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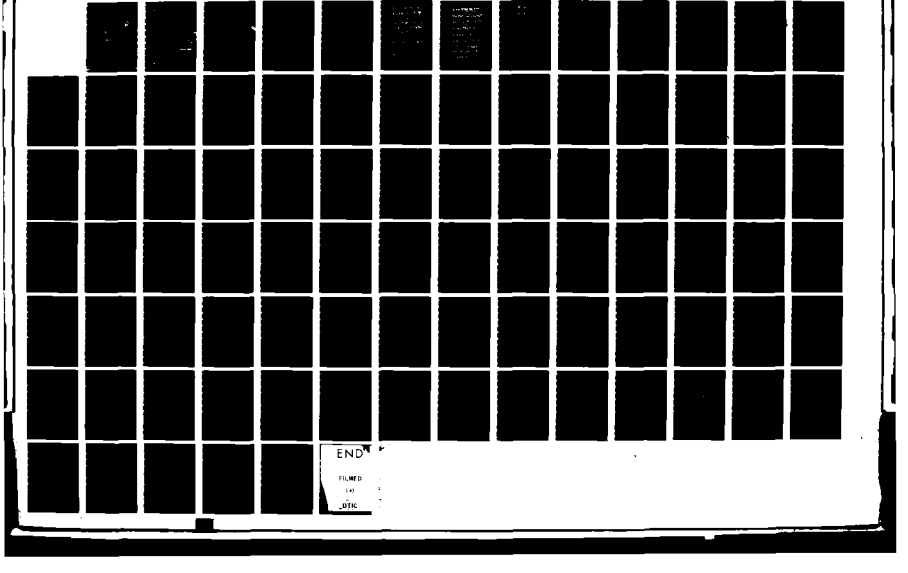

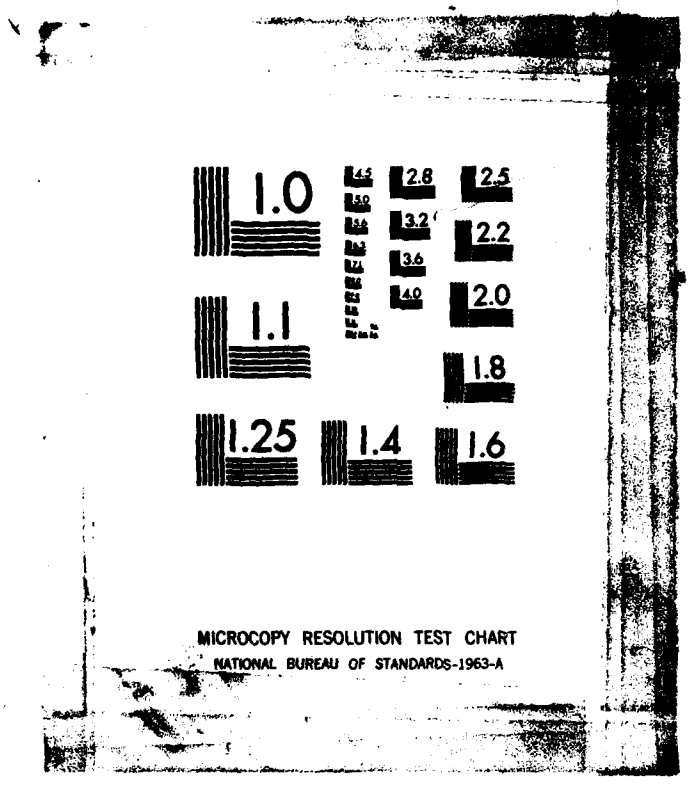
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UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

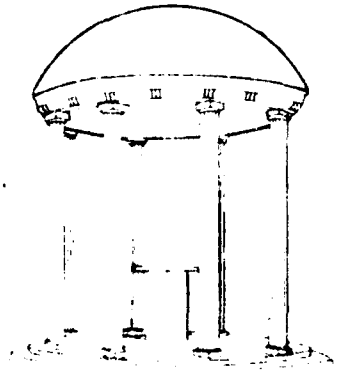
TESTING THE COST EFFECTIVENESS OF AN INVENTORY FILTERING RULE USING EMPIRICAL DATA

(12)

Technical Report #23

Douglas Blazer

February 1983



SCHOOL OF BUSINESS ADMINISTRATION

OPERATIONS RESEARCH AND SYSTEMS ANALYSIS

TESTING THE COST EFFECTIVENESS OF AN INVENTORY FILTERING RULE USING EMPIRICAL DATA

(12)

Technical Report #23

Douglas Blazer

February 1983

Work Sponsored By

Office of Naval Research (N00014-78-C0467)

Decision Control Models in Operations Research

Harvey M. Wagner
Principal Investigator
School of Business Administration
University of North Carolina at Chapel Hill

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In this report we evaluate the cost effectiveness of an inventory filtering rule shown in Technical Report #22. We use United States Air Force empirical individual customer order distributions to generate 1080 cases. We compare the operating characteristics of the inventory replenishment policy for the unfiltered orders to the policy for the filtered orders. We show that filtering can significantly reduce total expected costs, with the majority of reduction resulting from decreased inventory investment.

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FOREWARD

As part of the on-going program in "Decision Control Models in Operations Research," Mr. Douglas Blazer has extended the study of removing large demands in the determination of an inventory replenishment policy. In this report, he examines the cost effectiveness of a filtering rule which identifies a threshold value T such that any order equal to or exceeding T is specially handled. Using United States Air Force empirical customer order data, he generates two streams of customer orders; one stream with filtering and one without. The paper provides the results of comparing the cost performance of the inventory replenishment policy for the filtered orders to the unfiltered orders. Other related reports dealing with this program are given on the following pages.

Harvey M. Wagner
Principal Investigator

Richard Ehrhardt
Co-Principle Investigator

MacCormick, A. (1974), Statistical Problems in Inventory Control, ONR and ARO Technical Report 2, December 1974, School of Organization and Management, Yale University, 244 pp.

Estey, A. S. and R. L. Kaufman (1975), Multi-Item Inventory System Policies Using Statistical Estimates: Negative Binomial Demands (Variance/Mean = 9), ONR and ARO Technical Report 3, September 1975, School of Organization and Management, Yale University, 85 pp.

Ehrhardt, R. (1975), Variance Reduction Techniques for an Inventory Simulation, ONR and ARO Technical Report 4, September 1975, School of Organization and Management, Yale University, 24 pp.

Kaufman, R. (1976), Computer Programs for (s,S) Policies Under Independent or Filtered Demands, ONR and ARO Technical Report 5, School of Organization and Management, Yale University, 65 pp.

Kaufman, R. and J. Klincewicz (1976), Multi-Item Inventory System Policies Using Statistical Estimates: Sporadic Demands (Variance/Mean = 9), ONR and ARO Technical Report 6, School of Organization and Management, Yale University, 58 pp.

Ehrhardt, R. (1976), The Power Approximation: Inventory Policies Based on Limited Demand Information, ONR and ARO Technical Report 7, June 1976, School of Organization and Management, Yale University, 106 pp.

Klincewicz, J. G. (1976), Biased Variance Estimators for Statistical Inventory Policies, ONR and ARO Technical Report 8, August 1976, School of Organization and Management, Yale University, 24 pp.

Klincewicz, J. G. (1976), Inventory Control Using Statistical Estimates: The Power Approximation and Sporadic Demands (Variance/Mean = 9), ONR and ARO Technical Report 9, November 1976, School of Organization and Management, Yale University, 52 pp.

Klincewicz, J. R. (1976), The Power Approximation: Control of Multi-Item Inventory Systems with Constant Standard-Deviation-To-Mean Ratio for Demand, ONR and ARO Technical Report 10, November 1976, School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, 47 pp.

Kaufman, R. L. (1977), (s,S) Inventory Policies in a Nonstationary Demand Environment, ONR and ARO Technical Report 11, April 1977, School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, 155 pp.

Ehrhardt, R. (1977), Operating Characteristic Approximations for the Analysis of (s,S) Inventory Systems, ONR and ARO Technical Report 12, April 1977, School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, 109 pp.

Schultz, C. R., R. Ehrhardt, and A. MacCormick (1977), Forecasting Operating Characteristics of (s,S) Inventory Systems, ONR and ARO Technical Report 13, December 1977, School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, 47 pp.

Schultz, C. R. (1979), (s,S) Inventory Policies for a Wholesale Warehouse Inventory System, ONR Technical Report 14, April 1979, School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, 75 pp.

Schultz, C. R. (1980), Wholesale Warehouse Inventory Control with Statistical Demand Information, ONR Technical Report 15, December 1980, School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, 74 pp.

Ehrhardt, R. and G. Kastner (1980), An Empirical Comparison of Two Approximately Optimal (s,S) Inventory Policies, Technical Report 16, December 1980, School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, 22 pp.

Ehrhardt, R. (1980), (s,S) Policies for a Dynamic Inventory Model with Stochastic Lead Times, Technical Report 17, December 1980, School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, 20 pp.

Mosier, C. (1981), Revised (s,S) Power Approximation, Technical Report 18, February 1981, School of Business Administration, University of North Carolina at Chapel Hill, 18 pp.

Blazer, D. and M. McClelland (1981), An Inventory Model for Special Handling of Extreme Value Demands, Technical Report 19, December 1981, School of Business Administration, University of North Carolina at Chapel Hill, 10 pp.

Mitchell, J.C. (1982), Choosing Single-Item Service Objectives in a Multi-Item Base-Stock Inventory System, Technical Report 20, School of Business Administration, University of North Carolina at Chapel Hill, 30 pp.

Blazer, D. (1983), Operating Characteristics for an Inventory Model That Special Handles Extreme Value Demand, Technical Report #21, School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, 15pp.

Blazer, D. (1983), Evaluation of a "Large Pop" Filtering Rule for Inventory Management Systems, Technical Report #22, School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, 32pp.

ABSTRACT

In this report we evaluate the cost effectiveness of an inventory filtering rule shown in Technical Report #22. We use United States Air Force empirical individual customer order distributions to generate 1080 cases. We compare the operating characteristics of the inventory replenishment policy for the unfiltered orders to the policy for the filtered orders. We show that filtering can significantly reduce total expected costs with the majority of the reduction resulting from decreased inventory investment.

TABLE OF CONTENTS

1. INTRODUCTION

We showed in [1] and [3] that special handling of extreme value demand can significantly reduce costs for an infinite horizon inventory model with stationary linear holding and penalty costs. We assumed a periodic review model both with and without a fixed set-up cost. In [1] and [3] we assumed Poisson and negative binomial distributions for weekly demand. We defined a point τ such that any weekly demand equal to or exceeding τ is specially handled; existing stock is not used to satisfy the extreme value demand.

In a practical setting, the parameters for weekly demand distributions are uncertain and only can be estimated by past demand data. Seldom can all items in an inventory system be fitted to a common distribution like the Poisson or negative binomial. Further, an inventory manager cannot suspend action on an entire week's orders to determine if the total orders for the week meet or exceed some threshold value. Therefore, in a practical setting, an inventory manager needs a filtering rule that uses past individual customer order data to identify a point T, such that any order that is equal to or greater than T is specially handled.

We considered such a filtering rule in [2]. We examined the statistical performance of a filtering rule using simulated customer order distributions. We found the statistical performance of our

filtering rule to be superior to any of the classical statistical outlier rules or any other inventory filtering rules in the literature.

In this report, we examine the cost effectiveness of our inventory filtering rule in a practical setting. We use United States Air Force historic customer order data to generate customer order distributions. We sample from these empirical order distributions to generate a stream of orders. By applying the filtering rule to this stream of orders we obtain a weekly distribution of both filtered and unfiltered demand. We then use these weekly demand distributions in a periodic review inventory model and compare the resulting costs from the unfiltered demand to those from the filtered demand.

In Section 1.1, we describe the United States Air Force customer order data. We categorize the data according to high and low demand and according to high and low value to determine the sensitivity of special handling to these parameters. In Section 1.2, we describe the filtering rule and display the statistical results of applying the rule to the United States Air Force data. We document the periodic review inventory model in Section 1.3, and display the experimental design in Section 1.4.

In Section 2, we provide the results in the same format as [1]. We show the reduction in total costs in Section 2.1, the categorization of cost savings in Section 2.2, unfilled demand versus the reduction in inventory investment in Section 2.3, and the breakeven special handling costs in Section 2.4. Section 3 summarizes the results.

1.1 THE DATA

We use customer order data from the retail level of the United States Air Force inventory system. A year's customer order history was provided for items in the following Federal Supply Classes:

Screws

Rivets

Fastening Devices

Abrasive Material

Rings, Shims and Spacers

Fittings for Rope, Cable and Chain

Aircraft Hydraulic, Vacuum and De-Icing System Components

Toiletry Paper Products

Office

Office Devices and Accessories.

We took 30 items with at least 1 item from each of the classes above. We provide the order distribution for these 30 items in Appendix I. Table 1 provides a summary of the 30 items sequenced by the average dollar value of demand per year. We have assigned prices to the 30 items so that we can categorize the items as to whether they are high demand/low demand and high value/low value:

(1) if demand > 500 items per year, then the item is categorized as high demand, and

(2) if the price ≥ $250 per item, then the item is categorized as high value.

Table 2 provides a summary of the categorization.

30 ITEM SUMMARY

Average Dollar Value of Demand Per Year	ITEM	Average Orders Per Week	Average Customer Demand Per Year	Price
$3560544	A	5.07	11868.48	$ 300.00
3008200	C	.98	3008.20	1000.00
1984580	B	.78	3969.16	500.00
531232	J	.59	664.04	800.00
455832	I	1.28	1012.96	450.00
369512	AC	1.29	3695.12	100.00
268450	F	1.02	383.50	700.00
224055	L	1.00	298.74	750.00
220662	E	.69	490.36	450.00
220272	T	2.42	1101.36	200.00
130468	S	.81	2007.20	65.00
107770	R	1.64	431.08	250.00
61490	O	.86	122.98	500.00
32664	V	1.87	403.26	81.00
29173	AA	3.48	2224.06	13.00
19448	H	.73	388.96	50.00
16236	Q	1.05	16236.48	1.00
13182	X	1.47	202.80	65.00
11771	D	.75	392.34	30.00
10847	K	.51	1549.60	7.00
9110	AB	2.75	3036.54	3.00
6401	N	1.16	581.88	11.00
5125	M	1.57	465.93	11.00
4290	P	1.66	14300.78	.30
2754	W	1.21	5860.40	.47
2369	AD	4.23	1462.50	1.62
2221	Y	2.63	888.42	2.50
993	Z	1.90	680.42	1.46
248	G	1.46	451.10	.55
128	U	1.28	584.74	.22

Table 1

ITEM CATEGORIZATION

DEMAND \ VALUE	Low	High
Low	D,G,H,V,W,X	E,F,L,O,R
High	K,M,N,P,Q,S, T,U,Y,Z,AA, AB,AC,AD	A,B,C,I,J

Table 2

1.2 THE FILTERING RULE

We use the empirical order distribution to generate a stream of orders that are subjected to a filtering rule. In this section, we describe the filtering rule, the process for applying the filtering rule, and the results of applying the rule.

1.2.1 The Experimental Process

We filter out "large pop" customer orders with the rule:

Let $X_1, X_2, \ldots, X_k$ be the k largest customer orders during N weeks of orders, where X_1 is the largest individual order and X_k the smallest. Given a value $r>1$, let $X_0=rX_1$ and define J_1 as the set of j, for $1\leq j\leq 5$, such that $X_{j-1}\geq rX_j$. Given a value $\gamma>0$, let $w=\gamma(X_1-X_k)$. Define J_2 as the set of j for $6\leq j\leq k$, such that $X_{j-1}\geq rX_j$ and $X_{j-1}-X_j>w$. Set

$$T_r = \min_{j\in J_1 \cup J_2}(rX_j).$$

Any order that is equal to or larger than T_r is specially handled. The parameters for the filtering rule are N, k, γ, and r. We set k=10, r=1.8, and γ=.2. In [2] we showed the filtering rule worked well using 25 to 50 orders. Therefore, we set N based on the average number of customer orders per week, so that in the N periods there average between 25 to 50 customer orders. Let a be the average number of orders per week. The specific rule for N is:

(1) if $a \geq 4$ then N=10,

(2) if $2 \leq a < 4$ then N=13,

(3) if $.95 \leq a < 2$ then N=26, and

(4) if $a < .95$ then N=52.

In Table 3, we show N for each item.

Thus we sample from the empirical customer order distribution to generate N periods of customer orders. We then apply the filtering rule to find a value for T that is used to filter out any large pops in the next N periods of customer orders. We use the next N periods of customer orders to find a new value of T for the subsequent N periods. For N<52, we generate 250 weeks of demand; for N=52, we generate 510 weeks of demand. We use the first N weeks to "initialize" the process. We derive two weekly demand distributions: with filtering large pops and without.

1.2.2 The Results

We display the results in Table 3, which shows N (the parameter for the filtering rule), the item designation, the average demand per week (unfiltered and filtered), the percentage reduction in average demand, and the percentage of orders that are filtered. Note the significant reduction in demand per week due to the filtering.

STATISTICAL RESULTS OF OUR FILTERING RULE

INTERVAL N	Average Number of Orders Per Week	ITEM	Average Unfiltered Demand Per Week	Average Filtered Demand Per Week	Percent Reduction in Average Demand Per Week	Percent of Orders Filtered
10	5.07	A	228.24	194.75	33.5	4.67
	4.23	AD	28.13	21.83	22.4	5.86
13	2.42	T	21.18	11.84	44.1	6.92
	2.63	Y	17.09	6.89	59.7	7.01
	3.48	AA	43.16	32.79	24.0	7.90
	2.75	AB	58.40	5.94	89.8	11.63
26	.98	C	57.85	40.00	30.9	13.86
	1.02	F	7.28	4.28	42.0	14.07
	1.46	G	8.68	3.66	57.8	13.93
	1.28	I	19.48	9.36	52.0	12.63
	1.00	L	5.75	4.12	28.3	7.24
	1.21	M	112.70	79.84	29.2	8.24
	1.16	N	11.19	7.25	35.3	9.02
	1.66	P	275.02	201.44	73.6	14.47
	1.05	Q	312.24	248.80	20.3	6.75
	1.64	R	8.29	5.43	34.6	3.09
	1.28	U	11.25	7.57	32.7	6.32
	1.87	V	7.76	6.84	11.8	3.71
	1.57	W	8.96	8.02	10.5	1.45
	1.47	X	3.90	3.40	12.8	5.26
	1.90	Z	13.09	9.73	25.7	4.11
	1.29	AC	71.06	37.20	47.6	8.83
52	.78	B	76.33	69.24	9.3	2.01
	.75	D	7.55	5.06	33.0	11.87
	.69	E	9.43	7.61	19.4	4.49
	.73	H	7.48	6.35	15.2	3.30
	.59	J	12.77	7.32	42.7	14.93
	.51	K	29.80	18.41	38.2	10.00
	.86	O	2.37	1.00	57.9	15.04
	.81	S	38.60	35.60	7.8	2.75

Table 3

In all but 2 cases the average demand per week is reduced at least 10%, and in 23 of the 30 cases demand is reduced at least 20%. Also note that the percentage of orders that are filtered out never exceeds 15.04%. The percentage of orders that are filtered closely resembles the cumulative probability of demand specially handled in [1] and [3], which demonstrated significant cost savings.

1.3 THE MODEL

We assume a single-item inventory model. We also assume a periodic review of an item's inventory level and employ a stationary, discrete-time stochastic process to describe an item's demand. The demand sequence $q_1, q_2, \ldots, q_n$ consists of independently, identically distributed non-negative integer values. For each item there are two demand sequences: unfiltered demand and filtered demand as described in Section 1.2.

Demands are met as long as stock is sufficient; when a stock-out occurs, the unfilled demand is completely backlogged until a stock replenishment eventually occurs.

Items kept in inventory are conserved, there being no losses by deterioration, obsolescence, or pilferage; disposal is not allowed. Inventory on hand at the end of a current period is the inventory from the previous period plus any replenishment that arrives less demand in the current period. Replenishments are assumed to be delivered a fixed lead time L periods after being ordered. The time sequence of events within any period is taken to be order, delivery, demand.

We assume no time discounting of costs and postulate an unbounded horizon over which the item is demanded and stocked. We seek to minimize expected total cost per period.

The cost of a replenishment quantity y is assumed linear with fixed ordering cost K and constant unit cost c

$$c(y) = \begin{cases} K + cy & \text{for } y>0 \\ 0 & \text{for } y=0 \end{cases} .$$

Since all demand is filled eventually, and costs are not discounted, the constant unit cost c is not a factor in choosing a minimum cost policy, and is suppressed hereafter.

The inventory holding cost is proportional to any stock on hand at unit cost h

$$h(i) = \begin{cases} hi & \text{for } i>0 \\ 0 & \text{for } i\leq 0, \end{cases}$$

and the unit penalty cost π is applied to any quantity on backorder at the end of the period

$$\pi(i) = \begin{cases} 0 & \text{for } i\geq 0 \\ -\pi i & \text{for } i<0 \end{cases} .$$

The resulting expected total cost function, therefore, is linear in K, π, and h.

We postulate that control over replenishment is exercised by an (s,S) policy: whenever inventory x on-hand and on-order at the start of a period drops below s, an order is placed for a replenishment of size S-x.

We calculate approximate (s,S) policies using the Statistical Power Approximation [4]. The Statistical Power Approximation is an

algorithm for computing approximately optimal values for (s,S) using the sample mean $\bar{q}$ and variance $\bar{v}$ of demand. We assume that a demand history of fixed length is kept to compute the sample statistics, with equal weight being given to each observation. We call the fixed length a revision interval N, and it coincides with the number of periods used to derive the customer order threshold value T using the filtering rule. The values of $\bar{q}$, $\bar{v}$, and T may change from one interval to the next.

At each revision, we compute $\bar{q}$ and $\bar{v}$. Let t be a period at the beginning of which a revision is made; then

$$\bar{q} = \frac{\sum_{n=1}^{N} q_{t-n}}{N}$$

$$\bar{v} = \frac{\sum_{n=1}^{N} (q_{t-n} - \bar{q})^2}{N-1} .$$

The approximately optimal values (s,S) are found as follows. Let

$$D = (1.463)\bar{q}^{.364}\left(\frac{K}{h}\right)^{.498}[(L+1)\bar{v}]^{.0691} \qquad (1)$$

and

$$s_1 = (L+1)\bar{q} + [(L+1)\bar{q}]^{.416}\left(\frac{\bar{v}}{\bar{q}}\right)^{.603} U(z) \qquad (2)$$

$$S_1 = s_1 + D,$$

where U(z) is given by

$$U(z) = \frac{.182}{z} + 1.142 - 3.466z,$$

$$z = \left\{ \frac{\bar{q}^{.364}\left(\frac{K}{h}\right)^{.498}}{\left(1+\frac{\pi}{h}\right)[(L+1)\bar{v}]^{.431}} \right\}^{\frac{1}{2}} . \qquad (3)$$

If $\frac{D}{\bar{q}}$ is greater than 1.5, let $s=s_1$ and $S=S_1$. Otherwise compute

$$S_2 = (L+1)\bar{q} + a[(L+1)\bar{v}]^{\frac{1}{2}}, \qquad (4)$$

where a is the solution to

$$\Phi(a) = \frac{\pi}{\pi+h} \qquad (5)$$

and $\Phi(\cdot)$ is the cumulative distributuion function of the unit normal distribution. The policy parameters are given by

$$s = \text{minimum } \{s_1, s_2\}$$

$$S = \text{minimum } \{S_1, S_2\} .$$

The values of S_1, D, and S_2 are rounded to the nearest integer.

1.4 EXPERIMENTAL DESIGN

We study the model for the input parameters shown in Table 4. We employ both unfiltered and filtered weekly demand distributions from the 30 items in Table 1. Using the United States Air Force annual holding cost of 26% and the item's price from Table 1, we derive a holding cost per period (h=(.26*price per unit) /52). The stock out costs are set to result in service levels ($R = \frac{\pi}{\pi+h}$) of 80%, 90%, and 99%. The replenishment leadtimes are 0, 2, and 4. The set-up cost values are 16 and 32, which bracket the range of set-up costs that we have seen in practice. For example, the United States Air Force uses a set-up cost of $16.84. We use a full factorial experimental design, which generates 1080 combination of parameters; 540 cases are with filtering and 540 cases without filtering.

EXPERIMENTAL DESIGN

Parameters	Levels	Number of Levels
Demand Distribution	30 Items	30
Filtering	Unfiltered, Filtered	2
Service Level (R)	.80, .90, .99	3
Replenishment Leadtime (L)	0, 2, 4	3
Replenishment Set-up Cost (K)	16, 32	2

Table 4

2. RESULTS

We examine the reduction in total costs, categorize the cost savings, display the value of demand unfilled versus the reduction in inventory investment, and determine the breakeven special handling cost.

2.1 REDUCTION IN TOTAL COSTS

Appendix II presents six tables showing each item's reduction in total costs for different service levels R. We also show the percent reduction

$$\frac{\text{Total Expected Cost Per Period Unfiltered} - \text{Total Expected Cost Per Period Filtered}}{\text{Total Expected Cost Per Period Unfiltered}} \times 100$$

Each table is for a given set-up cost K and leadtime L. We present the items sequenced by average value per year demanded (see Table 1).

The results for the reduction in total costs are consistent over all parameter settings and generally agree with our findings in [1]. The percent reduction in total costs is monotonically increasing as:

(1) mean demand becomes sufficiently small;

(2) the service level ($\frac{\pi}{\pi+h}$) becomes sufficiently large; and

(3) the unit price becomes sufficiently large.

Note the results of increasing the set-up cost are not consistent and do not support our findings in [1]. In [1] the ratio $\frac{K}{h}$ was 0, 32, and 64, whereas in this report K=16 and 32 and the ratio $\frac{K}{h}$ varies from less than 1 to over 21,000. Secondly, for any one item the ratio $\frac{K}{h}$ does not change as significantly from one parameter setting to the next setting as in [1]. For example, the ratio $\frac{K}{h}$ for item L is 4.27 for K=16 and 8.53 for K=32.

To further illustrate the effect of unit price, we changed the unit cost for items I, J, and N. The results are consistent for all parameter settings; however, we only display L=0 and K=16 in Table 5.

THE EFFECT OF CHANGING UNIT PRICE
ON THE PERCENT REDUCTION OF TOTAL COSTS — L=0, K=16

Item	Price	R=.8	R=.9	R=.99
I	$450.00	62.5	64.3	69.7
	11.00	38.0	44.6	56.8
J	800.00	49.2	54.2	66.0
	50.00	37.2	44.3	54.1
N	11.00	21.8	24.1	38.4
	450.00	43.2	45.3	60.7

Table 5

Note we decrease the unit price for items I and J, and there is a decrease in the percent cost reduction. We increase the price for item N and the percent cost reduction increases.

2.2 CATEGORIZATION FOR COST SAVINGS

In Appendix III we categorize the cost savings into holding, penalty and set-up. Appendix III shows all 30 items with a separate table for each of the four high demand/low demand and high value/low value categories. We present all cases for L=0, R=.8, K=16 and K=32, and all cases for L=2, R=.9, K=16 and K=32. Thus, 16 of the 72 possible tables are shown. Tables 6 through 9 summarize the results of Appendix III. In Table 6, notice that the 30 item inventory system with parameter settings of L=0, R=.8, and K=16 saves a total of $677.86 per period which is a 31.7% cost reduction. More than half of that cost reduction comes from inventory holding cost savings. Over two-thirds of the cost savings comes from the 5 high demand/high value items.

The results of categorization of cost savings are consistent over all parameter settings and agree with our results in [1]. Filtering large pop customer orders:

(1) decreases the amount to stock, thereby decreasing the amount of holding costs.

(2) decreases the penalty cost incurred.

(3) decreases the frequency of replenishment, thereby decreasing the expected set-up cost.

CATEGORIZATION OF COST SAVINGS

SUMMARY

L=0
R=.8
K=16

	Unfiltered	Filtered	Difference	% Reduction
HIGH DEMAND/HIGH VALUE				
INVENTORY COST	$905.80	$642.95	$262.85	29.0
PENALTY COST	636.93	436.00	200.93	31.5
SET-UP COST	52.18	49.27	2.91	5.6
TOTAL COST	1594.91	1128.22	466.69	29.3
HIGH DEMAND/LOW VALUE				
INVENTORY COST	112.99	68.29	44.70	39.6
PENALTY COST	82.53	41.33	41.20	49.9
SET-UP COST	42.16	33.85	8.31	19.7
TOTAL COST	237.68	143.47	94.21	39.6
LOW DEMAND/HIGH VALUE				
INVENTORY COST	140.27	82.04	58.23	41.5
PENALTY COST	93.86	43.44	50.42	53.7
SET-UP COST	33.12	29.20	3.92	11.8
TOTAL COST	267.25	154.68	112.57	42.1
LOW DEMAND/LOW VALUE				
INVENTORY COST	14.06	12.22	1.84	13.1
PENALTY COST	9.11	7.68	1.43	15.7
SET-UP COST	13.64	12.52	1.12	8.2
TOTAL COST	36.81	32.42	4.39	11.9
TOTAL				
INVENTORY COST	1173.12	805.50	367.62	31.3
PENALTY COST	822.43	528.45	293.98	35.7
SET-UP COST	141.10	124.84	16.26	11.5
TOTAL COST	2136.65	1458.79	677.86	31.7

Table 6

CATEGORIZATION OF COST SAVINGS

SUMMARY

L=0
R=.8
K=32

	Unfiltered	Filtered	Difference	% Reduction
HIGH DEMAND/HIGH VALUE				
INVENTORY COST	$918.58	$652.44	$266.14	29.0
PENALTY COST	645.15	424.87	220.28	34.1
SET-UP COST	98.39	87.92	10.47	10.6
TOTAL COST	1662.12	1165.23	496.89	29.9
HIGH DEMAND/LOW VALUE				
INVENTORY COST	127.47	79.80	47.67	37.4
PENALTY COST	82.69	42.39	40.30	48.7
SET-UP COST	60.06	50.82	9.24	15.4
TOTAL COST	270.22	173.01	97.21	36.0
LOW DEMAND/HIGH VALUE				
INVENTORY COST	153.88	89.74	64.14	41.7
PENALTY COST	85.45	46.54	38.91	45.5
SET-UP COST	43.62	41.74	1.88	4.3
TOTAL COST	282.95	178.02	104.93	37.1
LOW DEMAND/LOW VALUE				
INVENTORY COST	17.13	15.33	1.80	10.5
PENALTY COST	11.18	9.39	1.79	16.0
SET-UP COST	20.41	18.52	1.89	9.3
TOTAL COST	48.72	43.24	5.48	11.2
TOTAL				
INVENTORY COST	1217.06	837.31	379.75	31.2
PENALTY COST	824.47	523.19	301.28	36.5
SET-UP COST	222.48	199.00	23.48	10.6
TOTAL COST	2264.01	1559.50	704.51	31.1

Table 7

CATEGORIZATION OF COST SAVINGS

SUMMARY

L=4
R=.9
K=16

	Unfiltered	Filtered	Difference	% Reduction
HIGH DEMAND/HIGH VALUE				
INVENTORY COST	$2805.13	$1977.96	$827.17	29.5
PENALTY COST	1882.55	1253.80	628.75	33.4
SET-UP COST	51.18	47.56	3.62	7.1
TOTAL COST	4738.86	3279.32	1459.54	30.8
HIGH DEMAND/LOW VALUE				
INVENTORY COST	371.77	218.87	152.90	41.1
PENALTY COST	206.06	88.14	117.92	57.2
SET-UP COST	40.75	30.95	9.80	24.0
TOTAL COST	618.58	337.96	280.62	45.4
LOW DEMAND/HIGH VALUE				
INVENTORY COST	465.48	273.74	191.74	41.2
PENALTY COST	215.34	85.17	130.17	60.4
SET-UP COST	31.07	25.30	5.77	18.6
TOTAL COST	711.89	384.21	327.68	46.0
LOW DEMAND/LOW VALUE				
INVENTORY COST	35.88	30.41	5.47	15.2
PENALTY COST	16.89	13.46	3.43	20.3
SET-UP COST	12.42	11.27	1.15	9.3
TOTAL COST	65.19	55.14	10.05	15.4
TOTAL				
INVENTORY COST	3678.26	2500.98	1177.28	32.0
PENALTY COST	2320.84	1440.57	880.27	37.9
SET-UP COST	135.42	115.08	20.34	15.0
TOTAL COST	6134.52	4056.63	2077.89	33.9

Table 8

CATEGORIZATION OF COST SAVINGS

SUMMARY

L=4
R=.9
K=32

	Unfiltered	Filtered	Difference	% Reduction
HIGH DEMAND/HIGH VALUE				
INVENTORY COST	$2868.13	$2013.14	$854.99	29.8
PENALTY COST	1803.01	1183.15	619.86	34.4
SET-UP COST	92.73	84.01	8.72	9.4
TOTAL COST	4763.87	3280.30	1483.57	31.1
HIGH DEMAND/LOW VALUE				
INVENTORY COST	415.50	223.68	191.82	46.2
PENALTY COST	191.59	90.65	100.94	52.7
SET-UP COST	54.09	46.01	8.08	14.9
TOTAL COST	661.18	360.34	300.84	45.5
LOW DEMAND/HIGH VALUE				
INVENTORY COST	507.62	275.76	231.86	45.7
PENALTY COST	219.34	111.81	107.53	49.0
SET-UP COST	38.78	39.04	-.26	-.7
TOTAL COST	765.74	426.61	339.13	44.3
LOW DEMAND/LOW VALUE				
INVENTORY COST	38.08	32.90	5.18	13.6
PENALTY COST	18.46	16.32	2.14	11.6
SET-UP COST	18.35	16.96	1.39	7.6
TOTAL COST	74.89	66.18	8.71	11.6
TOTAL				
INVENTORY COST	3829.33	2545.48	1283.85	33.5
PENALTY COST	2232.40	1401.93	830.47	37.2
SET-UP COST	203.95	186.02	17.93	8.8
TOTAL COST	6265.68	4133.43	2132.25	34.0

Table 9

2.3 UNFILLED DEMAND VERSUS THE REDUCTION IN INVENTORY INVESTMENT

We compare the amount of inventory investment saved with filtering to the cost of incurring that savings, specifically the increase in the total demand unfilled including the filtered orders. If we can save a significant amount of inventory investment without incurring a substantial increase in the amount of demand left unfilled, filtering large customer orders would appear beneficial.

Appendix IV displays the difference in the value of unfilled demand versus the reduction in inventory investment. We select 16 items: four from each of the four demand/value categories. We show one item from each category with parameter settings of L=0, R=.8, K=16 and K=32. We then select another item from each category with parameter settings of L=0, R=.9, K=16 and K=32. We repeat this process using the same parameters except L=4. Although only 16 of the 540 possible cases are shown, they are indicative of all the cases.

In practically all the cases, the amount of inventory saved exceeded the amount of demand left unfilled including the filtered orders. Even at service levels of 80%, filtering large orders incurs a significant savings in inventory investment for a relatively small amount of demand left unfilled. This conclusion holds for both high and low demand and for both high and low value. If an inventory manager is uncertain whether a "large pop" order will recur, then the use of the filtering rule can greatly reduce inventory levels.

2.4 BREAKEVEN SPECIAL HANDLING COST

So far we have not included any costs for special handling a large pop. In this section we find a special order cost per period that

equates the total costs for the model that filters large pops to the total costs for the model that does not filter large orders. We solve for the K' (fixed special order cost) that satisfies

$$K' \left(\begin{array}{c} \text{Probability of} \\ \text{a Special Order} \\ \text{in a Period} \end{array} \right) = \begin{array}{l} \text{Total Cost Per} \\ \text{Period for the} \\ \text{Unfiltered Model} \end{array} - \begin{array}{l} \text{Total Cost Per} \\ \text{Period for the} \\ \text{Filtered Model} \end{array} .$$

Table 10 presents the frequency distribution for the breakeven special costs. The table shows the percentage of cases where the breakeven special handling cost falls within specified intervals. We present the frequency distribution for all 540 cases categorized by high demand/ low demand and high value/low value. Note that for the high value items, in 94% of the cases breakeven special handling costs are at least 10 times the normal set-up cost. In some high value cases, a breakeven special handling cost is 1000 times that of the normal set-up cost. Breakeven special handling cost is more than double the normal set-up cost in 54% of all cases. It should be noted that the total is skewed toward low value items, since two-thirds of the items are low value.

BREAKEVEN SPECIAL HANDLING COST
FREQUENCY DISTRIBUTION

	High Demand High Value	High Demand Low Value	Low Demand High Value	Low Demand Low Value	Total
$0 \le K' < K$	.0	.53	.0	.47	.35
$K \le K' < 2K$	.0	.13	.0	.28	.11
$2K \le K' < 4K$	.0	.12	.01	.14	.08
$4K \le K' < 10K$	.0	.06	.11	.08	.06
$10K \le K' < 100K$	.42	.12	.73	.03	.26
$100K \le K'$	.58	.04	.15	.0	.14

Table 10

In a practical inventory setting, however, the vast majority of cases would be low valued. Therefore, if special handling of large orders incurred a fixed special handling cost, and if the inventory manager is reasonably assured that large orders would recur with the same frequency, then the filtering rule should be limited to use for higher valued items.

As in [1], when special handling costs are fixed, the higher the cost reduction, the more favorable the filtering rule. Note that increasing the amount of cost reduction does not necessarily mean increasing the percent of cost reduction. Hence, breakeven special handling costs monotonically increase as

(1) the service level increases,

(2) the leadtime increases, and

(3) the value increases.

3. SUMMARY

Table 11 presents the frequency distribution of percent cost savings categorized by high demand/low demand and by high value/low value. In 99.4% of the 540 cases we examined (Table 4), filtering large customer orders reduces total expected costs (excluding special handling costs). For high-valued items the average savings are 40 to 50%. Even for low-valued items the average savings are significant: 17.4% for low demand and 29.6% for high demand items. All three components of total costs are reduced, with holding costs providing the majority of the savings. In virtually all the cases the number of units saved in inventory investment exceeds the total amount of demand left unfilled (including orders that are filtered).

PERCENT COST REDUCTION
FREQUENCY DISTRIBUTION

Percent Cost Savings	High Demand High Value	High Demand Low Value	Low Demand High Value	Low Demand Low Value	Total
Less than 0	.0	.8	.0	.9	.6
[0-10)	1.1	16.3	.0	38.9	15.6
[10-20)	26.7	36.5	1.1	20.4	25.6
[20-30)	8.9	10.3	16.7	19.4	13.0
[30-40)	12.2	7.5	8.9	16.7	10.4
[40-50)	8.9	6.3	23.3	3.7	9.1
[50-60)	20.0	9.9	15.6	.0	10.5
[60-70)	17.8	3.6	25.6	.0	8.9
[70-80)	3.3	2.8	6.7	.0	3.0
[80-90)	1.1	3.6	2.2	.0	2.2
[90-100)	.0	2.4	.0	.0	1.1
Average Percent Savings	40.5	29.6	50.1	17.4	32.3

Table 11

The results of [1] and [3] and this report indicate filtering large customer orders can significantly reduce the costs of an inventory system if there are reasonable ways to special handle these large pops. There are a number of ways to special handle (not issue from existing stock) a large order, for example:

(1) better predict the large order,

(2) expedite replenishment of the backorder, or

(3) develop alternative procurement strategies.

Use of our filtering rule for these methods of special handling should probably be limited to high value items.

Another use of our filtering rule is to identify spurious orders. Inclusion of a large customer order into future stockage policy decisions greatly increases inventory levels. If that order size is not likely

to recur, inventory levels are greatly inflated at a significant increase in cost. If our filtering rule is used to identify spurious demands, it may be beneficial to include lower-valued items as well.

REFERENCES

1. Blazer, Douglas J., Technical Report #21, "Operating Characteristics for an Inventory Model that Special Handles Extreme Value Demands", School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, January, 1983.

2. Blazer, Douglas J., Technical Report #22, "Evaluation of a 'Large Pop' Filtering Rule for Inventory Management Systems", School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, February, 1983.

3. Blazer, Douglas J. and M. McClelland, Technical Report #19, "An Inventory Model for Special Handling Extreme Value Demands", School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, December, 1981.

4. Ehrhardt, Richard, Technical Report #12, "Operating Characteristic Approximations for the Analysis of (s,S) Inventory Systems", School of Business Administration and Curriculum in Operations Research and Systems Analysis, University of North Carolina at Chapel Hill, April, 1977.

APPENDIX I

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM A

Order Size	Cumulative Relative Frequency
28	.0057
31	.0114
36	.8523
42	.8580
65	.8637
72	.9546
73	.9603
108	.9717
144	.9774
180	.9831
216	.9945
252	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM B

Order Size	Cumulative Relative Frequency
45	.0286
50	.0857
69	.2246
75	.6817
78	.7388
100	.9102
150	.9388
200	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM C

Order Size	Cumulative Relative Frequency
30	.0286
50	.8000
100	.9714
200	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM D

Order Size	Cumulative Relative Frequency
6	.6250
9	.7917
11	.8334
20	.9584
35	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION

FOR

ITEM E

Order Size	Cumulative Relative Frequency
6	.0370
10	.8518
17	.8888
25	.9629
45	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION

FOR

ITEM F

Order Size	Cumulative Relative Frequency
1	.0294
3	.6470
10	.8823
20	.9411
40	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM G

Order Size	Cumulative Relative Frequency
2	.7460
4	.7777
5	.7936
9	.9206
26	.9365
34	.9682
50	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM H

Order Size	Cumulative Relative Frequency
1	.0303
4	.4242
5	.4545
6	.4848
8	.6666
15	.7272
20	.9393
24	.9696
36	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM I

Order Size	Cumulative Relative Frequency
1	.10
2	.15
6	.20
8	.80
10	.85
25	.90
44	.95
100	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM J

Order Size	Cumulative Relative Frequency
2	.0385
9	.1154
10	.2308
11	.6539
13	.6924
25	.8847
50	.9616
100	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM K

Order Size	Cumulative Relative Frequency
4	.0870
8	.1305
10	.1740
30	.5218
52	.6088
100	.9131
200	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM L

Order Size	Cumulative Relative Frequency
3	.44
5	.52
6	.92
26	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM M

Order Size	Cumulative Relative Frequency
8	.0588
10	.2353
12	.2941
25	.4706
35	.6471
100	.8236
200	8824
298	.9412
439	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM N

Order Size	Cumulative Relative Frequency
5	.05
6	.80
10	.90
32	.95
48	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM O

Order Size	Cumulative Relative Frequency
1	.6667
2	.7000
4	.8667
9	.9000
14	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM P

Order Size	Cumulative Relative Frequency
27	.0625
30	.1458
90	.2083
101	.3125
110	.4167
123	.5209
137	.5417
204	.6875
211	.8124
400	.9791
500	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM Q

Order Size	Cumulative Relative Frequency
100	.7273
696	.7727
700	.9545
1000	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM R

Order Size	Cumulative Relative Frequency
1	.1923
4	.9615
57	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM S

Order Size	Cumulative Relative Frequency
30	.3846
35	.4231
40	.4616
50	.5385
60	.8847
90	.9232
120	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM T

Order Size	Cumulative Relative Frequency
1	.0877
2	.2631
3	.3771
4	.5350
5	.6227
6	.7016
8	.7191
10	.7893
12	.8419
15	.8507
20	.9033
24	.9208
36	.9559
48	.9734
72	.9822
108	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM U

Order Size	Cumulative Relative Frequency
1	.0227
2	.0909
3	.2727
4	.3636
5	.3863
6	.5908
8	.6363
9	.6590
10	.9090
16	.9317
24	.9544
48	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM V

Order Size	Cumulative Relative Frequency
1	.0562
2	.5618
3	.6067
4	.6292
6	.8876
8	.8988
12	.9887
18	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM W

Order Size	Cumulative Relative Frequency
1	.0704
2	.2535
3	.4788
4	.6056
5	.7183
6	.8028
8	.8310
10	.9155
12	.9437
15	.9578
20	.9860
40	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM X

Order Size	Cumulative Relative Frequency
1	.2610
2	.739
3	.7825
4	.8984
6	.9564
8	.9854
10	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM Y

Order Size	Cumulative Relative Frequency
1	.3111
2	.5331
3	.6516
4	.7479
5	.7923
6	.8812
7	.8886
10	.9256
12	.9552
16	.9626
20	.9700
100	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM Z

Order Size	Cumulative Relative Frequency
1	.1717
2	.4242
3	.4747
4	.5959
5	.6565
6	.7676
8	.7878
10	.8383
12	.8686
16	.9090
24	.9292
32	.9595
36	.9898
60	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM AA

Order Size	Cumulative Relative Frequency
1	.0562
2	.1011
3	.1517
4	.1910
5	.2079
6	.2979
10	.3316
12	.8428
13	.8484
24	.9551
36	.9776
48	.9832
72	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION
FOR
ITEM AB

Order Size	Cumulative Relative Frequency
1	.3056
2	.6598
3	.7436
4	.8070
5	.8281
6	.8422
10	.9337
12	.9478
20	.9619
100	.9689
160	.9759
500	.9950
1000	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION FOR ITEM AC

Order Size	Cumulative Relative Frequency
1	.0597
2	.1045
3	.1493
4	.1941
5	.2241
6	.3584
10	.4629
12	.5077
15	.5525
20	.6122
24	.6271
30	.6719
37	.6868
44	.7017
50	.8062
75	.8211
100	.9526
150	.9405
200	.9700
400	1.00

APPENDIX I

EMPIRICAL CUSTOMER ORDER DISTRIBUTION FOR ITEM AD

Order Size	Cumulative Relative Frequency
1	.1667
2	.3380
3	.4769
4	.5741
5	.6482
6	.7501
8	.8057
9	.8196
12	.8705
16	.8751
17	.8797
20	.8843
24	.9862
36	.9808
48	.9954
72	1.00

APPENDIX II

APPENDIX II

REDUCTION IN TOTAL COSTS

Total Cost Savings/Percent Reduction in Total Costs

L=0
K=16

ITEM	YEARLY DOLLAR VALUE	R=.8	R=.9	R=.99
A	$3560544	49.05/15.4	72.15/15.9	462.60/35.0
C	3008200	204.50/36.2	313.50/38.7	1099.00/51.5
B	1984580	44.00/10.9	67.75/12.4	310.75/27.1
J	531232	83.20/49.2	136.80/54.2	540.80/66.0
I	455832	85.50/62.5	130.05/64.3	465.98/69.7
AC	369512	58.85/54.0	93.00/57.6	376.60/72.6
F	286450	34.65/43.4	52.85/45.3	170.80/58.0
L	224055	30.75/44.8	50.63/50.6	201.38/70.5
E	220662	13.05/22.7	19.13/24.4	76.73/36.6
T	220272	22.40/46.1	36.50/52.6	155.50/73.2
S	130468	1.04/3.2	1.98/4.6	-.65/-1.0
R	107770	19.38/53.1	35.88/63.4	115.00/79.0
O	61490	14.50/58.6	22.00/62.0	42.00/63.2
V	32664	1.09/10.0	1.70/12.8	3.44/17.6
AA	29173	1.25/13.5	1.29/12.5	.57/4.0
H	19448	.85/9.9	.83/7.7	.25/1.6
Q	16236	.83/10.6	1.19/12.5	.19/1.0
X	13182	.49/7.7	.55/7.7	-.39/-.04
D	11771	1.50/23.5	2.00/25.8	2.70/23.0
K	10847	1.46/23.0	2.36/29.1	4.29/32.2
AB	9110	4.80/75.6	7.11/80.0	18.93/91.1
N	6401	.95/21.8	1.19/24.1	3.01/38.4
M	5125	.20/5.4	.28/6.8	1.02/18.1
P	4290	.55/15.9	.63/16.8	1.17/24.0
W	2754	.51/17.7	.58/18.3	.30/7.2
AD	2369	.23/9.6	.33/12.3	.31/10.4
Y	2221	.96/38.8	1.18/42.1	2.45/57.8
Z	993	.22/13.6	.23/13.3	.41/20.1
G	248	.28/34.8	.31/36.4	.37/39.8
U	128	.09/16.2	.11/17.8	.13/19.9

APPENDIX II

REDUCTION IN TOTAL COSTS

Total Cost Savings/Percent Reduction in Total Costs

L=0
K=32

ITEM	YEARLY DOLLAR VALUE	R=.8	R=.9	R=.99
A	$3560544	82.80/23.2	109.50/23.2	230.55/19.3
C	3008200	195.00/34.3	339.00/41.2	1383.00/57.5
B	1984580	50.52/12.1	74.75/13.2	396.00/32.8
J	531232	86.00/48.1	140.00/53.8	584.40/74.4
I	455832	82.35/59.1	115.65/59.4	407.03/72.1
AC	369512	56.85/50.2	93.30/55.9	306.20/69.9
F	286450	32.55/39.4	42.00/37.9	93.45/42.2
L	224055	28.88/39.7	41.25/42.0	115.13/56.4
E	220662	13.50/21.4	22.50/25.6	31.95/20.1
T	220272	22.70/41.5	35.50/47.6	104.30/62.2
S	130468	1.85/4.9	2.54/5.3	3.22/4.1
R	107770	15.75/42.1	28.00/52.3	106.88/75.2
O	61490	14.00/52.3	22.0/57.9	45.75/62.9
V	32664	1.26/8.8	1.50/9.3	2.79/12.5
AA	29173	1.98/15.5	2.27/15.8	2.58/14.5
H	19448	1.05/9.4	.98/7.5	.93/4.9
Q	16236	.92/9.1	.93/8.2	.59/3.6
X	13182	.62/7.3	.42/.01	.49/4.0
D	11771	1.95/22.8	2.21/22.9	3.86/26.8
K	10847	2.01/23.6	2.58/26.2	4.77/31.2
AB	9110	6.07/74.0	8.65/79.0	21.31/89.4
N	6401	1.31/21.8	1.56/23.5	3.17/33.4
W	5125	.36/7.0	.41/7.2	.92/13.0
P	4290	.76/15.8	.87/17.1	1.15/18.9
M	2754	.67/17.0	.50/12.1	.78/14.8
AD	2369	.39/11.3	.44/12.1	.43/10.8
Y	2221	1.39/38.8	1.43/38.3	2.20/46.9
Z	993	.28/12.8	.39/16.2	.45/16.5
G	248	.40/35.6	.44/36.7	.49/38.0
U	128	.13/16.0	.16/18.3	.15/16.9

APPENDIX II

REDUCTION IN TOTAL COSTS

Total Cost Savings/Percent Reduction in Total Costs

L= 2
K= 16

ITEM	YEARLY DOLLAR VALUE	R=.8	R=.9	R=.99
A	$3560544	158.40/25.8	158.85/18.9	240.60/14.3
C	3008200	409.50/40.1	544.50/41.5	1690.50/50.0
B	1984580	78.50/11.9	163.50/18.2	306.25/19.3
J	531232	161.20/54.7	240.40/57.7	604.40/65.2
I	455832	133.65/61.2	219.15/66.6	857.93/80.3
AC	369512	111.15/57.9	145.10/58.2	540.70/74.8
F	286450	51.10/40.7	77.35/44.6	179.55/50.0
L	224055	51.00/46.9	77.25/51.5	237.38/66.3
E	220662	22.05/23.4	26.10/21.0	49.95/21.9
T	220272	46.80/54.0	64.10/56.3	174.90/66.5
S	130468	1.92/3.8	3.61/5.4	3.84/3.4
R	107770	38.00/62.8	63.00/69.6	212.00/83.1
O	61490	25.75/63.6	34.00/63.3	67.75/66.9
V	32664	1.42/10.4	5.06/25.8	6.40/22.5
AA	29173	1.65/15.2	2.22/17.2	1.66/8.7
H	19448	.93/8.1	.75/5.2	.00/0.0
Q	16236	.69/7.2	.73/6.1	1.69/8.2
X	13182	.39/5.4	.49/5.6	.65/4.9
D	11771	2.21/27.3	2.57/25.7	4.08/25.1
K	10847	2.55/29.5	3.84/34.1	5.84/32.4
AB	9110	7.95/83.9	12.94/88.7	26.66/92.8
N	6401	1.66/31.4	1.93/31.7	5.07/45.0
M	5125	.47/11.4	.41/8.9	1.89/25.8
P	4290	.73/19.4	.80/19.1	1.40/23.6
W	2754	.45/14.9	.63/17.8	.43/8.1
AD	2369	.33/13.0	.34/12.4	.48/14.3
Y	2221	1.28/45.1	1.63/49.6	3.27/62.8
Z	993	.30/18.2	.28/15.5	.41/16.9
G	248	.32/38.8	.33/38.1	.48/44.4
U	128	.10/18.1	.11/17.7	.14/19.9

APPENDIX II

REDUCTION IN TOTAL COSTS

Total Cost Savings/Percent Reduction in Total Costs

L= 2
K= 32

ITEM	YEARLY DOLLAR VALUE	R=.8	R=.9	R=.99
A	$3560544	169.35/26.5	169.50/20.4	84.45/4.9
C	3008200	385.50/38.2	497.00/37.6	1356.00/48.5
B	1984580	95.00/14.5	133.25/15.1	298.50/18.1
J	531232	148.80/51.5	218.40/54.3	466.40/57.5
I	455832	136.35/60.2	194.63/62.3	415.80/66.5
AC	369512	105.45/54.2	132.75/52.9	266.40/56.1
F	286450	52.15/40.1	78.05/43.1	163.10/47.6
L	224055	48.75/43.2	78.00/49.5	184.50/58.9
E	220662	21.83/21.7	25.43/20.0	70.65/29.0
T	220272	39.70/47.0	63.50/52.9	134.00/60.3
S	130468	2.99/5.6	2.60/3.8	4.13/3.6
R	107770	33.38/55.3	61.25/65.6	180.75/79.8
O	61490	25.75/60.2	32.25/60.0	75.25/68.9
V	32664	1.74/10.3	2.55/12.7	5.67/18.9
AA	29173	2.14/15.1	2.17/13.5	2.52/10.9
H	19448	1.25/9.0	1.10/6.7	2.63/10.4
Q	16236	.96/8.0	1.32/9.2	1.50/7.1
X	13182	.39/4.2	.59/5.4	.20/1.3
D	11771	2.54/25.4	3.09/26.1	6.45/34.0
K	10847	2.93/28.8	3.90/31.0	6.39/31.8
AB	9110	9.16/80.8	13.31/85.1	28.97/91.6
N	6401	1.55/23.9	2.08/27.8	4.00/34.7
W	5125	.34/6.7	.60/9.8	1.35/16.4
P	4290	.77/15.6	.96/17.5	1.41/20.1
M	2754	.58/14.2	.79/16.9	.48/7.9
AD	2369	.35/10.1	.55/14.6	.63/13.9
Y	2221	1.41/39.3	1.80/43.8	3.66/59.1
Z	993	.31/13.8	.35/14.1	.57/19.0
G	248	.39/34.7	.43/36.0	.55/40.5
U	128	.14/17.2	.15/17.7	.19/19.9

APPENDIX II

REDUCTION IN TOTAL COSTS

Total Cost Savings/Percent Reduction in Total Costs

L=4
K=16

ITEM	YEARLY DOLLAR VALUE	R=.8	R=.9	R=.99
A	$3560544	136.35/17.4	160.50/15.0	792.30/21.8
C	3008200	502.00/38.4	600.00/35.4	2120.00/49.5
B	1984580	89.50/10.7	169.50/15.5	568.25/25.5
J	531232	191.60/52.5	282.00/56.9	762.40/66.0
I	455832	180.45/62.9	247.28/64.3	818.10/75.8
AC	369512	137.10/56.5	161.35/52.6	625.85/72.3
F	286450	61.60/38.7	81.55/39.8	127.40/35.1
L	224055	61.88/45.5	85.88/48.8	192.75/55.4
E	220662	23.18/20.2	39.38/25.5	69.30/25.4
T	220272	64.70/56.0	82.60/56.6	184.60/60.7
S	130468	1.24/2.0	5.01/6.3	3.28/2.3
R	107770	50.88/64.8	73.75/69.2	224.63/81.1
O	61490	31.50/64.0	47.00/67.6	94.75/71.5
V	32664	1.70/10.6	3.28/16.3	7.70/22.1
AA	29173	1.72/14.0	2.30/15.0	2.22/9.6
H	19448	.73/5.4	1.83/10.6	3.63/12.6
Q	16236	.66/5.7	.73/5.2	.31/1.3
X	13182	.26/3.2	.23/2.3	1.20/1.2
D	11771	2.42/26.1	3.87/32.1	7.44/37.0
K	10847	2.99/29.7	4.27/33.5	5.85/27.5
AB	9110	10.66/87.1	17.98/91.2	33.47/94.1
N	6401	1.91/32.1	2.08/30.3	6.46/46.2
W	5125	.47/10.5	.57/11.0	2.69/29.9
P	4290	.74/18.6	.82/18.4	1.68/24.7
M	2754	.51/15.1	.53/13.6	.74/12.1
AD	2369	.32/12.5	.44/14.8	.33/9.0
Y	2221	1.47/48.3	2.05/54.9	3.85/65.4
Z	993	.25/14.7	.27/14.6	.61/23.1
G	248	.31/37.1	.33/37.9	.53/46.1
U	128	.10/17.4	.12/18.8	.16/22.0

APPENDIX II

REDUCTION IN TOTAL COSTS

Total Cost Savings/Percent Reduction in Total Costs

L = 4
K = 32

ITEM	YEARLY DOLLAR VALUE	R=.8	R=.9	R=.99
A	$3560544	114.60/13.4	153.45/14.7	418.95/14.4
C	3008200	434.50/34.1	687.00/40.3	2236.30/51.1
B	1984580	115.50/13.7	143.50/12.7	768.25/32.4
J	531232	188.40/51.1	247.20/50.5	508.00/54.0
I	455832	198.23/62.2	252.68/62.8	538.65/64.8
AC	369512	128.75/52.8	174.85/55.9	420.60/61.7
F	286450	72.10/41.0	92.40/41.2	207.55/44.5
L	224055	70.13/45.9	94.13/48.1	229.13/57.3
E	220662	27.23/22.0	35.78/21.8	93.83/30.6
T	220272	65.50/55.0	94.10/56.8	213.80/58.1
S	130468	2.86/4.4	1.66/2.0	14.85/9.9
R	107770	51.00/65.0	73.38/65.4	225.63/79.5
O	61490	30.75/60.9	43.25/62.9	87.25/68.7
V	32664	2.19/11.2	1.70/7.6	6.36/17.7
AA	29173	2.52/16.3	2.29/12.7	.04/.2
H	19448	1.23/7.9	1.78/9.1	3.20/10.6
Q	16236	1.06/7.6	-.01/-.2	.18/.7
X	13182	.68/6.5	.23/2.0	.00/.0
D	11771	2.97/26.6	3.69/27.2	6.57/31.0
K	10847	3.57/30.8	4.24/29.2	11.19/42.6
AB	9110	10.88/83.5	16.44/87.3	31.35/91.5
N	6401	1.82/26.2	2.45/29.7	7.03/46.4
W	5125	.51/8.9	.86/12.9	2.54/25.6
P	4290	.92/17.8	1.13/19.4	2.00/24.7
M	2754	.63/14.5	.46/9.7	.72/10.1
AD	2369	.45/12.9	.55/14.0	.75/16.0
Y	2221	1.76/44.6	2.07/47.1	4.65/64.1
Z	993	.33/14.2	.40/15.9	.62/18.9
G	248	.41/36.5	.46/37.1	.62/42.6
U	128	.15/17.6	.17/19.2	.23/23.6

APPENDIX III

APPENDIX III

CATEGORIZATION OF COST SAVINGS

L=0
R=.8
K=16

HIGH DEMAND/HIGH VALUE

	Unfiltered	Filtered	Difference
ITEM A ($3560544)			
Inventory Cost	$179.10	$149.31	$29.79
Penalty Cost	123.83	104.58	19.25
Set-Up Cost	16.38	16.38	0.00
ITEM C ($3008200)			
Inventory Cost	327.95	213.80	114.15
Penalty Cost	228.25	138.20	90.05
Set-Up Cost	9.35	8.70	.65
ITEM B ($1984580)			
Inventory Cost	232.75	207.83	24.92
Penalty Cost	162.85	143.73	19.12
Set-Up Cost	8.43	8.38	.05
ITEM J ($531232)			
Inventory Cost	94.04	46.76	47.28
Penalty Cost	68.36	32.64	35.72
Set-Up Cost	6.84	6.52	.32
ITEM I ($455832)			
Inventory Cost	71.96	25.25	46.71
Penalty Cost	53.64	16.85	36.79
Set-Up Cost	11.18	9.29	1.89

APPENDIX III

CATEGORIZATION OF COST SAVINGS

HIGH DEMAND/LOW VALUE

L=0
R=.8
K=16

	Unfiltered	Filtered	Difference
ITEM AC ($369512)			
Inventory Cost	$55.80	$26.29	$29.51
Penalty Cost	42.84	17.22	25.62
Set-Up Cost	10.29	6.58	3.71
ITEM T ($220272)			
Inventory Cost	21.83	12.00	9.83
Penalty Cost	18.44	7.27	11.17
Set-Up Cost	8.37	6.89	1.48
ITEM S ($130468)			
Inventory Cost	17.82	17.38	.44
Penalty Cost	9.37	8.90	.47
Set-Up Cost	5.45	5.33	.12
ITEM AA ($29173)			
Inventory Cost	3.31	2.80	.51
Penalty Cost	1.94	1.63	.31
Set-Up Cost	4.02	3.58	.44
ITEM Q ($16236)			
Inventory Cost	2.85	2.57	.28
Penalty Cost	2.31	2.15	.16
Set-Up Cost	2.63	2.23	.40
ITEM K ($10847)			
Inventory Cost	2.51	1.83	.68
Penalty Cost	1.97	1.48	.49
Set-Up Cost	1.86	1.57	.29
ITEM AB ($9109)			
Inventory Cost	2.99	.57	2.42
Penalty Cost	1.92	.15	1.77
Set-Up Cost	1.43	.82	.61

APPENDIX III

CATEGORIZATION OF COST SAVINGS

HIGH DEMAND/LOW VALUE

L=0
R=.8
K=16

	Unfiltered	Filtered	Difference
ITEM N ($6401)			
Inventory Cost	$1.45	$1.15	$ .30
Penalty Cost	1.11	.69	.42
Set-Up Cost	1.77	1.55	.22
ITEM P ($4290)			
Inventory Cost	1.07	.92	.15
Penalty Cost	.76	.59	.17
Set-Up Cost	1.62	1.39	.23
ITEM M ($2754)			
Inventory Cost	.92	.76	.16
Penalty Cost	.75	.65	.10
Set-Up Cost	1.23	.98	.25
ITEM AD ($2369)			
Inventory Cost	.83	.77	.06
Penalty Cost	.30	.27	.03
Set-Up Cost	1.29	1.15	.14
ITEM Y ($2221)			
Inventory Cost	.83	.56	.27
Penalty Cost	.52	.13	.39
Set-Up Cost	1.13	.82	.31
ITEM Z ($993)			
Inventory Cost	.55	.49	.06
Penalty Cost	.25	.18	.07
Set-Up Cost	.78	.70	.08
ITEM U ($128)			
Inventory Cost	.23	.20	.03
Penalty Cost	.05	.02	.03
Set-Up Cost	.29	.26	.03

APPENDIX III

CATEGORIZATION OF COST SAVINGS

L= 0
R= .8
K= 16

LOW DEMAND/HIGH VALUE

	Unfiltered	Filtered	Difference
ITEM F ($268450)			
Inventory Cost	$ 41.72	$ 25.20	$ 16.52
Penalty Cost	29.47	14.00	15.47
Set-Up Cost	8.75	5.99	2.76
ITEM L ($224055)			
Inventory Cost	35.32	19.46	15.86
Penalty Cost	25.09	11.10	13.99
Set-Up Cost	8.36	7.39	.97
ITEM E ($220662)			
Inventory Cost	30.31	24.82	5.49
Penalty Cost	19.19	12.22	6.97
Set-Up Cost	7.81	7.22	.59
ITEM R ($107770)			
Inventory Cost	19.04	7.71	11.33
Penalty Cost	12.31	3.84	8.47
Set-Up Cost	5.12	5.55	-.43
ITEM O ($61490)			
Inventory Cost	13.88	4.85	9.03
Penalty Cost	7.80	2.28	5.52
Set-Up Cost	3.08	3.05	.03

APPENDIX III

CATEGORIZATION OF COST SAVINGS

LOW DEMAND/LOW VALUE

L=0
R=.8
K=16

	Unfiltered	Filtered	Difference
ITEM V ($32664)			
Inventory Cost	$4.29	$3.81	$.48
Penalty Cost	2.72	2.30	.42
Set-Up Cost	3.96	3.76	.20
ITEM H ($19148)			
Inventory Cost	3.56	3.16	.40
Penalty Cost	2.43	2.20	.23
Set-Up Cost	2.63	2.42	.21
ITEM X ($13182)			
Inventory Cost	2.29	2.10	.19
Penalty Cost	1.31	1.24	.07
Set-Up Cost	2.71	2.50	.21
ITEM D ($11771)			
Inventory Cost	2.37	1.73	.64
Penalty Cost	1.78	1.28	.50
Set-Up Cost	2.23	1.88	.35
ITEM W ($5125)			
Inventory Cost	1.25	1.26	.04
Penalty Cost	.78	.63	.15
Set-Up Cost	1.71	1.69	.02
ITEM G ($248)			
Inventory Cost	.30	.21	.09
Penalty Cost	.09	.03	.06
Set-Up Cost	.40	.27	.13

APPENDIX III

CATEGORIZATION OF COST SAVINGS

L=0
R=.8
K=32

HIGH DEMAND/HIGH VALUE

	Unfiltered	Filtered	Difference
ITEM A ($3560544)			
Inventory Cost	$187.02	$141.78	$45.24
Penalty Cost	138.80	101.18	37.62
Set-Up Cost	30.59	30.60	-.01
ITEM C ($3008200)			
Inventory Cost	326.40	218.35	108.05
Penalty Cost	223.35	138.35	85.00
Set-Up Cost	19.15	17.40	1.75
ITEM B ($1984580)			
Inventory Cost	236.50	207.00	29.50
Penalty Cost	163.60	142.88	20.72
Set-Up Cost	18.38	18.08	.30
ITEM J ($531232)			
Inventory Cost	98.44	55.68	42.76
Penalty Cost	67.24	26.12	41.12
Set-Up Cost	13.28	10.84	2.44
ITEM I ($455832)			
Inventory Cost	70.22	29.63	40.59
Penalty Cost	52.16	16.34	35.82
Set-Up Cost	16.99	11.00	5.99

APPENDIX III

CATEGORIZATION OF COST SAVINGS

HIGH DEMAND/LOW VALUE

L=0
R=.8
K=32

	Unfiltered	Filtered	Difference
ITEM AC ($369512)			
Inventory Cost	$60.77	$32.31	$28.46
Penalty Cost	39.42	14.21	25.21
Set-Up Cost	13.05	9.90	3.15
ITEM T ($220272)			
Inventory Cost	25.86	13.47	12.39
Penalty Cost	17.81	8.41	9.40
Set-Up Cost	10.99	10.17	.82
ITEM S ($130468)			
Inventory Cost	18.57	17.35	1.22
Penalty Cost	10.56	10.14	.42
Set-Up Cost	8.77	8.55	.22
ITEM AA ($29173)			
Inventory Cost	4.31	3.64	.67
Penalty Cost	2.40	1.80	.60
Set-Up Cost	6.05	5.35	.70
ITEM Q ($16236)			
Inventory Cost	3.22	2.99	.23
Penalty Cost	3.04	2.82	.22
Set-Up Cost	3.87	3.39	.48
ITEM K ($10847)			
Inventory Cost	2.97	2.17	.80
Penalty Cost	2.66	1.93	.73
Set-Up Cost	2.89	2.41	.48
ITEM AB ($9109)			
Inventory Cost	3.37	.83	2.54
Penalty Cost	2.31	.16	2.15
Set-Up Cost	2.51	1.14	1.37

APPENDIX III

CATEGORIZATION OF COST SAVINGS

HIGH DEMAND/LOW VALUE

L= 0
R= .8
K= 32

	Unfiltered	Filtered	Difference
ITEM N ($6401)			
Inventory Cost	$1.96	$1.62	$.34
Penalty Cost	1.36	.86	.50
Set-Up Cost	2.68	2.22	.46
ITEM P ($4290)			
Inventory Cost	1.55	1.37	.18
Penalty Cost	.88	.66	.22
Set-Up Cost	2.39	2.03	.36
ITEM M ($2754)			
Inventory Cost	1.25	1.06	.19
Penalty Cost	.92	.72	.20
Set-Up Cost	1.77	1.49	.28
ITEM AD ($2369)			
Inventory Cost	1.30	1.13	.17
Penalty Cost	.32	.29	.03
Set-Up Cost	1.84	1.63	.21
ITEM Y ($2221)			
Inventory Cost	1.19	.83	.36
Penalty Cost	.69	.14	.55
Set-Up Cost	1.69	1.21	.48
ITEM Z ($993)			
Inventory Cost	.81	.73	.08
Penalty Cost	.27	.22	.05
Set-Up Cost	1.14	.98	.16
ITEM U ($128)			
Inventory Cost	.34	.30	.04
Penalty Cost	.05	.03	.02
Set-Up Cost	.42	.35	.07

APPENDIX III

CATEGORIZATION OF COST SAVINGS

LOW DEMAND/HIGH VALUE

L= 0
R= .8
K= 32

	Unfiltered	Filtered	Difference
ITEM F ($268450)			
Inventory Cost	$ 46.38	$ 26.53	$ 19.85
Penalty Cost	25.97	14.67	11.30
Set-Up Cost	10.29	8.72	1.57
ITEM L ($224055)			
Inventory Cost	39.75	22.05	17.70
Penalty Cost	22.99	11.36	11.63
Set-Up Cost	10.16	10.46	-.30
ITEM E ($220662)			
Inventory Cost	36.83	27.83	9.00
Penalty Cost	16.25	12.60	3.65
Set-Up Cost	10.15	9.32	.83
ITEM R ($107770)			
Inventory Cost	17.69	8.48	9.21
Penalty Cost	12.04	4.73	7.31
Set-Up Cost	7.69	8.46	-.77
ITEM O ($61490)			
Inventory Cost	13.23	4.85	8.38
Penalty Cost	8.20	3.18	5.02
Set-Up Cost	5.33	4.78	.55

APPENDIX III

CATEGORIZATION OF COST SAVINGS

L=0
R=.8
K=32

LOW DEMAND/LOW VALUE

	Unfiltered	Filtered	Difference
ITEM V ($32664)			
Inventory Cost	$ 5.09	$ 4.65	$ .44
Penalty Cost	3.30	2.81	.49
Set-Up Cost	5.90	5.59	.31
ITEM H ($19148)			
Inventory Cost	4.11	3.73	.38
Penalty Cost	3.04	2.74	.30
Set-Up Cost	4.05	3.67	.38
ITEM X ($13182)			
Inventory Cost	2.75	2.71	.04
Penalty Cost	1.62	1.49	.13
Set-Up Cost	3.99	3.68	.31
ITEM D ($11771)			
Inventory Cost	2.97	2.27	.70
Penalty Cost	2.21	1.56	.65
Set-Up Cost	3.37	2.77	.60
ITEM W ($5125)			
Inventory Cost	1.76	1.66	.10
Penalty Cost	.91	.76	.15
Set-Up Cost	2.52	2.42	.10
ITEM G ($248)			
Inventory Cost	.45	.31	.14
Penalty Cost	.10	.03	.07
Set-Up Cost	.58	.39	.19

APPENDIX III

CATEGORIZATION OF COST SAVINGS

L=4
R=.9
K=16

HIGH DEMAND/HIGH VALUE

	Unfiltered	Filtered	Difference
ITEM A ($3560544)			
Inventory Cost	$ 585.69	$ 462.41	$ 123.28
Penalty Cost	466.88	429.59	37.29
Set-Up Cost	15.56	15.74	-.18
ITEM C ($3008200)			
Inventory Cost	1014.05	673.50	340.55
Penalty Cost	672.85	414.10	258.75
Set-Up Cost	9.15	8.30	.85
ITEM B ($1984580)			
Inventory Cost	702.23	612.83	89.40
Penalty Cost	383.78	304.08	79.70
Set-Up Cost	8.53	8.25	.28
ITEM J ($531232)			
Inventory Cost	290.44	144.08	146.36
Penalty Cost	198.32	62.96	135.36
Set-Up Cost	6.96	6.36	.60
ITEM I ($455832)			
Inventory Cost	212.72	85.14	127.58
Penalty Cost	160.72	43.07	117.65
Set-Up Cost	10.98	8.91	2.07

APPENDIX III

CATEGORIZATION OF COST SAVINGS

HIGH DEMAND/LOW VALUE

L=4
R=.9
K=16

	Unfiltered	Filtered	Difference
ITEM AC ($369512)			
Inventory Cost	$ 179.51	$ 97.48	$ 82.03
Penalty Cost	116.51	40.65	75.86
Set-Up Cost	10.49	7.04	3.45
ITEM T ($220272)			
Inventory Cost	83.65	38.68	44.97
Penalty Cost	53.08	18.93	34.15
Set-Up Cost	9.32	5.74	3.58
ITEM S ($130468)			
Inventory Cost	59.49	55.17	4.32
Penalty Cost	15.43	15.00	.43
Set-Up Cost	4.98	4.72	.26
ITEM AA ($29173)			
Inventory Cost	7.50	5.96	1.54
Penalty Cost	4.21	3.84	.37
Set-Up Cost	3.60	3.22	.38
ITEM Q ($16236)			
Inventory Cost	8.16	7.75	.41
Penalty Cost	3.44	3.45	-.01
Set-Up Cost	2.35	2.02	.33
ITEM K ($10847)			
Inventory Cost	7.72	4.74	2.98
Penalty Cost	3.27	2.31	.96
Set-Up Cost	1.74	1.41	.33
ITEM AB ($9109)			
Inventory Cost	13.91	.81	13.10
Penalty Cost	4.71	.21	4.50
Set-Up Cost	1.10	.72	.38

APPENDIX III

CATEGORIZATION OF COST SAVINGS

HIGH DEMAND/LOW VALUE

L= 4
R= .9
K= 16

	Unfiltered	Filtered	Difference
ITEM N ($6401)			
Inventory Cost	$ 3.47	$ 2.21	$ 1.26
Penalty Cost	1.80	1.22	.58
Set-Up Cost	1.58	1.35	.23
ITEM P ($4290)			
Inventory Cost	2.05	1.62	.43
Penalty Cost	.95	.78	.17
Set-Up Cost	1.45	1.23	.22
ITEM M ($2754)			
Inventory Cost	1.88	1.57	.31
Penalty Cost	.92	.89	.03
Set-Up Cost	1.09	.90	.19
ITEM AD ($2369)			
Inventory Cost	1.35	1.14	.21
Penalty Cost	.51	.39	.12
Set-Up Cost	1.15	1.04	.11
ITEM Y ($2221)			
Inventory Cost	1.93	.77	1.16
Penalty Cost	.86	.18	.68
Set-Up Cost	.94	.73	.21
ITEM Z ($993)			
Inventory Cost	.85	.72	.13
Penalty Cost	.31	.26	.05
Set-Up Cost	.70	.61	.09
ITEM U ($128)			
Inventory Cost	.30	.25	.05
Penalty Cost	.06	.03	.03
Set-Up Cost	.26	.22	.04

APPENDIX III

CATEGORIZATION OF COST SAVINGS

L=4
R=.9
K=16

LOW DEMAND/HIGH VALUE

	Unfiltered	Filtered	Difference
ITEM F ($268450)			
Inventory Cost	$ 134.82	$ 87.64	$ 47.18
Penalty Cost	61.22	30.28	30.94
Set-Up Cost	9.00	5.53	3.47
ITEM L ($224055)			
Inventory Cost	110.18	64.58	45.60
Penalty Cost	57.83	19.09	38.74
Set-Up Cost	7.99	6.49	1.50
ITEM E ($220662)			
Inventory Cost	103.66	87.19	16.47
Penalty Cost	44.03	22.59	21.44
Set-Up Cost	7.00	5.45	1.55
ITEM R ($107770)			
Inventory Cost	68.69	19.95	48.74
Penalty Cost	33.81	7.96	25.85
Set-Up Cost	4.18	5.00	-.82
ITEM O ($61490)			
Inventory Cost	48.13	14.38	33.75
Penalty Cost	18.45	5.25	13.20
Set-Up Cost	2.90	2.83	.07

APPENDIX III

CATEGORIZATION OF COST SAVINGS

LOW DEMAND/LOW VALUE

L= 4
R=.9
K=16

	Unfiltered	Filtered	Difference
ITEM V ($32664)			
Inventory Cost	$ 11.21	$ 9.33	$ 1.88
Penalty Cost	5.29	4.09	1.20
Set-Up Cost	3.60	3.43	.17
ITEM H ($19148)			
Inventory Cost	10.35	9.47	.88
Penalty Cost	4.43	3.79	.64
Set-Up Cost	2.47	2.18	.29
ITEM X ($13182)			
Inventory Cost	4.99	4.75	.24
Penalty Cost	2.34	2.49	-.15
Set-Up Cost	2.40	2.24	.16
ITEM D ($11771)			
Inventory Cost	6.53	4.43	2.10
Penalty Cost	3.47	2.07	1.40
Set-Up Cost	2.06	1.69	.37
ITEM W ($5125)			
Inventory Cost	2.38	2.17	.21
Penalty Cost	1.24	.98	.26
Set-Up Cost	1.54	1.49	.05
ITEM G ($248)			
Inventory Cost	.42	.26	.16
Penalty Cost	.12	.04	.08
Set-Up Cost	.35	.24	.11

APPENDIX III

CATEGORIZATION OF COST SAVINGS

HIGH DEMAND/HIGH VALUE

L=4
R=.9
K=32

	Unfiltered	Filtered	Difference
ITEM A ($3560544)			
Inventory Cost	$ 569.94	$ 458.99	$ 110.95
Penalty Cost	442.19	399.44	42.75
Set-Up Cost	29.64	29.91	-.27
ITEM C ($3008200)			
Inventory Cost	1009.10	648.10	361.00
Penalty Cost	675.75	350.85	324.90
Set-Up Cost	18.60	17.30	1.30
ITEM B ($1984580)			
Inventory Cost	708.98	624.93	84.05
Penalty Cost	400.58	341.23	59.35
Set-Up Cost	18.10	18.10	0.00
ITEM J ($531232)			
Inventory Cost	331.24	185.92	145.32
Penalty Cost	146.00	47.08	98.92
Set-Up Cost	12.12	8.84	3.28
ITEM I ($455832)			
Inventory Cost	248.87	95.20	153.67
Penalty Cost	138.49	44.55	93.94
Set-Up Cost	14.27	9.86	4.41

APPENDIX III

CATEGORIZATION OF COST SAVINGS

HIGH DEMAND/LOW VALUE

L=4
R=.9
K=32

	Unfiltered	Filtered	Difference
ITEM AC ($369512)			
Inventory Cost	$ 214.49	$ 98.78	$ 115.71
Penalty Cost	84.76	29.72	55.04
Set-Up Cost	13.33	9.20	4.13
ITEM T ($220272)			
Inventory Cost	92.25	38.41	53.84
Penalty Cost	64.62	24.28	40.34
Set-Up Cost	8.78	8.85	-.07
ITEM S ($130468)			
Inventory Cost	57.25	54.44	2.81
Penalty Cost	19.57	20.85	-1.28
Set-Up Cost	8.10	7.99	.11
ITEM AA ($29173)			
Inventory Cost	8.40	7.02	1.38
Penalty Cost	4.19	3.91	.28
Set-Up Cost	5.41	4.77	.64
ITEM Q ($16236)			
Inventory Cost	8.21	8.03	.18
Penalty Cost	4.44	4.93	-.49
Set-Up Cost	3.43	3.13	.30
ITEM K ($10847)			
Inventory Cost	8.07	5.30	2.77
Penalty Cost	3.83	2.79	1.04
Set-Up Cost	2.63	2.21	.42
ITEM AB ($9109)			
Inventory Cost	12.65	1.09	11.56
Penalty Cost	4.28	.27	4.01
Set-Up Cost	1.90	1.03	.87

APPENDIX III

CATEGORIZATION OF COST SAVINGS

HIGH DEMAND/LOW VALUE

L=4
R=.9
K=32

	Unfiltered	Filtered	Difference
ITEM N ($6401)			
Inventory Cost	$ 3.96	$ 2.64	$ 1.32
Penalty Cost	1.88	1.13	.75
Set-Up Cost	2.39	2.01	.38
ITEM P ($4290)			
Inventory Cost	2.58	2.03	.55
Penalty Cost	1.13	.87	.26
Set-Up Cost	2.15	1.82	.33
ITEM M ($2754)			
Inventory Cost	2.15	1.94	.21
Penalty Cost	1.07	1.04	.03
Set-Up Cost	1.54	1.32	.22
ITEM AD ($2369)			
Inventory Cost	1.74	1.58	.16
Penalty Cost	.48	.36	.12
Set-Up Cost	1.71	1.44	.27
ITEM Y ($2221)			
Inventory Cost	2.14	1.08	1.06
Penalty Cost	.92	.20	.72
Set-Up Cost	1.33	1.03	.30
ITEM Z ($993)			
Inventory Cost	1.16	.99	.17
Penalty Cost	.36	.26	.10
Set-Up Cost	1.02	.89	.13
ITEM U ($128)			
Inventory Cost	.45	.35	.10
Penalty Cost	.06	.04	.02
Set-Up Cost	.37	.32	.05

APPENDIX III

CATEGORIZATION OF COST SAVINGS

L= 4
R= .9
K= 32

LOW DEMAND/HIGH VALUE

	Unfiltered	Filtered	Difference
ITEM F ($268450)			
Inventory Cost	$ 156.14	$ 85.72	$ 70.42
Penalty Cost	59.47	38.12	21.35
Set-Up Cost	8.82	8.05	.77
ITEM L ($224055)			
Inventory Cost	128.40	65.33	63.07
Penalty Cost	58.42	26.81	31.61
Set-Up Cost	8.89	9.56	-.67
ITEM E ($220662)			
Inventory Cost	118.49	89.60	28.89
Penalty Cost	36.45	29.70	6.75
Set-Up Cost	9.34	9.29	.05
ITEM R ($107770)			
Inventory Cost	60.06	20.81	39.25
Penalty Cost	45.65	10.35	35.30
Set-Up Cost	6.75	7.71	-.96
ITEM O ($61490)			
Inventory Cost	44.53	14.30	30.23
Penalty Cost	19.35	6.83	12.52
Set-Up Cost	4.98	4.43	.55

APPENDIX III

CATEGORIZATION OF COST SAVINGS

L=4
R=.9
K=32

LOW DEMAND/LOW VALUE

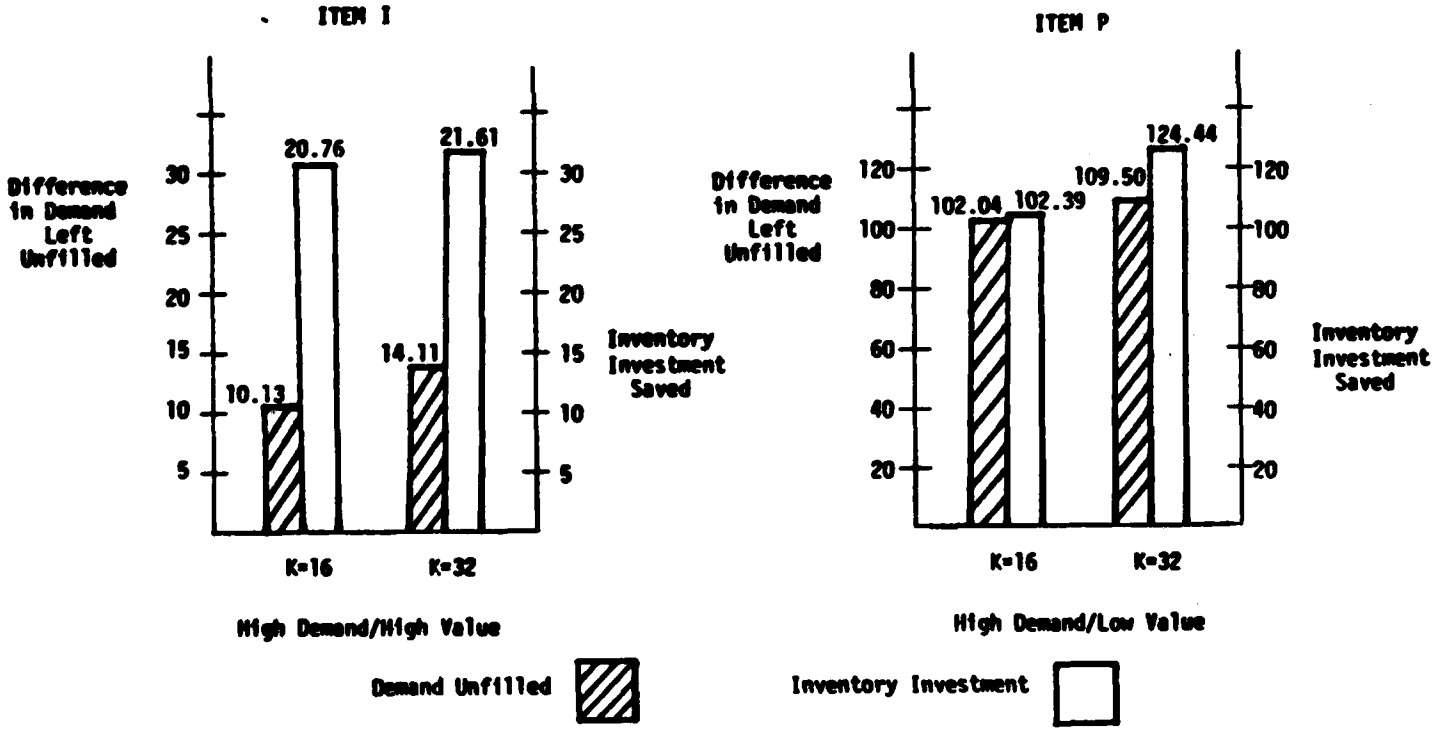
	Unfiltered	Filtered	Difference
ITEM V ($32664)			
Inventory Cost	$ 11.45	$ 10.12	$ 1.33
Penalty Cost	5.66	5.35	.31
Set-Up Cost	5.27	5.17	.10
ITEM H ($19148)			
Inventory Cost	10.61	9.61	1.00
Penalty Cost	5.12	4.72	.40
Set-Up Cost	3.72	3.41	.31
ITEM X ($13182)			
Inventory Cost	5.56	5.38	.18
Penalty Cost	2.58	2.71	-.13
Set-Up Cost	3.49	3.30	.19
ITEM D ($11771)			
Inventory Cost	6.91	4.81	2.10
Penalty Cost	3.54	2.51	1.03
Set-Up Cost	3.09	2.53	.56
ITEM W ($5125)			
Inventory Cost	2.97	2.60	.37
Penalty Cost	1.42	.99	.43
Set-Up Cost	2.27	2.21	.06
ITEM G ($248)			
Inventory Cost	.58	.38	.20
Penalty Cost	.14	.04	.10
Set-Up Cost	.51	.34	.17

APPENDIX IV

APPENDIX IV

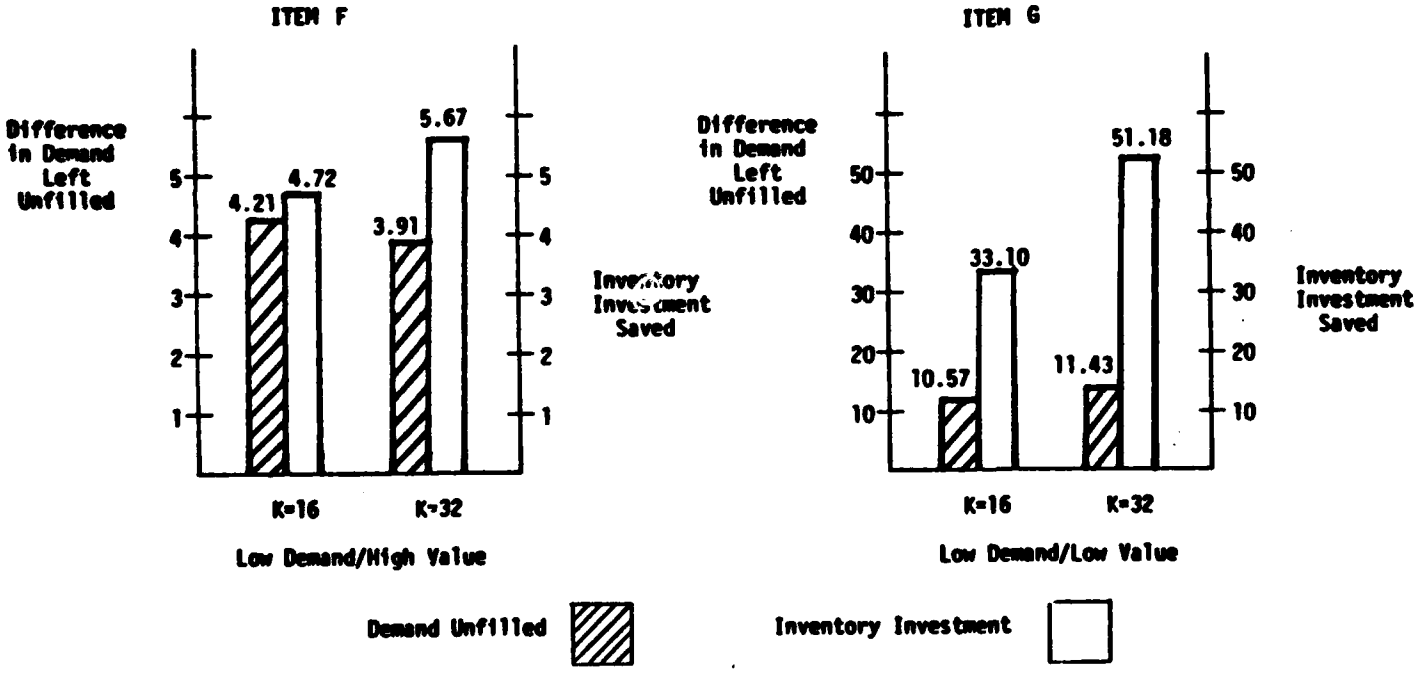
Unfilled Demand vs. the Reduction in Inventory Investment

L=0
R=.8



APPENDIX IV

Unfilled Demand vs. the Reduction in Inventory Investment

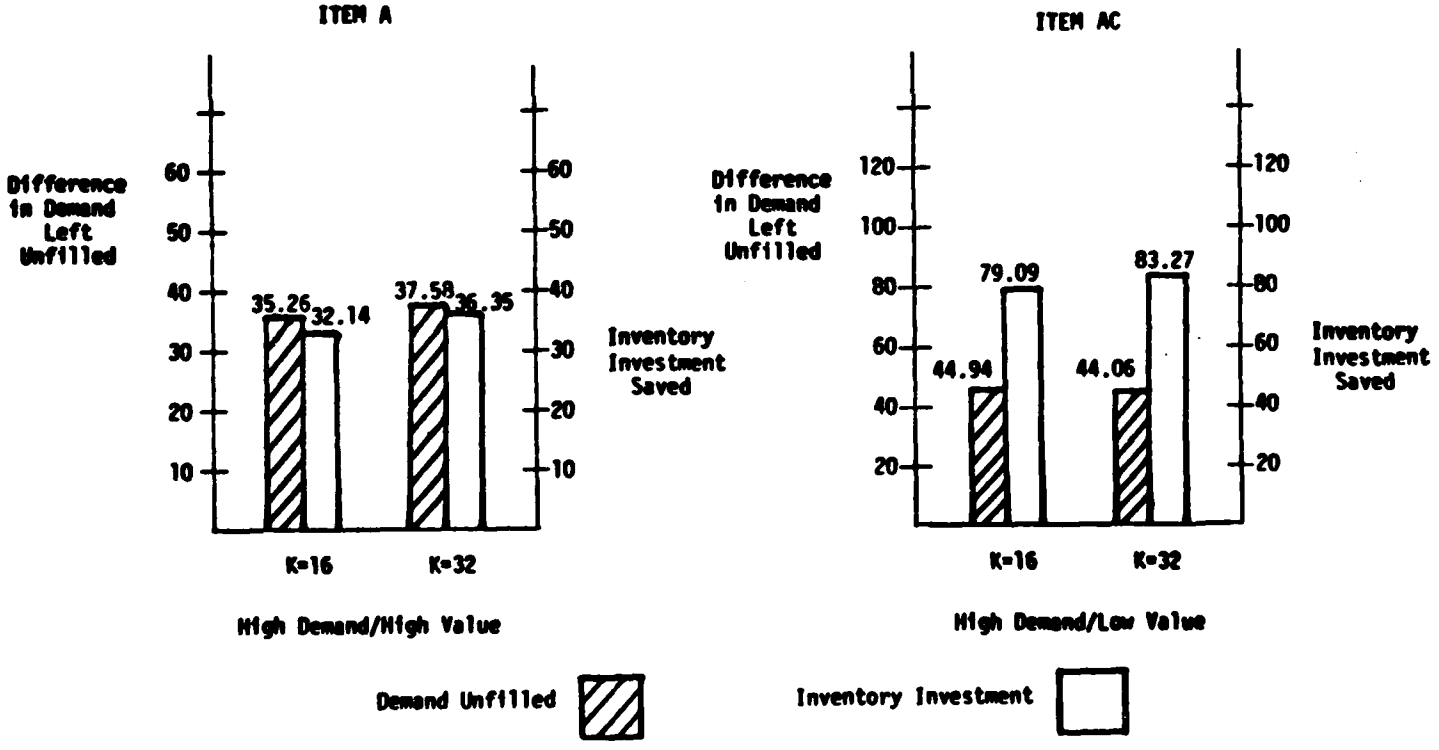


IV-1 (cont'd.)

APPENDIX IV

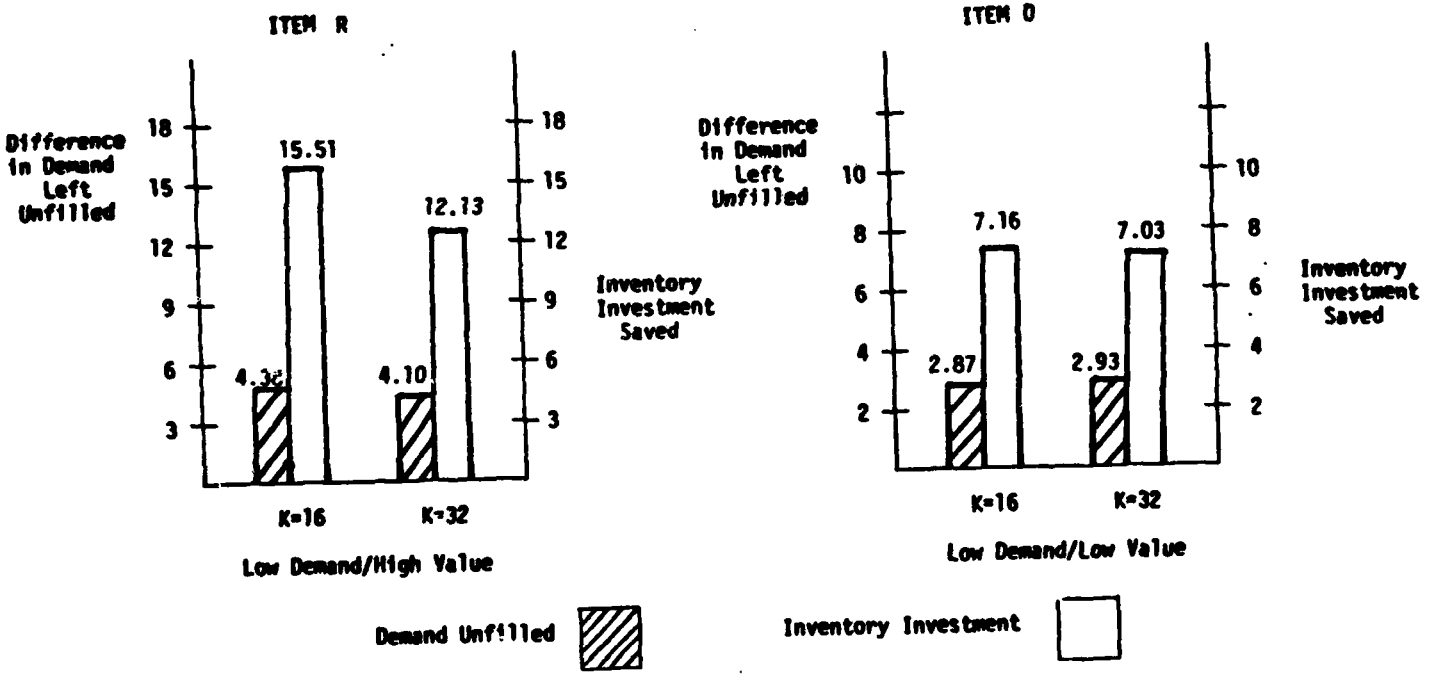
Unfilled Demand vs. the Reduction in Inventory Investment

L=0
R=.9



APPENDIX IV

Unfilled Demand Vs. the Reduction in Inventory Investment

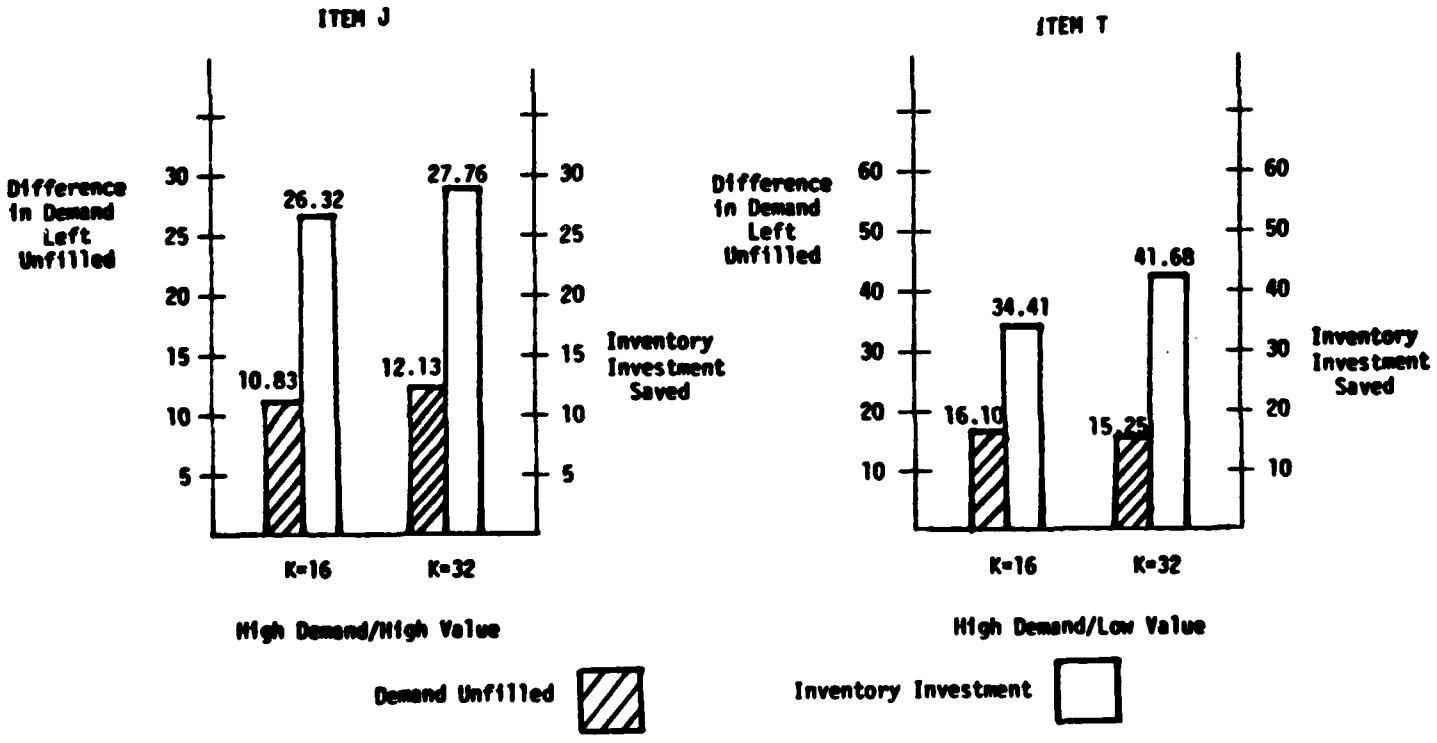


IV- 2 (cont'd.)

APPENDIX IV

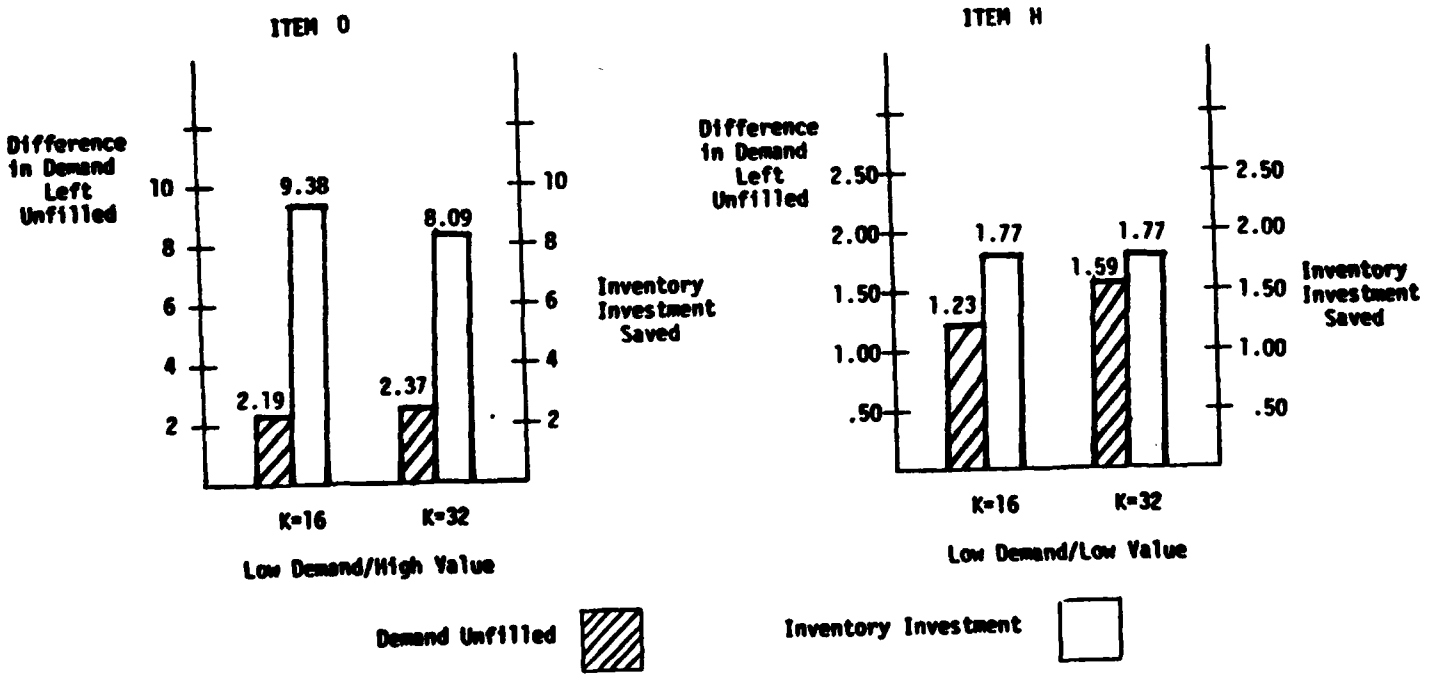
Unfilled Demand vs. the Reduction in Inventory Investment

L= 4
R=.8



APPENDIX IV

Unfilled Demand vs. the Reduction in Inventory Investment

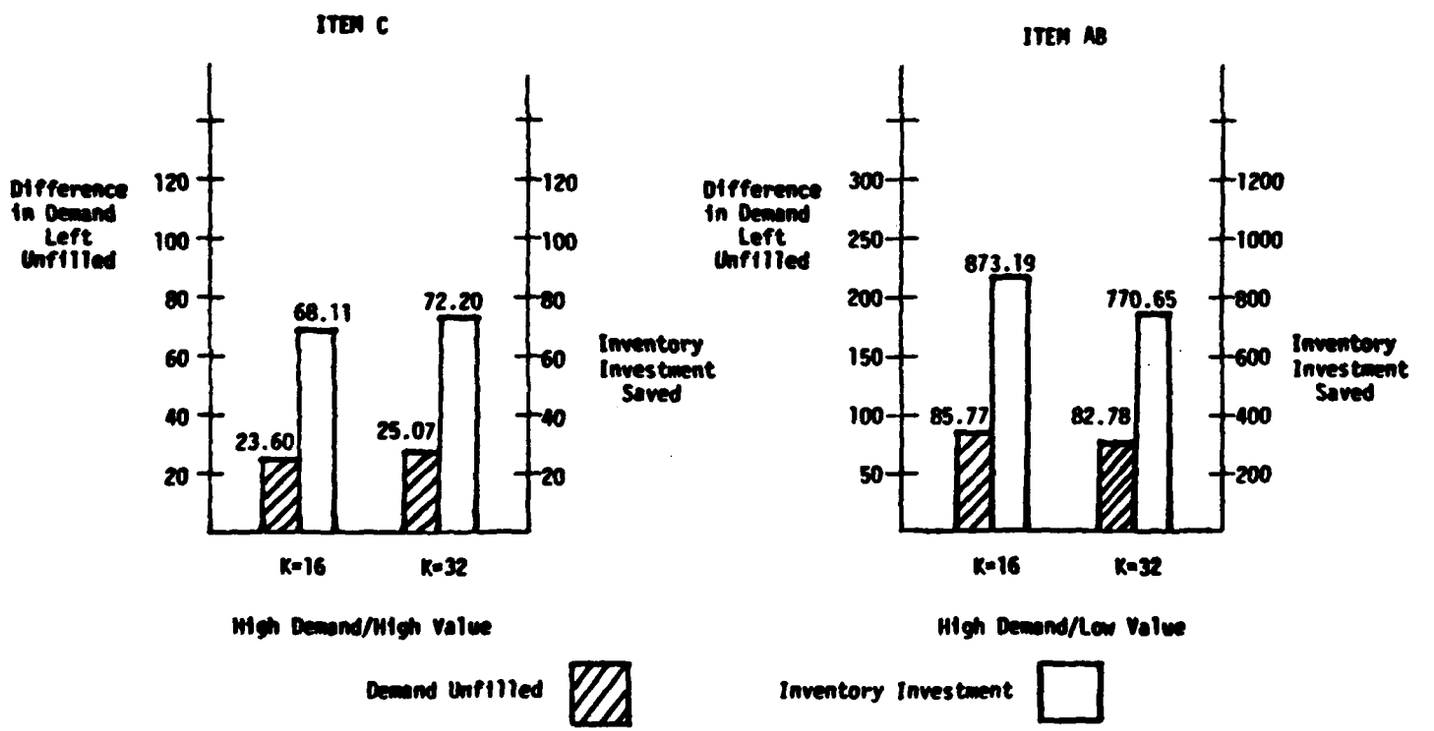


IV-3 (Cont'd.)

APPENDIX IV

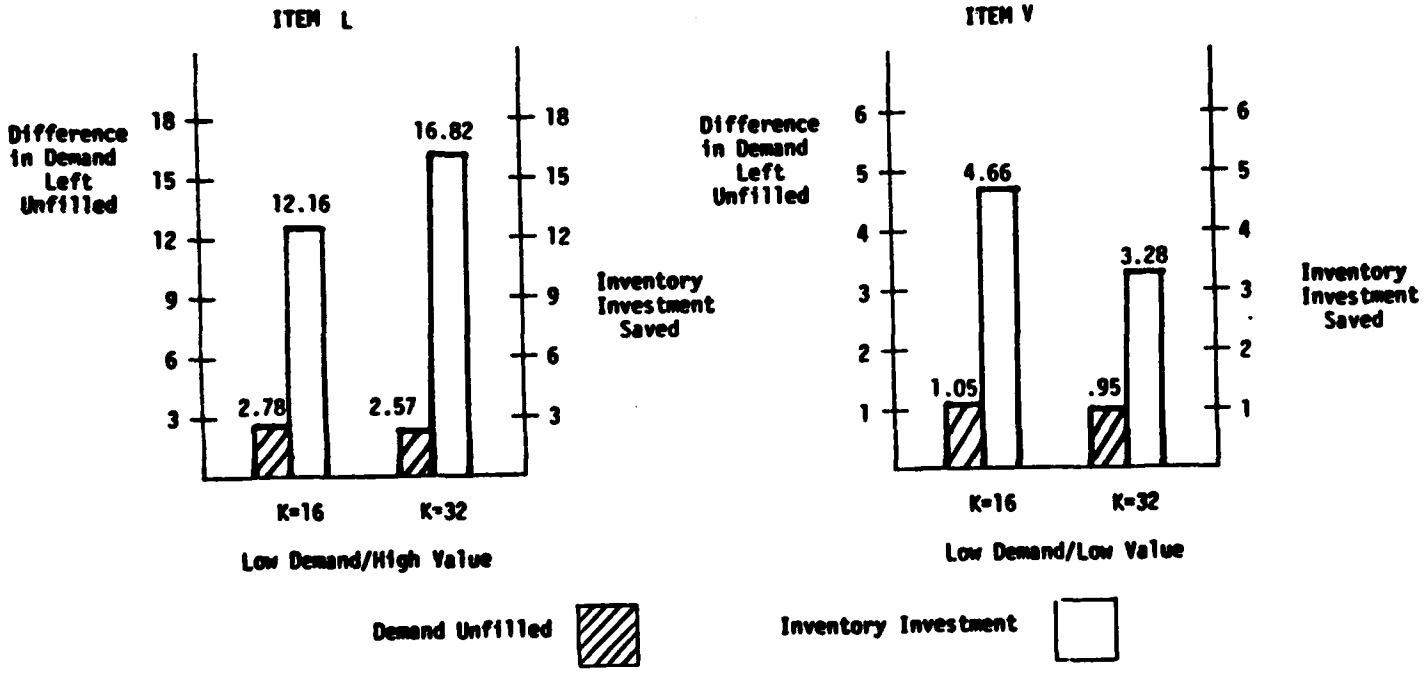
Unfilled Demand vs. the Reduction in Inventory Investment

L= 4
R= .9



APPENDIX IV

Unfilled Demand vs. the Reduction in Inventory Investment



IV-4 (Cont'd.)


3-8
DT