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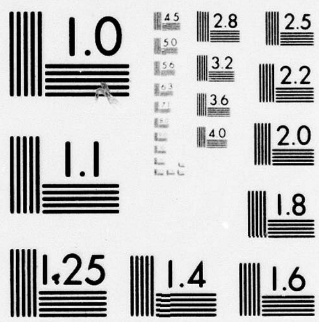

MICROCOPY RESOLUTION TEST CHART

AD-
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IRO REPORT No. 270

IMPROVEMENT OF EW/SIGINT SUPPORT

U.S. ARMY
INVENTORY
RESEARCH
OFFICE

JULY 1979

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

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

Since DARCOM took over responsibility of EW/SIGINT materiel in 1977, supply performance statistics have been quite low. Data from the Electronic Materiel Readiness Activity (EMRA) was gathered and analyzed. A modified Commodity Command Standard System (CCSS) computation process for both range and depth of stock is proposed. Because of the requirements of the CCSS models, various cost parameters are also developed to be used with the models. → next page

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(Abstract Continued)

cont. A computer simulation was written and run using the EMRA demand history. Results indicate a significant improvement in supply performance can be achieved with only a minor increase to present funding levels. Further improvement can be achieved by use of a DARCOM approved initial provisioning model.

ACKNOWLEDGEMENT

The author of this report wishes to thank Mr. George Anderson, DARCOM Programs and Projects Office, for his generous contribution of time and expertise in the area of electronic materiel and supply policies. Mr. Anderson also gave vital contributions to the writing of this report.

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SUMMARY

1. Background

In December 1976, the US Army Materiel Development and Readiness Command (DARCOM) took over the wholesale management responsibility of the Army Electronics Warfare/Signal Intelligence (EW/SIGINT) materiel (Federal Supply Class 5811) from the Army Security Agency (ASA). In February 1977, the National Inventory Control Point, Materiel Maintenance Point and Depot Complex was renamed the US Army Electronics Materiel Readiness Activity (EMRA).

A study was performed [7] by DARCOM to assess the supply situation and the general overall operation of the Electronics Materiel Readiness Activity. This study showed a very low level of supply performance; an average of about four out of 10 requisitions were supplied with stock off of the shelf, whereas Department of the Army (DA) goal is eight out of 10. As a result of this study, in May 1978 the Army Inventory Research Office (IRO) was asked to see what could be done to increase the performance of EW/SIGINT materiel.

IRO initial evaluation suggested the low supply performance levels were a result of the manner in which the range of items to be stocked was determined. Also, it was found that the depth of stockage, i.e., how much of each item is to be stocked, was insufficient. Additionally, the initial provisioning procedures were not sufficient to meet new criteria set up by DARCOM to justify budgetary procedures.

Additional factors which contributed to the low initial fill rates were outdated computer processing systems and extremely low equipment density and demand frequency.

2. Purpose and Objective

The purpose of this work was to devise supply stockage criteria which would enable EW/SIGINT materiel support to reach the DA goal of 80 percent initial fill. Initial fill in this context is the ability to fill a requisition from stock on-hand. To attain this goal it was necessary to develop (a) a consistent stockage policy (range of items to be stocked), (b) a consistent and compatible (within bounds of equipment and present levels) replenishment model (depth of stockage) and (c) justifiable initial provisioning computations.

3. Scope and Methods

The scope of this work included analysis to determine the main characteristics of the items involved. Among the characteristics investigated were demand (requisition and quantity), unit price, lead times, extended price (dollar value of annual demand), and distribution of due-out days.

After the data analysis, compatible stockage and replenishment models were considered which were within the bounds of the capabilities of the potential users. The stockage and replenishment models were obtained from existing literature and systems already implemented. A computer simulation of the supply system was developed to determine how effective the proposed model would be in relation to the present procedures.

The initial provisioning model was developed independently of this work. The Army Communications and Electronics Materiel Readiness Command (CERCOM) has been using an initial provisioning model (ACCLOGTROM) and IRO has developed another model (SESAME) for use in initial provisioning. No testing was done on these provisioning models per se in the work presented in this report.

4. Conclusions and Findings

The supply performance target of 80 percent for EMRA can be met by use of modified Commodity Command Standard System (CCSS) modules to compute replenishment requirements and stockage acceptance. To implement the procedures the cost parameters unique to EMRA must be used. These costs are:

Cost-to-order	(< $10000 Buy)	$146/buy
	(≥ $10000 Buy)	$878/buy
Holding Cost rate		.13/year
Cost to maintain item in stock		$9.55/year
Receipt cost		$7.20/line
Issue cost		$5.80/line

Safety levels and Order Quantities are computed using the same methodology as used by the CCSS Insurance item model and the Variable Safety Level/ Economic Order Quantity (VSL/EOQ) model of CCSS.

The range of items to be stocked should be determined using the CCSS COSDIF model which looks at the economic considerations of stocking and not stocking the item. The COSDIF model makes use of the values computed in the replenishment model and uses the same shortage cost value.

Use of the above CCSS models will enable EMRA to reach the DA goal of 80 percent initial fill where initial fill is the percent of requisitions which can be filled from stock on-hand. To reach this goal, however, an inadequacy in the present data system must be corrected. Many items presently do not have procurement lead time values available. To run the CCSS models these figures are necessary. The implementation of the initial provisioning models will necessitate an initial estimate of the value and for items already in the supply system, estimates will have to be made.

CHAPTER I

EW/SIGINT SUPPLY PROCEDURES

1.1 EW/SIGINT Materiel

Electronic Warfare/Signal Intelligence (EW/SIGINT) end items can be divided into two distinct categories - strategic and tactical. Strategic equipment is largely commercial design state-of-the-art equipment. The introduction of this equipment into the Army inventory can be expected to continue to be on a quick reaction basis with less than the desired level of support in documentation and repair parts. Tactical equipment, on the other hand, is equipment which has use only in the Army environment. Much of this equipment is projected for a large scale modernization effort since many of the tactical items are older and technology has bypassed many of these items.

Major contributing factors to EMRA's low initial fill (see Figure A) are:

a. EW/SIGINT materiel are low equipment density items.

b. EMRA uses insufficient procedures in computing both the range and quantity of items for stock.

c. EMRA uses non-standard provisioning techniques.

d. Insufficient funding for provisioning actions has typified EMRA operations.

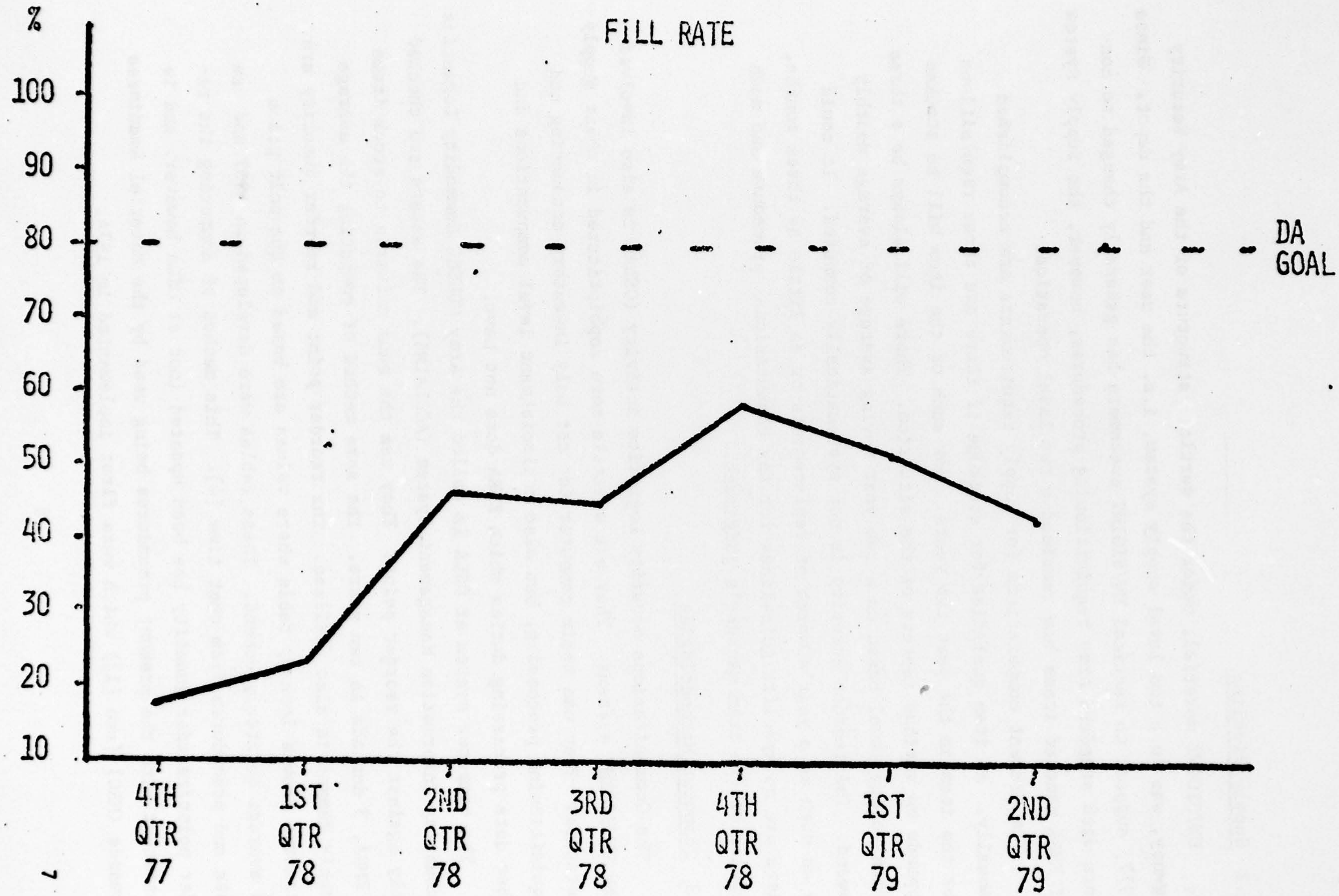
e. Many EMRA managed end items were introduced into field activities without documentation or provisioning. Repair parts associated with those end items can only be identified by EMRA when a failure occurs and a requisition is submitted.

f. Many of the EMRA managed end items, particularly tactical, use outdated technology and the parts are extremely difficult to procure.

g. By definition an EMRA managed repair part is an electronic item which is not available from the CERCOM, DLA, USN, USAF or any other DoD supplier. That is, it is not a commonly used item.

Each of the above factors has been or is being addressed. This work addresses only those problems associated with the requirements computation process for both range and quantity of items.

FIGURE A


FILL RATE
%
100
90
80
70
60
50
40
30
20
10
DA GOAL
4TH QTR 77
1ST QTR 78
2ND QTR 78
3RD QTR 78
4TH QTR 78
1ST QTR 79
2ND QTR 79

1.2 Supply Pipeline

EW/SIGINT materiel, under the vertical structure of the Army Security Agency, was in a two level supply system, i.e. the user and the depot. Since 1977, support to tactical EW/SIGINT customers has generally changed to conform with standard Army requisitioning procedures; however, the Supply System of EMRA managed items has remained a two level operation.

The present computations for supply requirements are accomplished manually. An item qualifies for stockage if there are three requisitions for the item in the past two years. How much of the item will be stocked depends on various aspects of the situation. There will always be a three month safety level based on a two year moving average of average monthly demand. The reorder quantity is not systematically computed. It could be as much as a year's worth of replacements or as little as three months. There are no specific guidelines for any computational procedure and much depends on the item manager's judgement.

1.3 Computer Methodologies

The Communications Security Logistics Activity (CSLA) is also involved with EW/SIGINT systems. They are a little more sophisticated in their supply operation. They use their computer for not only inventory accounting and requisitioning processing, but also replenishment level computations and other data processing duties which EMRA does not have.

The computer system at CSLA is called the Army COMSEC Commodity Logistics Accounting Information Management System (ACCLAIMS). The assets are checked daily against the reorder point. They use the same criteria to stock items as EMRA, 3 demands in two years. The same method of computing the average monthly demand is also utilized. The reorder point and reorder quantity are extracted from a look-up table where values are based on the unit price and average quarterly demand. These tables were developed in 1967 and use costs and procedures from that time [4]. This method of computing the reorder point/reorder quantity has been updated (not at CSLA however) and is consistent with the present procedures being used by the Material Readiness Commands (MRC) (see [1]) which were first implemented in 1974.

As a part of the improvement of EMRA performance, DARCOM is implementing an ACCLAIMS version at EMRA. The basic methodology would be those mentioned above with specific parameter changes as necessary for EMRA. ACCLAIMS also has a basic version of the standard initial provisioning model used by other DARCOM MRC's.

CHAPTER II

DATA ANALYSIS

2.1 Data Base

A two year demand history file and an inventory record file were obtained from EMRA. The demand history covered July 1976 through June 1978 and contains all demands seen by EMRA; i.e. demands for items managed by EMRA as well as those not managed by EMRA. These items were distinguishable to some degree. Although the items managed by EMRA could be discerned, the items procured by NSA but managed by EMRA could not. Since NSA procures for all Services, they do not order in a comprehensive manner to any one observer. Furthermore, they order from procurement either semi-annually or annually. The NSA items could not be distinguished by the data available.

A check with the item managers indicated there were no big buildups or cutbacks during the period involved; thus, no big peaks or valleys of demand are expected.

2.2 Demand Characteristics

The demand history file was broken out by unit price (UP), quantity demand (QTY), frequency of demands (FREQ), and extended price (EXTPR) where extended price is the unit price times the average yearly demand. Figures 1, 2 and 3 show the demand divided as explained for year 1, year 2 and year 1 and 2 together. The extended price for years 1 and 2 together is the two-year dollar value of demand not the annual dollar value of demand. From this information it is observed that EMRA items are rather low price - approximately 60 percent have unit price less than $50 - the requisitions are for small amounts - approximately 70 percent have a yearly quantity of 2 or less - the number of requisitions per year is few - 80 percent have 2 or less requisitions per year - and finally the annual yearly dollars of demand for 50 percent of the items is less than $100.

It is observed from Figure 3 that 6773 or 81 percent of the items do not qualify for stockage under the EMRA stockage criteria (3 demands in two years). What are the characteristics of these items? Figure 4 shows the

EMRA DEMAND YEAR 1

UP	#NSN	%	CUM
≤ 5	1639	31.3	31.3
5-10	634	12.1	43.4
10-15	248	4.7	48.1
15-20	292	5.5	53.6
20-25	104	1.9	55.5
25-50	470	8.9	64.4
50-100	426	8.1	72.5
100-500	947	18.1	90.6
500-1000	191	3.6	94.2
1000-3000	180	3.4	97.6
3000-5000	47	.8	98.4
5000-10000	27	.5	98.9
> 10000	18	.3	99.2

ANNUAL FREQ	#NSN	%	CUM
0	2967	36.2	36.2
1	3804	46.4	82.6
2	702	8.6	91.2
3	231	2.8	94.0
4	128	1.6	95.6
5	95	1.2	96.8
6	71	.9	97.7
7	42	.5	98.2
8	28	.3	98.5
9	27	.3	98.8
10	22	.3	99.1
11-15	38	.5	99.6
16-20	19	.2	99.8
21-25	7	.1	99.9
26-30	1	.01	
> 30	8	.1	100

QTY DMD	#NSN	%	CUM
0	2967	36.2	36.2
1	1892	23.1	59.3
2	882	10.8	70.1
3	325	4.0	74.1
4	320	3.9	78.0
5	224	2.7	80.7
6-7	273	3.3	84.0
8-10	298	3.6	87.6
11-15	246	3.0	90.6
16-20	173	2.1	92.7
21-25	98	1.2	93.9
26-30	73	.9	94.8
> 30	419	5.1	99.9

EXT PR	#NSN	%	CUM
≤ 5	895	17.1	17.1
5-20	951	18.2	35.3
20-100	1110	21.2	56.5
100-300	786	15.0	71.5
300-500	323	6.1	77.6
500-1000	349	6.6	84.2
1000-3000	377	7.2	91.4
3000-5000	120	2.2	93.6
5000-10000	109	2.0	95.6
> 10000	203	3.8	99.4

FIGURE 1

EMRA DEMAND YEAR 2

UP	#NSN	%	CUM
≤ 5	1385	31.2	31.2
5-10	501	11.3	42.5
10-15	202	4.5	47.0
15-20	246	5.5	52.5
20-25	91	2.0	54.5
25-50	415	9.3	63.8
50-100	468	10.5	74.3
100-500	733	16.5	90.8
500-1000	162	3.6	94.4
1000-3000	152	3.4	97.8
3000-5000	41	.9	98.7
5000-10000	24	.5	99.2
> 10000	11	.2	99.4

ANNUAL FREQ	#NSN	%	CUM
0	3759	45.9	45.9
1	2965	36.2	82.1
2	803	9.8	91.9
3	262	3.2	95.1
4	123	1.5	96.6
5	60	.7	97.3
6	49	.6	97.9
7	43	.5	98.4
8	18	.2	98.6
9	12	.1	98.7
10	20	.2	98.9
11-15	38	.5	99.4
16-20	13	.2	99.6
21-25	12	.1	99.7
26-30	3	.04	
> 30	10	.1	99.8

QTY DMD	#NSN	%	CUM
0	3759	45.9	45.9
1	1537	18.8	64.7
2	770	9.4	74.1
3	297	3.6	77.7
4	296	3.6	81.3
5	165	2.0	83.3
6-7	200	2.4	85.7
8-10	301	3.7	89.4
11-15	172	2.1	91.5
16-20	129	1.6	93.1
21-25	92	1.1	94.2
26-30	54	.7	94.9
> 30	418	5.1	100

EXT PR	#NSN	%	CUM
≤ 5	765	17.2	17.2
5-20	767	17.3	34.5
20-100	979	22.0	56.5
100-300	610	13.7	70.2
300-500	242	5.4	75.6
500-1000	306	6.9	82.5
1000-3000	344	7.7	90.2
3000-5000	128	2.8	93.0
5000-10000	114	2.5	95.5
> 10000	176	3.9	99.4

FIGURE 2

EMRA DEMAND YEAR 1 & 2

UP	#NSN	%	CUM
≤ 5	2608	31.8	31.8
5-10	996	12.1	43.9
10-15	380	4.6	48.5
15-20	472	5.7	54.2
20-25	167	2.0	56.2
25-50	750	9.1	65.3
50-100	770	9.4	74.7
100-500	1365	16.6	91.3
500-1000	284	3.4	94.7
1000-3000	260	3.1	97.8
3000-5000	71	.8	98.6
5000-10000	41	.5	99.1
> 10000	26	.3	99.4

ANNUAL FREQ	#NSN	%	CUM
0	--	--	--
1	5391	65.8	65.8
2	1382	16.8	82.6
3	461	5.6	88.2
4	243	2.9	91.1
5	151	1.8	92.9
6	101	1.2	94.1
7	102	1.2	95.3
8	73	.8	96.1
9	42	.5	96.6
10	34	.4	97.0
11-15	106	1.2	98.2
16-20	39	.4	98.6
21-25	20	.2	98.8
26-30	14	.1	98.9
> 30	31	.3	99.2

QTY DMD	#NSN	%	CUM
0	--	--	--
1	2782	33.9	33.9
2	1364	16.6	50.5
3	530	6.4	56.9
4	532	6.4	63.3
5	335	4.0	67.3
6-7	405	4.9	72.2
8-10	520	6.3	78.5
11-15	366	4.4	82.9
16-20	271	3.3	86.2
21-25	188	2.2	88.4
26-30	118	1.4	89.8
> 30	779	9.5	99.3

EXT PR	#NSN	%	CUM
≤ 5	1412	17.2	17.2
5-20	1449	17.6	34.8
20-100	1798	21.9	56.7
100-300	1169	14.2	70.9
300-500	476	5.8	76.7
500-1000	545	6.6	83.3
1000-3000	598	7.3	90.6
3000-5000	189	2.3	92.9
5000-10000	195	2.3	95.2
> 10000	359	4.3	99.5

FIGURE 3

EMRA DEMAND **YEAR 1 and 2**

UP	#NSN	%	CUM	QTY	#NSN	%	CUM
# REQ IN TWO YEARS = 1							
≤ 5	1828	33.9	33.9	1	2782	51.6	51.6
5-10	706	13.0	46.9	2	830	15.3	66.9
10-15	241	4.4	51.3	3	229	4.2	71.1
15-20	334	6.1	57.4	4	259	4.8	75.9
20-25	105	1.9	59.3	5	183	3.4	79.3
25-50	491	9.1	68.4	6-7	169	3.1	82.4
50-100	501	9.2	77.2	8-10	265	4.9	87.3
100-500	803	14.8	92.4	11-15	157	2.9	90.2
500-1000	162	3.0	95.4	16-20	127	2.3	92.5
1000-3000	131	2.4	97.8	21-25	77	1.4	93.9
3000-5000	46	.8	98.6	26-30	37	.6	94.5
5000-10000	22	.4	99.0	> 30	276	5.1	99.6
> 10000	21	.3	99.3				
# REQ IN TWO YEARS = 2							
≤ 5	393	28.4	28.4	1	0	--	--
5-10	154	11.1	39.5	2	534	38.6	38.6
10-15	78	5.6	45.1	3	148	10.7	49.3
15-20	74	5.3	50.4	4	147	10.6	59.9
20-25	28	2.0	52.4	5	57	4.1	64.0
25-50	127	9.1	61.5	6-7	104	7.5	71.5
50-100	140	10.1	71.6	8-10	89	6.4	77.9
100-500	263	19.0	90.6	11-15	60	4.3	82.2
500-1000	53	3.8	94.4	16-20	51	3.6	85.8
1000-3000	53	3.8	98.2	21-25	36	2.6	88.4
3000-5000	11	.7	98.9	26-30	25	1.8	90.2
5000-10000	7	.5	99.4	> 30	131	9.4	99.6
≤ 10000	1	.C7	99.47				

FIGURE 4

unit price and quantity of demand for the two categories of requisition frequency - 1 and 2 in two years. Low unit price is very noticeable among these items - 50 percent are for less than $25 - and low quantities also. From this data it can be said that EMRA does have a low cost, slow moving inventory.

Conversely, 1417 or 19 percent of the items do qualify for stockage just on the demand criteria alone. These items were not broken down any further since it was considered to be more important to find out about the items not being stocked than about the items that were stocked.

2.3 Miscellaneous Data Information

As pointed out in Section 2.1 there was inventory information available also. Figure 5 shows some of the information. This data was as of the last day of June 1978. Hence, at that time 50 percent of the items with procurement lead time (PLT) had PLT values less than 90 days. The average PLT (from items with a PLT value) was 93.11 days. This indicates, as EMRA personnel had said, that quite a few of the items can be procured off commercial supplier shelves and long processes of obtaining items are not observed for procuring the items. As pointed out in the previous section, the annual dollar values of demand for quite a few items is rather small, long contract negotiations are not necessary for these items. However, it should also be noted that there are a great number of items - over 50 percent - with no PLT value at all. EMRA does not rely very much on the PLT value in its computations for requirement levels at the present time. Although there is a space in the computation card for the reorder point to be broken down, quite often this field is blank and just the reorder point is filled in. Also, for newer items the item manager simply does not know what the PLT value is or should be. Hence, the field is left blank.

The rest of Figure 5 deals with due-out items. Due-outs are filled fairly quickly - over 50 percent are filled within 30 days. Eighty-two percent of the items (NSNs) with due-outs have only one requisition which was unfilled and only 1 percent of the items have 10 or more requisitions which could not be filled immediately. The distribution of unit price for items with due-out is quite similar to the distribution of unit price for all items which are demanded (Figures 1 and 2).

EMRA INVENTORY HISTORY

PLT	#NSN	%	CUM
≤ 15	359	12.5	12.5
15-30	346	12.1	24.6
30-45	378	13.2	37.8
45-60	259	9.0	46.8
60-90	336	11.7	58.5
90-120	201	7.0	65.5
120-150	169	5.9	71.4
150-180	525	18.3	89.7
180-210	115	4.0	93.7
210-240	62	2.2	95.9
240-270	41	1.4	97.3
270-300	45	1.6	98.9
300-360	34	1.2	100
> 360	1	.03	
= 0	3910	57.7	

Mean PLT - 93.11 days

DO(REQN) PER NSN	#NSN	%	CUM
1	659	82.4	82.4
2	88	11.0	93.4
3	18	2.2	95.6
4	13	1.6	97.2
5	2	.2	97.4
6	4	.5	97.9
7	4	.5	98.4
8	3	.4	98.8
9	2	.2	99.0
≥10	7	.9	99.9

DAYS ON DO	#NSN	%	CUM
≤ 30	664	58.7	58.7
31-60	115	10.2	68.9
61-90	93	8.2	77.1
91-120	44	3.9	81.0
121-180	49	4.3	85.3
> 180	167	14.7	100

UNIT PRICE OF DO	#NSN	%	CUM
≤ 5	270	33.8	33.8
5-10	83	10.4	44.2
10-15	28	3.5	47.7
15-20	31	3.9	51.6
20-25	12	1.5	53.1
25-50	53	6.6	59.7
50-100	69	8.6	68.3
100-500	130	16.2	84.5
500-1000	33	4.1	88.6
1000-3000	38	4.8	93.4
3000-5000	17	2.1	95.5
5000-10000	10	1.2	96.7
> 10000	26	3.2	99.9

FIGURE 5

2.4 Cost Parameters

In addition to the basic data described above, various costs were approximated for incorporation into the inventory model. The holding cost is necessary for use in the models considered in this work. This work specifically examined the holding cost rate at EMRA and this cost is estimated to be .13 per item unit cost per year (see Appendix A for more details on the derivation of the costs for this section). This cost is low because the obsolescence rate is very low, .01.

Another cost needed for evaluation of inventory models is the procurement set-up cost. This is the variable cost associated with procuring stock from an outside source, but does not include the purchase price of the items procured. This is just the administrative cost necessary to get a contract awarded (see Appendix A). This cost is $146 per buy for a purchase less than $10000 and $868 per buy for a purchase greater than or equal to $10000.

Another cost found was the cost per item to maintain stock in storage. This cost reflects those parts of storage cost which do not depend on the dollar value stocked. An example is the cost of taking a physical inventory. The cost to maintain an item in stock for one year is $9.55.

Other costs developed for completing the inventory model were the receipt cost of $7.20 per stock number and the issue cost of $5.80 per stock number. Again the derivation of these costs are given in Appendix A.

CHAPTER III

PROPOSED MODELS

3.1 Requirements Computation

Two questions to be answered in an inventory problem are how much should be stocked and which items should indeed be stocked? The second question will be answered in the next section. The amount to be stocked can be broken down into the reorder point and the reorder quantity. Combined, these two values yield the requisitioning objective (RO) the maximum desired stock on-hand plus on-order. The reorder point is subdivided into the safety level and the expected procurement lead time.

Among the features of the Commodity Command Standard System (CCSS) is a Variable Safety Level/Economic Order Quantity (VSL/EOQ) module which computes safety levels and reorder quantities for the items. The CCSS computation for VSL values is divided into two parts; those items with average lead time demand greater than 20 units and those with lead time demand less than 20 units. The less than 20 units computation is based on an approximation to the negative binomial probability distribution. However, this technique tends to become inaccurate for very small mean demand values. CCSS evades this problem by making other approximations for very small mean demand values. Another CCSS module, the insurance item model, uses the same underlying probability distribution of demand, but because of the small mean values used with the model, the exact negative binomial probability distribution is used.

These two CCSS modules were combined to compute the VSL portion of the requirements model. The exact negative binomial probability distribution is used when the lead time demand is less than three units. If lead time demand is greater than three units, the approximation to the negative binomial is used. If the lead time demand is greater than or equal to 20, the Laplace probability distribution is used. The Wilson Lot size formula is used to compute the procurement quantity. This value is smaller than the procurement quantity computed in CCSS.

The safety level is restricted to non-negative values and is less than three standard deviations of lead time demand. The procurement quantity, on the other hand, is at least one unit but less than five years worth of supplies.

3.2 Stockage

The stockage criteria from CCSS was thought to be acceptable for this inventory situation also. The CCSS stockage criteria model - called COSDIF for cost differential - finds the cost difference between stocking and not stocking the items. If it is economical to stock the item, it should be stocked at the levels computed in the last section.

The cost differential model has two aspects to it. One is the cost of various actions necessary to replenish or stock items. The other is the probability distribution of not getting a demand given a certain frequency of demand over the past two years. These probabilities are referred to as zero probabilities and the basic values used were derived by the US Army Tank-Automotive Materiel Readiness Command (TARCOM) [8]. Again modifications were made to COSDIF for implementation of this work (see Appendix C). Some analysis should be done to see if these modifications could be used in the CCSS module as presently implemented since they could help the other ICPs in their stockage computations.

The costs used in the COSDIF model are: cost to order, cost to receive stock, holding cost rate, cost of issuing stock, fixed cost of maintaining an item in stockage, a percent premium when buying on demand and a shortage cost. These costs are as shown in Section 2.4 except the percent premium when buying on demand which is discussed in Appendix C and the shortage cost which is discussed in Appendix B.

3.3 Initial Provisioning

The time during which this study was underway, DARCOM determined that initial provisioning budget and procurement requirements would have to be determined by means of a standard, approved methodology. Thus, the Provisioning Budget Forecast Procedure (BBSIP) has been prescribed as the procedure to be used in developing forecasts of budgetary requirements for anticipated initial provisioning actions. The ARCSIP procedure, which is included in CCSS, is prescribed for use for actual procurement of initial provisioning requirements.

For systems for which ERPSLs are approved, one of the models certified by the DARCOM Technical Working Group on Provisioning Models (SESAME), ACCLOGTROM, MOD-METRIC at this time) must be used.

No tests were made of these procedures at EMRA during the course of this project. However, since EMRA provisioning requirements are now submitted as a portion of the CERCOM requirements, arrangements have been made for these procedures to be used at EMRA in the future with the advice and assistance of CERCOM personnel. No serious difficulties are anticipated in this regard.

CHAPTER IV

ANALYSIS OF METHODS

4.1 Evaluation Technique

To test whether the proposed models are beneficial a simulation was devised. This simulation used data from EMRA as the basic starting point. Available were two years of demand data and inventory information which included stock on-hand and due-in from procurement as of the cutoff date of the data. Two years of simulation is usually not sufficient to draw conclusions with confidence. Hence, a method was devised to extend the demand data (see Section 4.2) for an additional year.

The simulation attempts to mimic the routine supply operations of EW/SIGINT materiel at the depot level. Requisitions are received, stock is depleted, orders placed, orders arrive, backorders filled, and requirement replenishment levels computed. In doing these processes several measures are kept to determine how each procedure is operating in relation to the other. It should be kept in mind that the results are correct in their relative relationships to procedures being tested but absolute costs or performance are not observed.

The DARCOM goal of 80 percent initial fill was set as the target. Another target was the same dollar value of inventory as the present model. The present model is run and the value of inventory is projected. Based on this value then the proposed model is run with a suitable shortage cost to get the same inventory dollar value.

Another aspect of consideration is the number of items to be stocked. Performance could be increased by stocking more items. Just stocking additional items may not be the answer. Active items or potentially active items which will not add significantly to the inventory cost are the types of item being sought to stock. This will enable the performance target to be better realized and the cost objective to be met at the same time. Hence, the simulation was concerned with essentially three measures: (a) initial fill rate, (b) inventory dollars, and (c) number of items stocked.

4.2 Extension of Data for Simulation

The simulation was accomplished in the following manner. The forecast for mean demand is based on the first year of history only. All levels computations were based on this forecast. If the full two years were used to forecast demand, the statistics obtained would be for the demand patterns forecasted and would be better than anything which would happen in the actual operation of any methodology for managing inventory. Since all methods tested used the 12 month average and not the 24 month, it was felt that all policies would be equally affected.

Since the stockage criteria model as set up today must work with a two year demand base, all policies used the full two years to determine whether the item should be stocked.

The first year of data was used as a partial warmup period for the final statistics of the simulation. It was partial because the cost accumulations are begun the first year and the performance statistics are only for the second and third year. The third year of data is obtained by using the second year over again. Hence, the forecasts are completely independent of the performance statistics used in the results.

4.3 Steady State Results

The results presented in this section refer to three major alternatives: the present manual procedure, the ACCLAIMS automatic computation, and the proposed CCSS modified procedures. Although the current procedures specify that an item will be stocked if it has three demands in two years, items may also be stocked for other reasons, e.g., the item may be essential to the operation of the end items and then the manager will want to stock the item for that reason. However, only the demand based criteria could be programmed in the simulation.

Figure 6 shows the basic results for the present system, ACCLAIMS, and the proposed CCSS modified model. The various values for the CCSS model are obtained via different shortage cost values (λ). This figure shows that a substantial improvement can be made over the present system by implementing the CCSS modified models. Since these results are only for stocking items

COST/PERFORMANCE (PRESENT VS ALTERNATIVES)

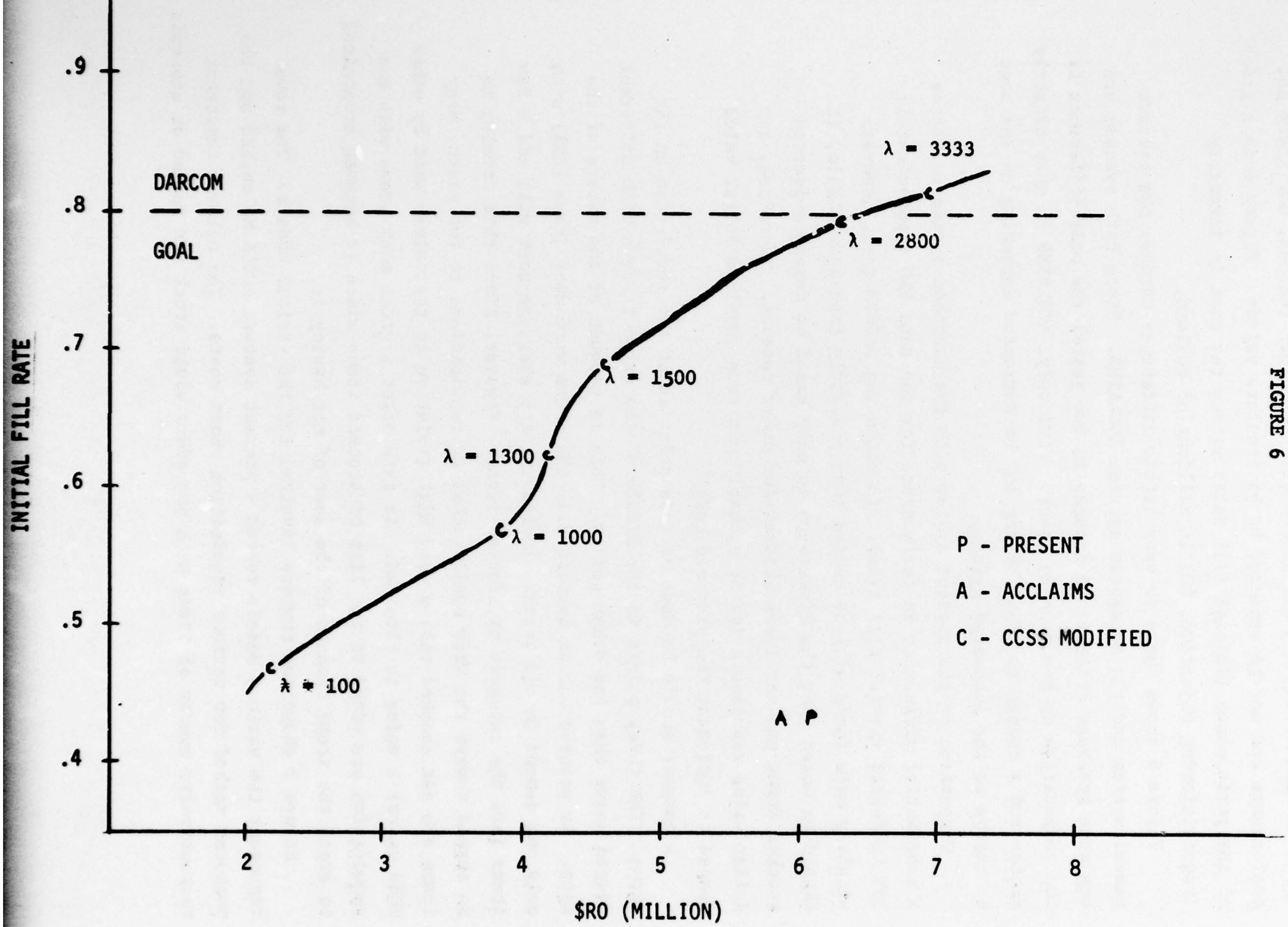


FIGURE 6

based on demand data and not essentiality or other reasons, the costs and performance can not be expected to be absolute values. Figure 6 is a graph of the performance (initial fill rate) versus the cost in inventory (requisitioning objective, RO) in millions of dollars.

Figure 6 shows there is very little difference between the present manual system and the automated system, ACCLAIMS. Since both systems use the same stockage criteria (3 demands in two years) the only difference is the computation on how much to stock. Obviously, ACCLAIMS is only slightly better and a change to ACCLAIMS may not be warranted depending on the cost to change to the automated system.

Comparison of the present system with the proposed system indicates a substantial difference in performance for the same $RO (approximately 30% increased initial fill rate). To reach the DARCOM goal, however, slightly more funds will be needed than presently expended. Again, it should be noted that the discussion is only based on demand supported stocked items and not items stocked for other reasons. Therefore, any dollar value representation is probably not true absolute dollar value needed to implement the proposed model.

A comment should be made at this point about the aberration on the curve. The three points in the middle of the graph trace a much different sloped curve than the other points. This is because of the nature of the data. As pointed out in Section 2.1, there are very many items (65%) with only one demand in two years. Increasing the shortage cost will add a few items into the category of stocked items. However, since this catalog is so skewed toward the very small number of requisitions in two years, many items are not stocked till a very high (relative to the values used by other CCSS users) λ value is obtained. At this point a great many items with one requisition are added to the list of stocked items since it becomes economical to stock the items because of the cost of not having it.

Figure 7 shows the numbers involved for the various models. The rows represent the various models tested - present system, ACCLAIMS method and the proposed method for various requisition short costs. The columns represent respectively; number of items each procedure would stock for demand or economic

FIGURE 7

EMRA MANAGED ITEMS

(EXPECTED VALUES) (ALL DOLLARS IN MILLION)

	# STOCK	# BUY	$ BUY	$ RO	$ EOQ	FILL	SATIS	ACCOM
PRESENT	1246	4166	4.74	6.09	3.96	.438	.756	.437
ACCLAIMS	1246	3892	4.58	5.84	3.85	.438	.757	.437
PROPOSED								
λ = 100	1457	3921	4.73	2.15	1.62	.468	.812	.544
1000	2462	3735	4.74	3.81	2.39	.570	.834	.670
2800	5953	3701	4.76	6.27	3.23	.799	.883	.912
3333	6341	3701	4.78	6.88	3.45	.819	.886	.936

reasons only, the expected number of buys per year and the dollar value of these buys (both stocked and non-stocked items), the dollar value of the inventory levels required by the model (the requisitioning objective), and the dollar value of the reorder quantity (EOQ) portion of the RO. The last three columns are the performance values for each model. They represent the fraction of all requisitions filled from stock on-hand (FILL), the fraction of requisitions for stocked items which are satisfied from stock on-hand (SATIS) and the fraction of all requisitions which are for stocked items whether they are filled or not (ACCOM).

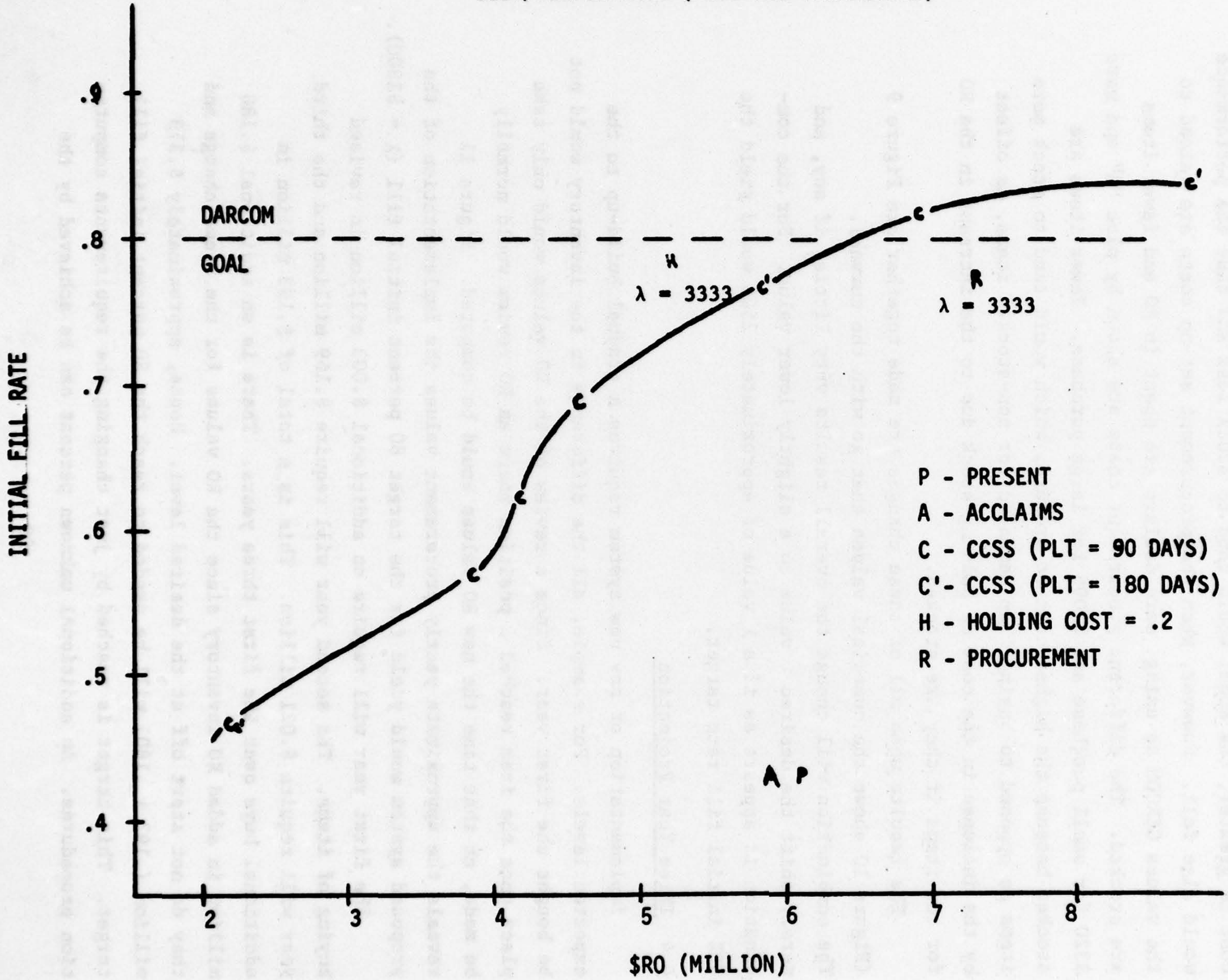
It is observed that even though the number of items which should be stocked is much greater for the proposed model, much less money is required in RO dollars to derive the improved level of performance. Hence, the proposed model is stocking not only different items but also vastly different levels of the item which are stocked.

Figure 7 shows a λ value of 2800 yields the DARCOM target of 80 percent initial fill rate (actually $\lambda = 2800$ yields 79.9 percent). Although many items are stocked for the proposed model with this λ value, the difference in $RO is only .18 million. It is also observed that the accommodation is a significant amount higher than the present system and the satisfaction is also slightly higher. All in all, it appears as if the proposed model can help in the support of EW/SIGINT materiel.

Figure 8 shows the results of various changes to different parameters used in the model. Since there are so many items without a PLT value in the data and since the PLT is a vital parameter in the computations of the proposed model, a PLT value was substituted for those items without a value in the data. The results for Figure 6 are for a lead time of 90 days if no value was given for that item. The mean of the PLT values for items which had values was 90 days. However, this appears to be a very short lead time for the majority of items; hence, a longer time was chosen for the missing PLTs. This value was 180 days. The results in Figure 8 show that the lead time has no affect other than to make the λ value smaller to achieve the same performance level. Instead of $\lambda = 2800$ to achieve initial fill rate of 80%, now a λ of approximately 2000 could be used to achieve the same target. This means of course different items would be stocked and at different levels than with the shorter lead time and an equal λ value (2000).

FIGURE 8

COST/PERFORMANCE (MODIFIED PARAMETERS)



If the holding cost rate is increased to .20, the result for a λ value of 3333 is shown in Figure 8 by the plot of "H". Since the holding cost is greater, the model would tend to stock less and thus the performance would also fall. However, when the procurement set-up costs are raised to the values CERCOM is using, more dollars are spent in RO and fewer items are stocked. The different procurement costs are shown by plot "R" and were $320 for small purchase and $1096 for large purchase. Fewer items are stocked because the higher cost to procure, which would tend to stock more items as opposed to buying when demanded for non-stocked items, is offset by the increase in the cost of holding stock due to the increase in the RO for the items if they are stocked.

The results when all of these changes are made together are Figure 9 (Figure 10 shows the numerical values that go with the curves). The combination will change the overall results very little, if any, and merely shift the desired λ value to a slightly lower value. For the combination it appears as if a λ value of approximately 2500 would yield the 80% initial fill rate target.

4.4 Three Year Projection

Implementation of any new system requires a gradual build-up to the expected levels. For example, all the difference in the inventory would not be bought the first year. Since a review of the RO values would only take place once the item reached a position where an RO review would normally be made, at that time the new RO values would be computed. Figure 11 reveals the approximate yearly procurement values the implementation of the proposed system would yield for the target 80 percent initial fill (λ = $2800).

The first year will require an additional $.003 million in revised buying of items. The second year will require $.169 million and the third year will require $.021 million. This is a total of $.193 million in additional buys over the first three years. There is an additional $.180 million in added RO inventory since the RO values for the items change and they do not start off at the desired level. Hence, approximately $.373 million (.193 + .180) will be needed to reach the 80 percent initial fill target. This target is reached by just changing the requirements computation procedures. An additional unknown percent can be achieved by the

FIGURE 9

COST/PERFORMANCE (COMBINED MODIFICATIONS)

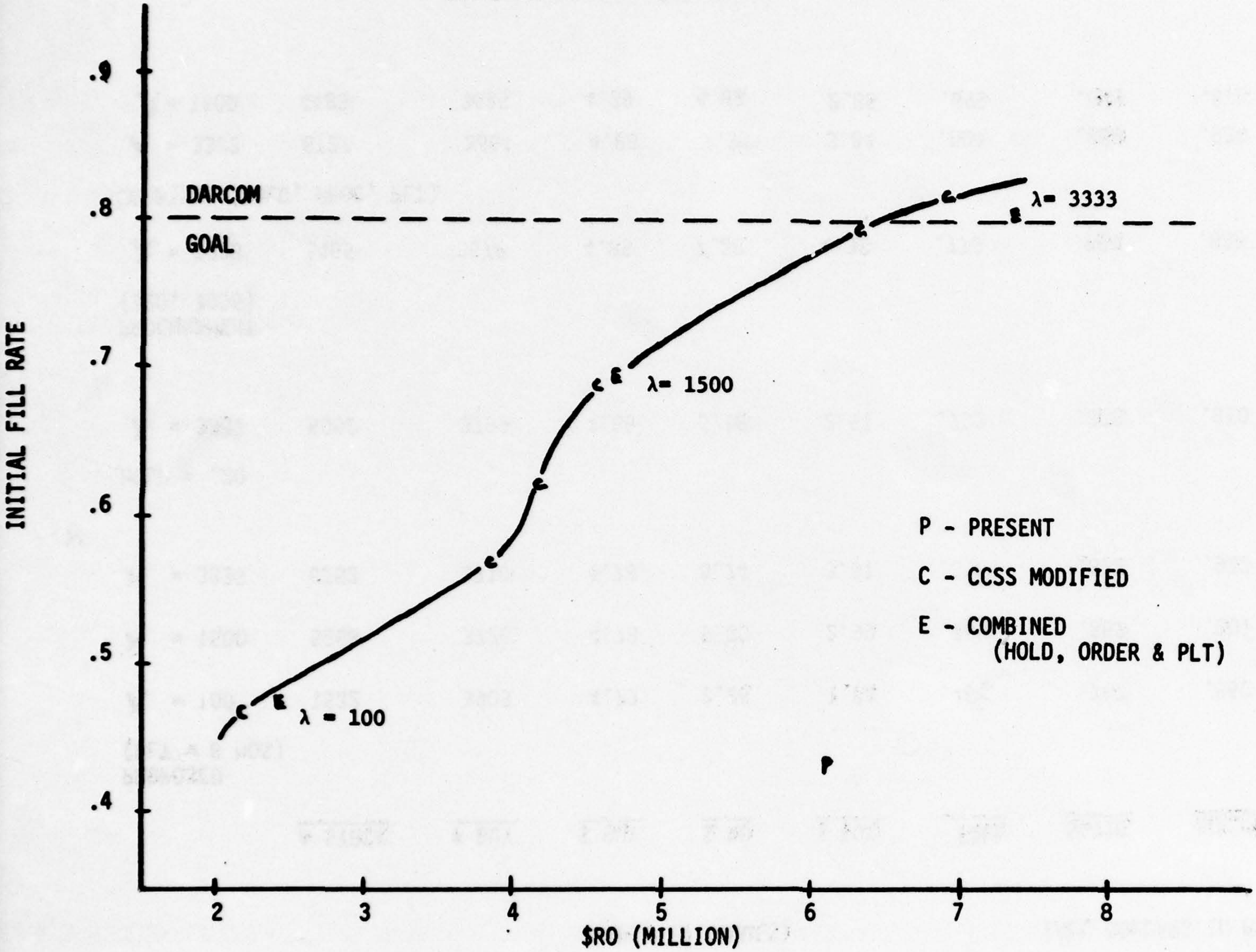


FIGURE 10

EMRA MANAGED ITEMS

(EXPECTED VALUES) (ALL DOLLARS IN MIL)

	# STOCK	# BUY	$ BUY	$ RO	$ EOQ	FILL	SATIS	ACCOM
PROPOSED (PLT = 6 MOS)								
λ = 100	1532	3903	4.73	2.28	1.64	.468	.787	.560
λ = 1500	5668	3726	4.78	5.80	2.99	.769	.857	.901
λ = 3333	6752	3710	4.78	8.74	3.81	.836	.872	.972
HOLD = .20								
λ = 3333	6062	3799	4.85	5.16	2.51	.793	.878	.910
PROCUREMENT (320, 1096)								
λ = 3333	5466	3578	4.85	7.28	4.35	.779	.884	.888
COMBINED (HOLD, PROC, PLT)								
λ = 3333	6127	3664	4.86	7.39	3.84	.804	.869	.934
λ = 1500	4483	3685	4.89	4.69	2.85	.699	.849	.819

FIGURE 11

THREE YEAR PROJECTION OF FUNDS

DOLLAR VALUE OF BUYS

PRESENT

1st	2nd	3rd
6.224	4.573	4.742

PROPOSED (λ = 2800)

6.227	4.742	4.763

DIFFERENCE **TOTAL**

+ .003 + .169 + .021 = + .193 ($MIL)

implementation of a better initial provisioning model. Since the provisioning models were not tested in this work, the exact measure in initial fill is not projected. However, from previous studies it can be expected that some increase in the initial fill rate will be observed.

APPENDIX A

DERIVATION OF EMRA COST PARAMETERS

The costs developed for use in the proposed model (Chapter III) are derived from EMRA data. Derivation of the costs involved going over the various costs desired and seeing what functions are involved and the cost of each function. Some of the data covered FY77 and some covered FY78.

The first cost examined has the holding cost rate. The holding cost rate is made up of four components. They are:

Investment

Obsolescence

Other Losses

Storage

The investment rate is set by DoDI 7041.3 at 10 percent. The obsolescence and other losses rates are derived along guidelines set up by DoDI 4140.39 [6]. The obsolescence rate is defined to be the ratio of the number of transfers to all property disposal officers divided by the applicable stratified on-hand and on-order assets. The assets so designated represent the maximum expected on-hand and reorder quantities at any point in time. The EMRA value of the ratio is .0137 where there were $.143 million in transfers to the property disposal officer and $10.440 million ending inventory in August 1978.

EMRA said very little of their inventory was subject to pilferage, shrinkage, inventory adjustments and the like - categories considered in other losses; however, there was no documentation available to develop a precise value. Hence, the lowest rate was used for this value but with the knowledge that this is only a gross approximation. The value used was .01.

The storage cost rate consists of the care of materiel in storage, rewarehousing costs, physical inventory, preservation and packaging, etc., as described in DoDI 4140.39. The storage cost rate was estimated at .01.

The holding cost rate per year is the sum of these four components:

Investment	.10
Obsolescence	.01
Other Losses	.01
Storage	.01
Total	.13

The next cost needed for the computation of the requirements and stockage models is the order cost per buy. To derive the cost to order when a procurement is necessitated, it is necessary to follow a requisition to see what happens to it and see where it goes. A requisition is received from the field at the Field Support Branch where it is logged in and given an edit check. From Field Support it goes to the item manager who does what is needed depending on the situation with the item. If necessary, the item manager will compute a new RO and initiate the process for a procurement. If procurement is required, the notice goes to the Logistical Support Branch where the purchase request and confirmation (PR&C) and the necessary funding transactions are accomplished. After the funding is taken care of, the PR&C goes to the central processing activity where the contract is drawn up and awarded (if a contract is needed and if bidders have to be notified). The Procurement Branch activities are divided around the $10000 value. If the expected buy is less than $10000, a simple technique of choosing a contractor is made and the process is much less time consuming than activities necessary for contracts over $10000. The contract must be verified in some cases by the Legal Department and from there the contract goes back to the Logistical Support Branch where the contract file is maintained. The more expensive contracts are administered by the Defense Contract Administration Service (DCAS) although EMRA keeps a file for itself.

In the development of the costs, there is a further breakdown into direct and indirect costs. The indirect costs refer to leave and personnel benefits such as insurance. DoDI 7220.21, Inclosure #1, states that these benefits should be computed at a rate of .29.* Thus, the breakdown for the

*This value has been revised to .44, 11 October 1978. Our runs were made with the old value; however, Figures 9 and 10 show the expected results using the larger value.

cost to order for smaller purchases is:

Cost-to-Order (Buy < $10000)

	Direct	Indirect	Total
Field Support	1.34	.39	1.73
Materiel	.85	.25	1.10
Logistic Support	11.28	3.27	14.55
Procurement (Legal)	100.00	29.00	129.00
Total	113.47	32.91	146.38

For larger purchases there is an additional cost of contract administration which is the responsibility of DCAS for many contracts. The basic cost was derived in 1970 [2] and is adjusted by 1.026 per year (for 7 years) to get the cost shown here:

Cost-to-Order (Buy $\geq$ $10000)

	Direct	Indirect	Total
Field Support	1.61	.47	2.08
Materiel	1.12	.32	1.44
Logistic Support	11.60	3.36	14.96
Procurement (Legal)	500.00	145.00	645.00
DCAS			214.23
Total	514.33	149.15	877.71

The other costs derived here are applied only to the stockage acceptance model, COSDIF. The first cost examined was the cost associated with receiving items to be put into stock. The routine observed when stock arrives to be put into storage is the following. The first action is a recording of the information that something has arrived. After the log in, an inspection of the package is made to see if any damage has been encountered in transportation. Also, the item is examined to make sure it meets the specifications of what was ordered. After the inspection, a location is chosen where the items will be stored. A check is also made to see if the item already has a bin or location. After a location is found, it is actually moved to that location and then a card is made up describing the item, when it arrived and where it is located.

All of the above functions are done at the storage location; however, there are also some functions performed in conjunction with the receipt of stock not done at the storage location. The Logistic Support Branch also gets involved. All of the above actions are manually accomplished. However, there is a computer program available which does give an inventory of items in storage. Logistic Support is responsible for entering the information into the computer system. Field Support Branch also gets the information and updates some of these files.

There were 24528 receipts for FY77 and the cost is:

Receipt Cost

	Cost/Line
Log In	1.45
Inspection	2.02
Location	1.35
Stock	.90
Location	.27
Logistic Support	1.09
Field Support	.12
Total	7.20

After materiel is received into stock, physical inventories are necessary to adjust the computer files to the actual availability of stock. The Field Support Branch does the inventory and has six people assigned to this function. They range from E-3 to E-6 and GS-4 to GS-7. There were 5473 items on the stockage list at the time the data was received and the cost per time in stock is $9.55. There were no other costs associated with maintaining an item in storage.

Eventually, the item will be issued for use by somebody. The issue is initiated with the receipt of a Material Release Order (MRO). The MRO is logged in and sent to a location clerk who finds the location of the item. A stock clerk than pulls the item from the location and takes it to be inspected for operating conditions. After inspection, it goes to a packing area. The packing area is parcel post for small shipments and bulk packing for larger shipments. Very little is done with parcel post shipments, which accounts for approximately 90% of the issues, but a great deal of time may be needed for bulk shipments. A crate may have to be made, packing material obtained, etc., which may require up to two days to get ready for shipment.

The breakdown for the issue cost is:

Issue/Line

Function	Cost/Line
Receive MRO	.08
Location	1.35
Stock	.50
Inspection	.27
Shipment	
Parcel Post	1.22
Bulk	2.38
Total	5.80

With these costs, the replenishment requirements and the stockage acceptance model value can be computed.

APPENDIX B

PROPOSED REQUIREMENTS MODEL

The requirements computations used in the proposed model are described in two other reports done by IRO. They are the Insurance Item Model [5] and the VSL/EOQ Model [3] both of which are used in CCSS, the Army wholesale level computer system.

The proposed model uses the insurance model if the lead time demand is less than three and the VSL/EOQ model if the lead time demand is equal to or greater than three. Both models are modified over what they are in CCSS. The insurance model in CCSS uses catalog information. That is, since insurance items are items such that no demands are expected, newer items would always yield requisition objective values of zero. Instead, the catalog of insurance items yields a small lead time value and small RO values can be computed. However, since EW/SIGINT items of concern in this work have expected demand, although very few, the catalog approach was not used. The remainder of the calculation technique was employed however since it is an exact computation using the negative binomial probability distribution and more accurate for very small mean values than the VSL/EOQ model.

Likewise the VSL/EOQ model is not used fully in the proposed model. The VSL/EOQ model uses an approximation to the negative binomial for small demands (< 20 units of lead time demand) and an approximation to the normal probability distribution for the larger means ($\geq$ 20). The proposed model uses both of these procedures but uses a different reorder quantity or EOQ value. The proposed model used the Wilson or Square Root formulation whereas the VSL/EOQ model used a computation which yields a value at least as great as the Wilson. Since most of the items are slow moving, the smaller EOQ value seemed to be more desirable.

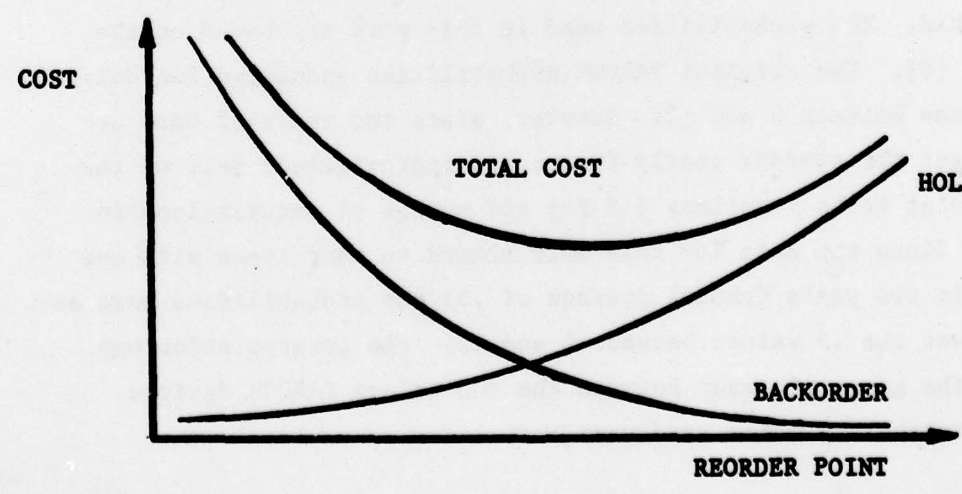
The VSL/EOQ model has constraints on both the safety level and the EOQ computations. The safety level is restricted to non-negative values which are less than three standard deviation of lead time demand. The constraints are carried over in the proposed model. The EOQ is constrained between 3 months and 3 years in CCSS. However, in the proposed model the EOQ is restricted to one unit or 5 years of supply.

The standard deviation of demand for the proposed model is the same computation as the CCSS methodology. The computation is based on a percent error figure applied to the wholesale level of supply. These values were used in this work.

Both the insurance model and the VSL/EOQ model are based on the same objective function; annual total cost (holding, ordering and shortage) is minimized. Mathematically, that is:

$$\text{Min:} \quad T = C_H \, (R+Q/2) + P\frac{D}{Q} + \lambda \, \frac{B}{S} \qquad \text{(B1)}$$

where C_H is the holding cost rate times the unit price of the item, R is the reorder point, Q is the reorder quantity, P is the procurement set-up cost, D is the average yearly demand of the item, λ is the requisition short cost, B is the expected backorders at any point in time, and S is the average requisition size. The λ value is the controlling parameter. Raising and lowering λ affects the compution of R (higher λ implies higher R) and hence the cost can be raised or lowered accordingly. Holding cost (first term in (B1)) will increase with R and shortage cost (third term) will decrease with increase in R. The total cost curve is convex however, and beyond a certain point, the λ value will only increase the total cost. The cost breakout looks like



APPENDIX C

STOCKAGE ACCEPTANCE MODEL

The criterion used to determine if items should be stocked or not are outlined here. The decision is determined by economical considerations only and essentiality does not enter the process. The reason essentiality does not play a role is at the present time there is no acceptable method of defining what ranking an item should have in terms of its significance to the operation of the end item.

The economic considerations balance the cost of stocking the item with the cost of not stocking the item. The cost of stocking the item included the cost of having stock in inventory, the cost of ordering new items, the cost of receiving stock, the cost of issuing stock and the shortage cost. The cost of not stocking an item consists of the ordering cost, the premium on ordering on demand and the shortage cost.

The shortage cost in the requirements model and the stockage model are disjoint costs in CCSS. This is done because DARCOM set up two goals - one for each model - and they can only be reached by using disjoint shortage costs. However, the proposed models - both requirements and stockage - use the same shortage cost since there is only one goal.

In addition to the costs involved, there are probabilities of receiving no demand given an average yearly frequency. These are very important values and contribute much to which items are to be stocked and which items are not stocked. The probabilities used in this work are based on the TARCOM study [8]. The original TARCOM probabilities accounted for only interger values between 0 and 12. However, since two years of data are examined to get the average yearly frequency, approximately half of the values are going to be fractions (.5 for odd number of requisitions in two years). Since the data for this work showed so many items with one requisition in two years (annual average of .5) the probabilities were expanded to cover the .5 values between 0 and 12. The interpolation was taken to be the geometric mean between the two values TARCOM derived. Hence, the probability table used was:

Annual Frequency	Prob Zero Demand	Annual Frequency	Prob Zero Demand
0	.78	6	.05
.5	.52	6.5	.04
1	.35	7	.04
1.5	.28	7.5	.03
2	.23	8	.02
2.5	.18	8.5	.01
3	.14	9	.01
3.5	.10	9.5	.01
4	.07	10	.01
4.5	.06	10.5	.01
5	.06	11	.01
5.5	.05	11.5	.01

As with the CCSS stockage model, any item with an average yearly frequency of 12 or more is automatically stocked, i.e., it is not run through the COSDIF computation. Otherwise, the cost of stocking the item is compared with the cost of not stocking the item.

The actual expression for this computation is

$$COSDIF = E_1\,Pr(Z) + E_2\,[1 - Pr(Z)] \qquad (C1)$$

where

$$E_1 = PS + 2(H)U(D)\left(\frac{PLT}{365} + \frac{1}{FP}\right) + 2(H)U(D)(SLY) + 2(FI)$$

$$E_2 = (PS)(FP) + H(U)\sqrt{Q\left(S + \frac{Q-1}{2}\right)} / (S-1+Q) -$$

$$U(D)(PM) - (FD)\left[PN - I + \left(\frac{PLT-5}{365}\right)\lambda\right] + H(U)(D)(SLY)$$

and Pr(Z): Probability of no demand given the annual frequency.

PS: Cost to procure plus the receipt cost for stock item.

H: Annual holding cost rate.

U: Unit price of item.

D: Annual quantity demanded.

PLT: Procurement lead time in days.

FP: Annual procurement frequency

SLY: Safety level expressed in years.

FI: Fixed cost of maintaining an item in stock.

S: Average requisition size.

Q: Reorder quantity.

PM: percent premium when buying on demand.

FD: Frequency of demand per year.

PN: Cost to procure a non-stocked item.

I: Cost of issuing stock.

λ: Annual cost per requisition short.

The costs used in this computation are derived in Appendix A. These costs are valid only for use at the EMRA facility as it presently is. Likewise, each ICP uses costs relevant to its operations when this evaluation is made on CCSS.

The above expression (C1) is evaluated for every item with demand. If COSDIF is negative, the cost to stock is less than the cost to not stock and thus that item is stocked. A positive COSDIF of course indicates the item is not stocked.

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