact of Non-Optical Reorder Points [7].

To use Equation (A.5.1), the probability distributions of order and ship time for each DSU was represented by a two point probability mass function chosen to have the mean and variance of OST found empirically for that DSU (Section 2.2).

Demand variability. The appropriate measure of demand variability to use in making projections is variance about the forecasted mean, not the true mean. It is found under the assumption that demand has a stationary, Stuttering Poisson distribution.

Let d_1 - demand over one month

F - forecast of monthly demand

B - base period in months used in moving average forecast

L - number of months for which demand is to be forecasted

$\sigma^2(\ )$ - variance of variable in parenthesis

VAR - desired variance

Assuming demand is stationary,

$$\sigma^2(F) = \sigma^2(d_1)/B$$

$$VAR = L\sigma^2(d_1) + L^2\sigma^2(F) = L\sigma^2(d_1)[1 + L/B]$$

Under the Stuttering Poisson assumption,

$$\sigma^2(d_1) = Ex(d_1) * [(2)\ Ex(S) - 1]$$

As an approximation, F is substituted for $Ex(d_1)$ and observed for expected S.

Use of Negative Binomial. Cumulative density functions and conditional demand expectations and densities can be quickly computed by the Camp-Paulson approximation to the Negative Binomial as discussed in Section A.6. This approximation was used with one exception even though demand was assumed to have a Stuttering Poisson distribution. The rationale is that both come from the same family and should be equally suitable. There is no one distribution which fits demand for all items.

In computing steady state backorders (cf A.4) exact values of the Negative Binomial were used. This was efficient because one set of probabilities could be computed for this purpose per item, for use in evaluating all policies, and because computation of exact Negative Binomial densities is relatively easy.

Results of the validation effort supported these decisions.

A.6 Computational Formulas

Non-integer arguments. In applying some of the heuristic approaches described, we may get non-integer arguments for cumulative distribution functions, or conditionals, which are defined only over integer values. In such cases we used linear interpolation.

Geometric Conditionals. Two identidies* were necessary to efficiently calculate the conditional deficits (Section A.4). Let

$$f(x) = pq^{x-1} \tag{A.6.1}$$

Then using well known results for geometric power series:

$$\sum_{x=a}^{b} f(x) = p \sum_{x=a-1}^{b-1} q^{x} = q^{a-1} - q^{b} \tag{A.6.2}$$

and

$$\sum_{x=a}^{b} xf(x) = p \sum_{x=a}^{b} x\, q^{x-1} = p \frac{d}{dq} \sum_{x=a}^{b} q^{x}$$

and omitting some algebra

$$= q^{a-1} [a + q/p] - q^{b}[(b+1) + q/p]$$

*Richard Urbach derived the identities shown.

Conditional demand for Negative Binomial. Let the Negative Binomial density be defined:

$$\text{(A.6.4)} \qquad f(x;\ r,q) = \frac{\Gamma(v+x)}{\Gamma(v)\Gamma(x+1)}\ p^{v}q^{x} \qquad (q = 1 - p)$$

Then an identity simplifies computation of conditional means and permits use of the Camp Paulson cumulative distribution function approximation for this purpose:

$$\text{(A.6.5)} \qquad \sum_{i=o}^{K} i\ f(i;v,q) = \frac{rq}{p}\ f(K-1;\ r+1,\ q)$$

where F is the Netative Binomial c d f. Conditionals are then evaluated using

$$\text{A.6.6)} \qquad \sum_{i=K+1}^{\infty} i\ f(i;v,q) = Ex(i) - \sum_{i=o}^{K} i\ f(i;v,q)$$

Scaling of Negative Binomial Densities. This problem arose for some items: we needed exact Negative Binomial densities (for use in computing steady state backorders) for arguments > M, where M = 100, but we wished to calculate densities only for arguments up to 100.

We used scaling. Let x be the original random variable. We calculated densities f'( ) for the variable x' such that:

$$Ex(x') = Ex(x) \cdot \frac{100}{M}$$

$$\gamma(x') = \gamma(x)$$

Then we used $f'(x \cdot 100/M) \approx f(x)$.

Multi-event conditionals. The following problem arises in evaluating ending inventory positions. Let p_{jk} and d_{jk} be the probability and conditional expectations respectively that demand is in the interval $[a_j,\ a_k]$. Find $p_{i-1,i}$ and $d_{i-1,i}$ for i=1,2,3 where $a_o = 0$ and $a_3 = \infty$. This solution technique is used:

Find $p_{2,3}$, $d_{2,3}$ and $p_{1,3}$, $d_{1,3}$; i.e. use twice the routine applicable to the simple conditional mean case where we evaluate conditionals given demand $\geq$ some constant.

Then:

$$p_{12} = p_{13} - p_{23}$$

$$p_{12}d_{12} = p_{13}d_{13} - p_{23}d_{23} => $$

$$d_{12} = (p_{13}d_{13} - p_{23}d_{23})/p_{12}$$

$$p_{o1} = 1 - p_{13}$$

$$p_{o1}d_{o1} = Ex(d) - p_{13}d_{13} =$$

$$d_{o1} = \frac{Ex(d) - p_{13}d_{13}}{p_{o1}}$$

APPENDIX B

VALIDATION

B.1 Approach

A simulation program was constructed* which simulated buys through the end of the year and backorders through the end of the year + one OST. Then a representative group of items was defined. Each item was run through the B/PE and simulator and answers were compared.

The representative group was defined by starting with a base case, and then varying one input at a time as in a sensitivity analysis. For the base case:

AYD (Average Yearly Demand)	=	60
AYF (Average Yearly Frequency)	=	10
R (Baseline reorder point)	=	12
Q (Baseline reorder quantity)	=	20
Starting on hand	=	R + Q/2
OST	=	2 Months

Each item was run for time horizons of 3 months and 6 months. For each item/time horizon combination, 4 simulation runs were necessary. First the baseline R,Q were simulated, and then 4 policy modifications: cut R by 25%, cut R by 50%, cut Q by 50%, do not stock. Not stocking is equivalent to an R of - 1 and a Q of 1.

Demands in the simulator were randomly generated in accordance with the Stuttering Poisson distribution. Results from each simulation run were based on the average of 4000 replications. This was found to be a sufficient number to insure that potential variability in simulation output due to initial random number seed would be insignificant.

The B/PE for comparison purposes was modified so that all cumulative distribution functions, with one exception, were based on the Stuttering Poisson, computed by the method of Feeney and Sherbrooke**. The exception was the calculation of steady state availability for which the

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*Simulator was designed and programmed by Mark Prestoy with help from Martin Cohen.

**See their paper in Management Science, January 1966.

exact Negative Binomial was retained for convenience and because of the way the program evolved.

In projecting backorders, there was no "netting" out (Section A.4) to be consistent with the simulation.

B.2 Results

Results for all items are reproduced as Figure B-1 and following tables. For the base case units bought and backordered are shown as absolute values. The % changes are then shown (simulated on left, projected on right). Earlier versions of the B/PE worked well for some of these cases and poorly on others.

Projections of amount bought are very good. Projections of backorders for baseline policy are significantly understated, most typically by about 10%. Estimates of impact on backorders of changes in R and Q seem adequate for purposes of comparing policies. There is a definite bias against the non-stock policy. Looking at the base case, we note that a 58.5% increase over 5.03 gives a total of 7.99 while a 75.1% increase over 4.53 gives a total of 7.93. What is happening is that we project actual backorders for the non-stock case quite well, but get erroneous % changes because we have understated backorders for the baseline policy.

It is apparent from a quick review of the results, both simulated and projected, that changing Q is almost always more effective than changing R; i.e., the ratio of change in amount bought ÷ change in backorders is higher. Why then did we get opposite results over the catalogue of items? As discussed in Section 3.3, the answer has to do with the effect of the EOQ policy. To be sure this was in fact the reason, another test was made.

All items in the sample were rerun using the production version of the B/PE, with the Negative Binomial approximations, and variable OST. It was assumed OST was 1/2 month with 80% probability and 8 months with 20% probability. Then effectiveness ratios were computed for each item in terms of % change in buy ÷ % change in backorders. The ratio is shown in Figure B.2. Again cutting Q was almost always more effective.

This indicates that neither the use of the Negative Binomial or variable OST explains why cutting R worked better overall when it did worse by item and confirms the validity of the explanation in Section 3.3.

A final test was made to see if scaling (Section A.6) had a serious impact. Items were projected using scaling, and without (calculating densities for $x > 100$). There was a small difference in absolute numbers and almost none in % changes.

B.3 Other Checks

In the production runs, on the full data bases, checks were made for anomolous conditions. The algorithm can break down and project higher backorders for the baseline policy then for the policy modifications, and even project negative backorders (after "netting" out, Section A.4). In almost all cases, this happens when the probability of a buy is very small, and the B/PE disregards the answers.

HORIZON = 90 DAYS	AMOUNT BOUGHT		BACKORDERS	
BASE	16.78	16.56	5.03	4.53
CUT R 25%	17.6%	17.4%	12.1%	14.2%
CUT R 50%	33.1%	33.4%	23.9%	26.6%
CUT Q 50%	26.3%	26.5%	11.3%	14.0%
NO STOCK	83.4%	83.5%	58.8%	75.1%

HORIZON = 180 DAYS				
BASE	32.68	32.37	8.50	7.63
CUT R 25%	8.9%	9.4%	17.8%	21.3%
CUT R 50%	18.9%	19.0%	37.5%	43.8%
CUT Q 50%	16.9%	16.8%	22.6%	25.0%
NO STOCK	65.0%	64.8%	130.3%	155.7%

SIMULATED VS PROJECTED

BASE CASE

FIGURE B-1

HORIZON = 90 DAYS	AMOUNT BOUGHT		BACKORDERS	
BASE	17.77	17.48	11.31	11.04
CUT R 25%	11.0%	10.0%	2.2%	2.7%
CUT R 50%	19.7%	19.1%	4.1%	5.1%
CUT Q 50%	19.5%	19.4%	3.4%	4.9%
NO STOCK	61.5%	61.5%	14.9	17.1

HORIZON = 180 DAYS				
BASE	34.25	33.81	18.25	17.65
CUT R 25%	7.2%	7.3%	4.3%	4.9%
CUT R 50%	14.4%	14.3%	8.5%	9.6%
CUT Q 50%	14.9%	15.1%	7.8%	9.1%
NO STOCK	50.8%	51.4%	34.4%	36.2%

SIMULATED VS PROJECTED

DECREASE FREQUENCY

(AYF = 3)

HORIZON = 90 DAYS	AMOUNT BOUGHT		BACKORDERS	
BASE	17.15	16.41	1.76	1.52
CUT R 25%	23.8%	24.7%	47.2%	51.7%
CUT R 50%	46.9%	48.2%	99.4%	100.9%
CUT Q 50%	36.0%	34.0%	23.3%	28.1%
NO STOCK	96.1%	95.9%	189.%	233%

HORIZON = 180 DAYS				
BASE	30.70	30.89	2.90	2.62
CUT R 25%	9.6%	9.6%	64.1%	67.8%
CUT R 50%	18.1%	19.0%	149%	157.5%
CUT Q 50%	15.2%	16.6%	52.1%	57.3%
NO STOCK	70.8%	71.3%	592%	591%

SIMULATED VS PROJECTED

INCREASE FREQUENCY

(AYF = 30)

HORIZON = 90 DAYS	AMOUNT BOUGHT		BACKORDERS	
BASE	8.52	8.32	2.29	2.06
CUT R 25%	—		—	
CUT R 50%	34.2%	33.3%	27.1%	30.3%
CUT Q 50%	27.1%	26.6%	12.7%	15.3%
NO STOCK	85.1%	84.9%	67.7%	85.2%

HORIZON = 180 DAYS				
BASE	16.36	16.22	3.87	3.49
CUT R 25%	—		—	
CUT R 50%	18.5%	19.1%	42.4%	48.5%
CUT Q 50%	16.6%	16.7%	25.3%	27.5%
NO STOCK	65.8%	65.7%	150.%	177.0%

SIMULATED VS PROJECTED

SCALE BY 1/2

(AYD = 30; on hand = 11; Base R = 6; Base Q = 10)

HORIZON = 90 DAYS	AMOUNT BOUGHT		BACKORDERS	
BASE	17.01	16.72	7.17	6.59
CUT R 25%	17.1%	16.8%	12.7%	14.8%
CUT R 50%	32.3%	32.1%	23.7%	28.7%
CUT Q 50%	16.2%	16.2%	9.8%	11.1%
NO STOCK	74.6%	74.7%	51.9%	63.4%

HORIZON = 180 DAYS				
BASE	32.18	31.87	12.02	11.00
CUT R 25%	9.4%	9.4%	18.1%	21.1%
CUT R 50%	18.7%	18.6%	35.9%	43.5%
CUT Q 50%	9.3%	9.2%	15.4%	16.1%
NO STOCK	53.7%	53.6%	98.1%	115.6%

SIMULATED VS PROJECTED

DECREASE Q

(Q = 10; on hand = 17)

HORIZON = 90 DAYS	AMOUNT BOUGHT		BACKORDERS	
BASE	13.93	13.18	2.64	2.40
CUT R 25%	20.7%	21.2%	6.8%	9.8%
CUT R 50%	39.1%	37.7%	17.4%	18.7%
CUT Q 50%	40.2%	37.8%	7.6%	8.6%
NO STOCK	92.1%	91.8%	52.7%	67.0%

HORIZON = 180 DAYS				
BASE	33.20	32.31	5.15	4.55
CUT R 25%	10.8%	11.5%	15.0%	19.4%
CUT R 50%	21.8%	22.4%	33.0%	39.4%
CUT Q 50%	31.7%	30.6%	21.4%	22.8%
NO STOCK	80.9%	80.4%	142.%	174.3%

SIMULATED VS PROJECTED

INCREASE Q

(Q = 40; on hand = 32)

HORIZON = 90 DAYS	AMOUNT BOUGHT		BACKORDERS	
BASE	.420	.43	.252	.197
CUT R 25%	31.0%	26.6%	2.8%	3.9%
CUT R 50%	50.7%	46.7	6.3%	6.6%
CUT Q 50%	32.4%	33.3%	3.6%	4.1%
NO STOCK	92.4%	91.3%	16.7%	45.4%

HORIZON = 180 DAYS				
BASE	3.63	3.61	1.243	1.13
CUT R 25%	19.3%	19.4%	10.1%	10.2%
CUT R 50%	34.7%	35.4%	18.9%	19.1%
CUT Q 50%	27.5%	27.4%	8.9%	10.8%
NO STOCK	82.9%	83.3%	51.7%	68.3%

SIMULATED VS PROJECTED

LONG SUPPLY

(on hand = 64)

HORIZON = 90 DAYS	AMOUNT BOUGHT		BACKORDERS	
BASE	8.33	8.19	2.84	2.61
CUT R 25%	20.5%	21.5%	6.7%	9.2%
CUT R 50%	39.5%	38.4%	15.8%	17.1%
CUT Q 50%	29.5%	29.3%	8.5%	9.6%
NO STOCK	75.6%	86.8%	41.9%	53.8%

HORIZON = 180 DAYS				
BASE	22.68	22.43	6.25	5.59
CUT R 25%	12.4%	12.5%	13.8%	18.0%
CUT R 50%	24.4%	24.1%	29.6%	36.2%
CUT Q 50%	20.8%	20.4%	17.4%	20.4%
NO STOCK	72.1%	71.8%	100.%	123.3%

SIMULATED VS PROJECTED

HIGH ON HAND

(on hand = 32)

HORIZON = 90 DAYS	AMOUNT BOUGHT		BACKORDERS	
BASE	3.07	3.01	.997	.912
CUT R 25%	—	—	—	—
CUT R 50%	29.1%	28.5%	14.2%	16.2%
CUT Q 50%	27.7%	26.5%	10.1%	9.4%
NO STOCK	80.7%	80.5%	46.5%	58.2%

HORIZON = 180 DAYS				
BASE	5.75	5.72	1.594	1.523
CUT R 25%	—	—	—	—
CUT R 50%	17.7%	17.8%	25.0%	23.9%
CUT Q 50%	18.9%	18.6%	19.6%	18.6%
NO STOCK	65.8%	65.3%	101.0%	112.6%

SIMULATED VS PROJECTED

LOW R

(AYD = 10; AYF = 5; on hand = 4; base R = 2; base Q = 4; OST = 2 months)

HORIZON = 90 DAYS	AMOUNT BOUGHT		BACKORDERS	
BASE	16.70	16.56	1.16	1.02
CUT R 25%	17.9%	17.4%	22.4%	28.3%
CUT R 50%	33.5%	33.4%	50.9%	60.0%
CUT Q 50%	26.4%	26.5%	14.7%	18.4%
NO STOCK	83.9%	83.5%	225.9%	272.2%

HORIZON = 180 DAYS				
BASE	32.97	32.37	2.13	1.88
CUT R 25%	9.6%	9.4%	37.1%	39.5%
CUT R 50%	19.0%	19.0%	80.3%	91.6%
CUT Q 50%	17.3%	16.8%	31.5%	32.8%
NO STOCK	65.2%	64.8%	527.%	60.6%

SIMULATED VS PROJECTED

SHORT OST

(OST = 15 days)

HORIZON = 90 DAYS	AMOUNT BOUGHT		BACKORDERS	
BASE	17.12	16.56	32.52	32.22
CUT R 25%	17.3%	17.4%	1.3%	1.4%
CUT R 50%	33.6%	33.4%	2.1%	2.2%
CUT Q 50%	27.0%	26.5%	2.0%	2.4%
NO STOCK	83.4%	83.5%	3.3%	3.7%

HORIZON = 180 DAYS				
BASE	33.17	32.37	45.41	44.6
CUT R 25%	9.3%	9.4%	2.2%	2.5%
CUT R 50%	19.4%	19.0%	4.0%	4.4%
CUT Q 50%	17.1%	16.8%	3.9%	4.8%
NO STOCK	64.8%	64.8%	7.1%	7.8%

SIMULATED VS PROJECTED

LONG OST

(OST = 240 days)

CASE	HORIZON	RATIOS CUT R 25%	CUT R 50%	CUT Q 50%
Base	3 mos.	4.5	4.1	6.7
	6	1.2	1.1	2.0
Low freq	3	13.4	11.1	8.4
	6	2.7	2.6	2.7
Hi freq	3	12.4	12.0	15.5
	6	3.3	2.7	4.6
Scale	3	4.5	4.1	6.6
	6	1.3	1.1	2.0
Low Q	3	3.6	3.3	4.9
	6	1.1	1.0	1.5
Hi Q	3	7.0	6.4	9.0
	6	1.6	1.5	2.6
Hi ASS	3	8.8	8.0	11.4
	6	2.0	1.9	3.1
Long Supply	3	39.	35.	51.
	6	7.5	6.9	10.3
Low R	3	—	4.2	5.5
	6	—	1.2	1.8

INDIVIDUAL ITEM EFFECTIVENESS RATIOS

FIGURE B.2

APPENDIX C

SUPPLEMENTARY RUNS

Figures C.1 and C.2 differ from those in the main text in that an empirical variance estimator was used (Section 2.2). Projected backorders went up and effectiveness ratios went down somewhat, but ranking of the alternatives was not affected.

Figures C.3 and C.4 differ from those in the main text in that priority class I items, and then priority class I and II items, were excluded from the data base. The only effect of any note was that effectiveness ratio for the retention modification policy went down significantly when priority class I items were eliminated (Figure C.3). Ranking of alternatives was unchanged.

3RD INFANTRY DIVISION: EMPIRICAL VARIANCE

HORIZON	POLICY	DOLLARS SAVED (b)	DECREASE IN FILL (c)	EFFECTIVENESS RATIO (b) ÷ (c)
3 MONTHS	(BASE)		(81.7%)	
	CUT ROWP 25%	17.9%	1.9%	9.4
	CUT ROWP 50%	33.2%	4.3%	7.7
	CUT OP LEVEL 50%	10.9%	1.6%	6.8
	ADD 3 to RETAIN CRITERIA	7.6%	0.7%	10.9
6 MONTHS	(BASE)		(80.9%)	
	CUT ROWP 25%	9.8%	2.6%	3.8
	CUT ROWP 50%	19.1%	6.3%	3.0
	CUT OP LEVEL 50%	6.1%	2.5%	2.4
	ADD 3 TO RETAIN CRITERIA	5.3%	1.3%	4.1

FIGURE 6.1

FT CARSON: EMPIRICAL VARIANCE

HORIZON	POLICY	DOLLARS SAVED (b)	DECREASE IN FILL (c)	EFFECTIVENESS RATIO (b) ÷ (c)
3 MONTHS	(BASE)		(88.1%)	
	CUT ROWP 25%	5.9%	0.5%	11.8
	CUT ROWP 50%	10.5%	1.2%	8.8
	CUT OP LEVEL 50%	9.8%	1.6%	6.1
	ADD 3 to RETAIN CRITERIA	7.6%	3.4%	2.2
6 MONTHS	(BASE)		(87.0%)	
	CUT ROWP 25%	3.3%	0.7%	4.7
	CUT ROWP 50%	6.0%	1.7%	3.5
	CUT OP LEVEL 50%	5.7%	2.5%	2.3
	ADD 3 TO RETAIN CRITERIA	4.8%	5.2%	0.9

FIGURE C.2

3RD INFANTRY DIVISION: EXCLUDING PRIORITY CLASS I

HORIZON	POLICY	DOLLARS SAVED (b)	DECREASE IN FILL (c)	EFFECTIVENESS RATIO (b) ÷ (c)
3 MONTHS	(BASE)		(83.1%)	
	CUT ROWP 25%	20.5%	1.9%	10.8
	CUT ROWP 50%	40.1%	4.0%	10.0
	CUT OP LEVEL 50%	13.8%	1.9	7.3
	ADD 3 to RETAIN CRITERIA	6.2%	0.5%	12.4
6 MONTHS	(BASE)		(83.0%)	
	CUT ROWP 25%	10.8%	2.3%	4.7
	CUT ROWP 50%	21.6%	5.3%	4.1
	CUT OP LEVEL 50%	7.4%	2.6%	2.8
	ADD 3 TO RETAIN CRITERIA	4.6%	0.9%	5.1

FIGURE C.3

3RD INFANTRY DIVISION: EXCLUDING PRIORITY CLASS I AND II

HORIZON	POLICY	DOLLARS SAVED (b)	DECREASE IN FILL (c)	EFFECTIVENESS RATIO (b) ÷ (c)
3 MONTHS	(BASE)		(83.0%)	
	CUT ROWP 25%	20.6%	1.9%	10.8
	CUT ROWP 50%	40.2%	4.0%	10.1
	CUT OP LEVEL 50%	15.0%	1.9%	7.9
	ADD 3 to RETAIN CRITERIA	6.6%	0.4%	16.5%
6 MONTHS	(BASE)		(82.9%)	
	CUT ROWP 25%	10.7%	2.3%	4.7
	CUT ROWP 50%	21.3%	5.2%	4.1
	CUT OP LEVEL 50%	8.1%	2.6%	3.1
	ADD 3 TO RETAIN CRITERIA	4.9%	0.7%	7.0

FIGURE C.4

APPENDIX D

VALIDITY OF PRIORITY CLASS DEFINITIONS

A test was made of the validity of basing priority class on the average issue priority designation of requisitions for an item. Are users consistent in what items they submit priority requisitions for?

Nine months of requisitions were available for each of the DSUs. For each item, the requisitions were divided in half; those which occurred in the first five months, and those which occurred in the second four months. An item was included in the test only if it had at least three requisitions in the first half and at least one in the second half.

The research question was: would the items with high priority requisitions in the first half be those with high priority requisitions in the second half?

Table D.1 shows the results. For example, 10.2% of 3rd Infantry items qualified for priority class 1 or 2 based on first half of their requisitions. These items accounted for 55% of all items qualifying based on second half of requisitions.

The numbers in Figure D-1 show there is in fact some consistency in which items the users, operating within the guidelines of AR 725-50, consider important. Had there been no consistency at all, the %'s for first half and second half would have been the same (i.e. 10.2% of first half items would account for 10.2% of second half items).

In an effort to get even better consistency figures, an alternative method for assigning priority was tried. Priority classes were based on highest issue priority recorded on an item instead of the average. The logic was that the average might be brought down by items the user was ordering to restock his PLL when not at zero balance. Results, shown in Figure D-2, were not particularly promising in that consistency shown is certainly no higher than in Figure D-1.

CONSISTENCY

UNIT	PRIORITY CLASS	% OF ITEMS (1ST HALF)	COVERAGE (2ND HALF)
3RD INF	1	1.1%	30.0%
	1 + 2	10.2%	55%
CARSON	1	3.9%	18%
	1 + 2	38.3%	60%

FIGURE D-1

CONSISTENCY: ALTERNATIVE METHOD

UNIT	PRIORITY CLASS	% OF ITEMS (1ST HALF)	COVERAGE (2ND HALF)
3RD INF	1	15%	57%
CARSON	1	33%	52%

FIGURE D-2

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