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DP-MS-83-105

USE OF MICROCOMPUTERS FOR INVENTORY MANAGEMENT WITH UNCERTAIN DEMAND

by

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Paper proposed for presentation at the
American Production and Inventory Control Society
Specialty Seminar
Palm Springs, California
January 30, 31, February 1, 1984

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OBJECTIVE

This paper describes how a microcomputer is used for analysis of inventory trends to optimize inventory investment and customer service level in a distribution environment with uncertain demand, and to support an inventory subsystem resident on a main computer.

INTRODUCTION

The inventory to be managed consists of 71,000 items, or 22,000 general stores stock items and 49,000 spare parts stock items with value of $22 million. Two major changes are being made within an elapsed period of six months:

(1) a new online inventory control subsystem is part of a procurement cycle system developed "in house" over the last three years using purchased data base management and teleprocessing systems.

(2) installation of an automatic storage and retrieval system of seven carousels 90 feet long and 10.5 feet high will provide a better flow and control of material; new double-deep racks in remaining areas will be used for bulk or low volume items.

The microcomputer is used primarily with software packages to perform analyses with spreadsheets, to manage data files, to create graphs, and to write reports as a word processor. Downloading data from the large PCS Data Base on the mainframe to the microcomputer for more detailed analysis of problem areas is a method which saves response time as well as saving duplication of data entry and validation.

THE BASIC CONTROL FUNCTION

Inventory management has the function of controlling quantity on hand using only two decision variables:

* How much to order and when?

For thirty years the answer to the first question has been provided by the mathematical technique called Economic Order Quantity or EOQ, calculated by:

$$EOQ = \sqrt{\frac{2AS}{rv}}$$

where A = Ordering Cost
S = Units Sold per Period
r = Cost of Carrying 1 Unit 1 Period
v = Unit Cost

Only three factors influence EOQ: ordering cost, carrying cost, and units sold; the units sold factor (demand) usually is uncertain and must be estimated.

The answer to the second question, when to order, may be formulated as:

OP = S during lead time plus safety stock

For order point (OP), uncertainty is anticipated in demand and in lead time which means that deterministic decision models would be useful only in theory. However, optimum values of the decision variables that will minimize total inventory cost may be calculated based on a selected stochastic process.

Model Selection

Forecasting is the beginning of all business planning; it may be intuitive or elegant, for periods short or long, costly or cheap, and unreliable or accurate, but some estimation of future events is made. Kinds of forecasting techniques may be sorted into three groups: qualitative (such as Delphi, market research, or panel), statistical (such as moving average, exponential smoothing, or adaptive), or causal (such as regressive, econometric, or surveys). [1]

Time series models may be used in demand forecasting. The simplest ones like index numbers and moving averages are purely descriptive, and are not subject to measurement of reliability. When data is collected sequentially over time, the assumption of independent random errors, the key to regression models is probably not true; such data is usually correlated. For inferential purposes, probabilistic models such as a regressive model for secular and seasonal effects combined with an auto-regressive model for cyclical effects are generally recommended. However, a highly complex mathematical model does not assure a more accurate forecast. By necessity forecasts assume that historical data exists, and that past performance is relevant for predicting future values. This assumption is not always true, and there is a continuing need to measure how well the forecast is actually working. The model which produces the least error should be used until a better one is found.

THE PROCUREMENT CYCLE SYSTEM

The inventory control function operates not in isolation but as a member of an overall service group for procurement. The new computer system replaces a set of individual systems, primarily of the batch type which had patchwork interfaces, to serve the needs of Purchasing, Accounts Payable, and Stores (including Inventory Management, Receiving, and Disbursing). The new system minimizes data entry, provides validation at entry, and shares real time information, substantially reducing paper work and filing. There are six subsystems involved, of which four are in production, and the last two will be implemented on March 1. The scope of work performed in fiscal year 1983 is shown in figure 1. The subsystems of the Procurement Cycle System are related to each other as shown in figure 2.

Implementation Dates	Subsystem	Records
9/1/81	RECEIVING	130,000 Line Receipts
9/1/82	EXCESS	45,000 Disposal Lists 1,000 Items
3/1/83	PURCHASING	55,453 Requisitions 42,620 Orders $204 MM
3/1/83	ACCOUNTS PAYABLE	136,518 Invoices 64,198 Checks
3/1/84	INVENTORY MANAGEMENT	71,000 Items $22 MM
3/1/84	DISBURSING	250,000 Orders Filled

figure 1

FILES

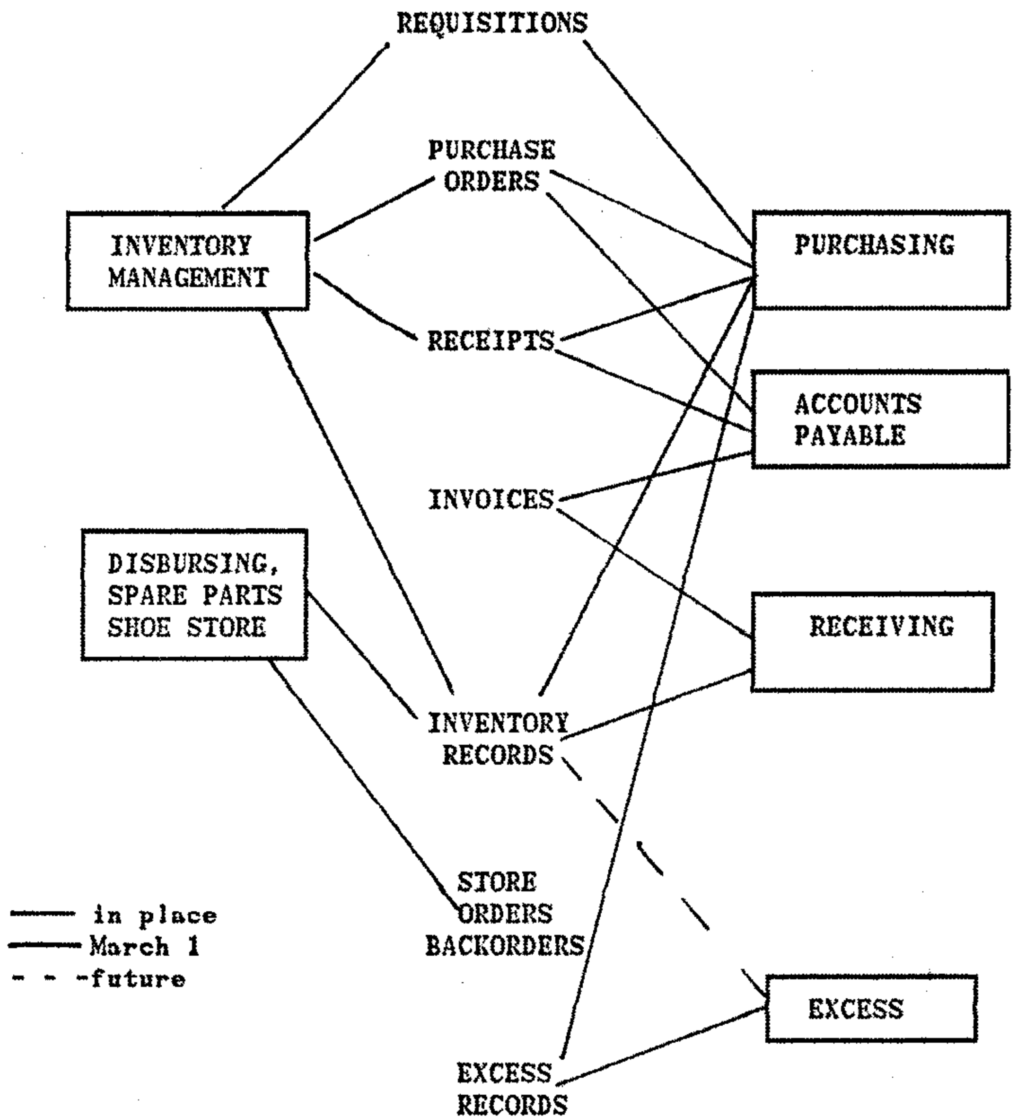

figure 2

PCS is a menu-driven system with main menu screen as shown in figure 3.

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                     PROCUREMENT CYCLE SYSTEM

              ACTION:    ENTER  13  TO EXIT
                          OR A SELECTION NUMBER

   REQUISITIONS             STORES                         MISCELLANEOUS

 1. ORDER FORM             19. STORES ORDER ENTRY         30. SHIPPING
 2. STORES                 20. BACKORDER ENTRY            31. STATUS
 5. MEDICAL                21. STORES ORDER STATUS        32. TABLES
 6. IND HYGIENE            22. INVENTORY MANAGEMENT       33. TICKLERS
 7. ACCOUNTABILITY         23. DISBURSING                 34. VENDOR
                           24. SAFETY SHOE SALES          35. CONTRACTS
 9. DIRECT PO ENTRY        25. EXCESS
10. PURCHASING
11. RECEIVING               CATALOGS
12. ACCT PAYABLE
                           26. COMMODITY
                           27. STORES
                           28. EXCESS
```

figure 3

In addition to the obvious benefits to the primary service group, there are substantial advantages to all qualified users on the plant site since they can make inquiries about the status of requisitons, purchase orders, or receiving reports; also, the Stores catalog can be used to look up items for entering store orders directly, and to check their status. There are miscellaneous options to provide vendor information; messages may be sent and received via the "tickler" option as electronic mail.

INVENTORY MANAGEMENT SUBSYSTEM

The Inventory Management Subsystem provides online operations for all of the actions displayed in the screen in figure 4, which appears when Action 22 is selected on the PCS main menu. The data elements for these transactions are contained in six data base structures of which the Stores Item data base is the largest with 71,000 records, each with record length of 1143 characters. The enormity of the data bases on the mainframe and the heavy use of those structures make the process of downloading specific data to the microcomputer for further analysis a definite advantage.

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             *** STORES INVENTORY MANAGEMENT MENU ***

        ENTER  NI  FOR NEW ITEM SETUP
               II  FOR ITEM INQUIRY FOR CHANGE OR DELETE
               RA  FOR REORDER ANALYSIS
               RI  FOR REQUISITION ISSUE
               RR  FOR RETURNED REQUISITION REVIEW
               IS  FOR ITEM STATUS
               CA  FOR CATALOG
               DS  FOR PRINT SPARE PARTS DATA SHEET
               IA  FOR INVENTORY ADJUSTMENT
               CH  FOR CAPTION HISTORY
               TH  FOR TRANSACTION HISTORY
               MR  FOR MISCELLANEOUS RECEIPTS
               TR  FOR TRANSFERS
               SR  FOR SUSPENDED RECEIPT ADJUSTMENT
               EN  FOR END OF SESSION - RETURN TO PCS MENU

        ENTER ACTION:          CAPTION:          ITEM NUMBER:

ENTER (OPTIONALLY) FOR ACTION CA OR DS
 EMS DUPONT NO:     BLDG:        AREA:            EQUIP NO:
KEYWORD
```

figure 4

Reorder Analysis

A review of items for reordering is made each night in a batch computer run. This is functionally equivalent to having a continuous review of EOQ and OP. Every item is classified as one of eight order techniques:

DR — Dynamic	—	Dynamic Reorder Point and Dynamic Order Quantity
FP — Fixed Reorder Point	—	Fixed Reorder Point and Dynamic Order Quantity
MM — Maximum-Minimum	—	Fixed Reorder Point and Fixed Order Quantity
OR — Order on Request	—	Order to Cover Recorded Backorders
AB — Accumulation	—	Accumulate Backorders and Reorder at Scheduled Reorder Date
NR — No Reorder	—	Do Not Reorder
CT — Contract Order	—	Various Contract Types;
CF — Check File	—	Order Point and Quantity Determined by Analyst Requisition Review on 15th of each month

Requisitions are automatically issued for items when inventory on hand is equal to or less than the fixed or calculated order point. In both OP and EOQ calculations the uncertain element of projected monthly use or demand must be estimated. Approximately 20,000 items are of the dynamic reorder type and are subject to the forecast procedure.

Estimating Demand

The present projection of monthly use is simply an average of the last twelve months' usage. Several changes are planned for refining the demand forecast. It is generally recognized that items differ in their demand patterns, and that demand cannot be forecast in the same way for all items. Application of different forecasting methods (dependent upon activity and availability of historical data) will be used in conjunction with exception reports based on tracking signals and measures of bias to identify forecasts that are not working well. The automatic model selection will be a part of the inventory management subsystem of PCS, and the detailed analysis of problems will be performed on a microcomputer.

ANALYSIS OF PROBLEMATIC ITEMS

The demand for some items cannot be estimated with reliability because patterns of past demand exhibit extreme variation. This "lumpy demand" should be recognized and reflected in the EOQ and OP calculations and reordering process.

Simulation is a technique which uses representative or artificial data to reproduce in a model various conditions that are likely to occur in the actual performance of a system. It may be as simple as manual variation of a parameter value or as sophisticated as Monte Carlo simulation with random numbers.

The effect of errors in estimation can be evaluated through sensitivity analysis which involves assigning alternative values to parameters and comparing the results to find which ones are particularly sensitive or which parameters most affect the optimal solution. For example, in the EOQ, if order quantity varies widely when carrying cost is changed, it is said to be sensitive to carrying cost. Performing these iterations will show EOQ relatively insensitive to parametric variation because of the dampening effect of the radical sign. Mistakes in estimating these variables are less serious for EOQ than for the order point.

A software package [2] which was developed for microcomputers performs simple variation of demand and sensitivity analysis, and allows the analyst to change values and recalculate EOQ and OP, as shown in figures 5 and 6. The microcomputer marketplace offers numerous forecasting packages and should be searched to find one which will closely match specific business requirements.

EXAMPLE: Fast-moving item, many small sales

Input:		
	Number of Days in 1 Period	= 365
	Carrying Cost 1 Unit 1 Period	= 25.00
	Ordering Cost	= 50.00
	Units Sold/Used per Period	= 1600
	Lead Time in Days	= 30
	Average Size Sale in Units	= 5
	Percent Probability Stockout	= 0
Output:	Economic Ordering Quantity	= 80
	Ordering Point	= 234
	Total Inventory Cost 1 Period	= $7662.50

Variation: Sensitivity Analysis

1. Vary Units Sold/Used per Period:

	EOQ	OP
1300	72	199
1350	73	205
1400	75	211
1450	76	217
1500	77	223
1550	79	228
1600	80	234

Note that both EOQ and OP are sensitive to usage change and OP is more sensitive than EOQ.

2. Vary Average Size of Sale:

	EOQ	OP
2	80	196
3	80	211
4	80	223
5	80	234

Note that EOQ does not change with size of sale, but OP does

3. The combined effect of decrease in annual sales and avg size of sale on EOQ and OP (sales = 1300 and size = 2)

EOQ	OP	TOTAL COST
72	165	$5927.78
80	234	7662.50
		$1734.72

Compare difference: if demand drops and inventory is constant at 1600, the minimum excess carrying cost is $1734.72.

figure 5

EXAMPLE: Sporadic demand: average size of sale is larger than units sold per period

Input:

Number of Days in 1 Period	=	30
Carrying Cost 1 Unit 1 Period	=	.25
Ordering Cost	=	65.00
Units Sold/Used per Period	=	8
Lead Time in Days	=	45
Average Size Sale in Units	=	18
Percent Probability Stockout	=	1

Output:

Economic Ordering Quantity	=	64
Ordering Point	=	46
Total Inventory Cost 1 Period	=	$ 336.10

Variation: Sensitivity Analysis

1. Vary Units Sold/Used per Period:

	EOQ	OP
10	72	53
20	102	84
30	125	111
40	144	136

2. Vary Average Size of Sale:

	EOQ	OP
15	64	43
20	64	48
25	64	52
30	64	56

3. Vary Percent Probability of Stockout:

	EOQ	OP
0	64	50
1	64	46
2	64	43
3	64	41
4	64	39

figure 6

ANALYSIS OF INVENTORY TRENDS

The opposing goals of minimizing inventory investment and maximizing customer service level can be optimized, given that constraints of the two functions are known. Policy determines if tradeoffs in one are made to accommodate the other. If the decision is made to avoid stockouts by assuming a zero probability, the safety stock may be too high, and the investment will contain that fixed, unproductive cost. Alternatively, if inventory investment is substantially reduced while demand and other factors are constant, customer service level will fall. A microcomputer may be used to track performance in the two areas.

Minimizing Inventory Investment

By definition, inventory is a stock of goods remaining idle at a given point in time. It is waiting, must be on hand, but ideally it should be there "just in time" to be used. The pragmatic approach to minimize size of inventory investment is to monitor and control every identifiable way that surplus inventory occurs; for example:

1. Target high value parts and investigate for possible reduction
2. Eliminate inactive material and review often for obsolescence
3. Reduce unreleased material held up in receiving
4. Reduce unreleased material held up for inspection
5. Use "Number of Months Supply" reports to identify surplus and modify reordering until in control
6. Reduce safety stock by better forecasting and anticipation of material needs
7. Improve lead time and get supplier to ship more frequently and precisely
8. Restrict access to material

Spreadsheets provide a convenient way to keep ongoing records of inventory investment changes, and also may be graphically represented as shown in figure 7. This example is used directly from a microcomputer printer as part of a monthly report.

TRACKING INVENTORY INVESTMENT CHANGE ($000)
Stores and Spare Parts Fiscal Year 1983
Planned V. Actual

COL / ROW	A	B	C	D	E	F	G
1		INVENTORY	CHG SINCE				
2		VALUE	SEP 1982	NEW ITEMS	DELETED	ESCAL	UNIT VOL
3	SEP	19,523					
4	OCT	20,072	549	4	(19)	183	381
5	NOV	20,935	1412	50	(71)	271	1162
6	DEC	21,618	2095	102	(72)	311	1754
7	JAN	21,696	2173	128	(141)	460	1726
8	FEB	21,665	2142	199	(156)	557	1542
9	MAR	21,676	2152	280	(161)	763	1270
10	APR	21,738	2215	304	(191)	679	1423
11	MAY	22,534	3011	358	(210)	1534	1329
12	JUN	22,102	2579	525	(334)	861	1527
13	JUL	22,619	3096	606	(336)	957	1869
14	AUG	22,782	3259	750	(340)	1017	1832
15	SEP	22,397	2874	838	(363)	1092	1307
16	FOR		4597				

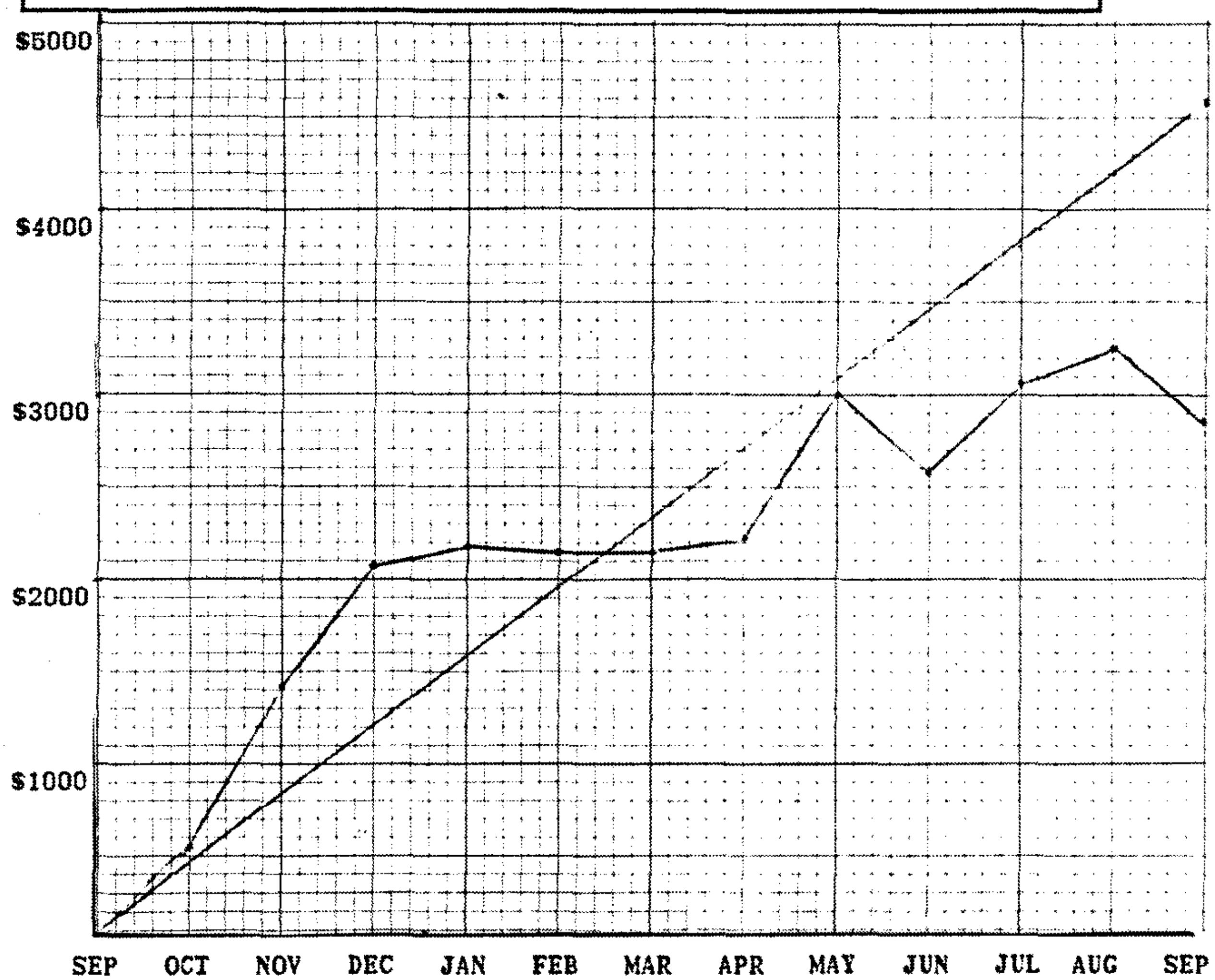

figure 7

<u>Turnover Analysis</u> is commonly used to measure inventory efficiency. Figure 8 is an example of a spreadsheet which can be an ongoing tracking and reporting method. Turnover is defined as the number of times inventory is replaced during a time period; it is a measurement of inventory investment to support a given level of sales. It is found by dividing the cost of goods sold for the period by the average inventory for the period. Its validity would assume that inventory is balanced and able to satisfy customer requirements with a minimum of surplus.

MONTHLY INVENTORY AND SALES ($000)
General Stores Fiscal Year 1983

COL / ROW	A	B	C	D	E
1		INVENTORY	SALES	RATIO/	RATIO
2		VALUE	VALUE	MONTH	* 12
3	OCT	6493	1294	.20	2.39
4	NOV	6649	1322	.20	2.39
5	DEC	6883	1062	.15	1.85
6	JAN	6983	1293	.19	2.22
7	FEB	6992	1200	.17	2.06
8	MAR	6905	1178	.17	2.05
9	APR	6965	1461	.21	2.52
10	MAY	7656	1054	.14	1.65
11	JUN	7027	1128	.16	1.93
12	JUL	7441	915	.12	1.48
13	AUG	7648	1105	.14	1.73
14	SEP	8034	1141	.14	1.70
15	TOTAL	71821	14153	.19	2.36

figure 8

The overall turnover may conceal significant fluctuations in the individual items making up the totals. A company could measure its inventory turns at four times a year and find it acceptable, but an item-by-item analysis could show that 20% of the items were turning 30 times annually while 80% were turning about once; and 25% could have inventory greater than 12 months supply while 25% could have had stockouts in the last year. If so, the average turnover figure does not reflect the true condition of the inventory, and a microcomputer can be used to identify and report on unacceptable turnover by item in a spreadsheet organized as shown in figure 9. Identification of inactive investment can be developed further as shown in figure 10.

IDENTIFICATION OF SURPLUS INVENTORY INVESTMENT
TURNOVER ANALYSIS BY ITEM, GENERAL STORES

COL / ROW	A	B	C	D	E	F	G	H	I
1	CAP	ITEM	ABBREV	CUMM %	INVENTORY		MONTHS	GT	GT
2			DESC	ITEMS	ON HAND	DEMAND	COVERG	12	24

figure 9

IDENTIFICATION OF INACTIVE INVENTORY INVESTMENT

GENERAL STORES

COL / ROW	A	B	C	D	E	F	G	H	I
1	CAP	ITEM	ABBREV	Inventory	Last	ONE	TWO	THREE	FOUR
2			DESC	Value	Issue	YR	YRS	YRS	YRS
3	23	9057.00	Funnel Buckner	$24,123.23	1/81	0	0	0	
4	20	1900.00	Boot with Seal	$ 6,540.00	3/79	0	0	0	0
5	14	2525.00	Metal Gasket O	$ 5,888.09	2/81	0	0		
6	23	13690.00	Ring, Retainer	$ 4,909.40	7/81	0	0		
7	4	1930.00	Machine Bolt H	$ 4,066.89	5/81	0	0		
8	23	14015.00	Needle Shroud	$ 3,987.65	2/81	0	0		
9	16	144.10	Test Weld Coup	$ 3,844.84	4/80	0	0	0	
10	5	1966.00	Drewgard	$ 2,624.60	1/80	0	0	0	0
11	15	15750.70	Pipe 6 inch	$ 2,203.16	9/80	0	0	0	
12	4	29876.00	Plastic Tape	$ 1,817.60	12/80	0	0	0	
13	12	39647.05	Tube, Counter	$ 1,280.37	3/80	0	0	0	
14	14	2610.00	Gasket O Ring	$ 1,224.33	1/81	0	0	0	
15				$62,510.16	1/81	0	0	0	

figure 10

A value distribution analysis sorts inventory items by decreasing order of annual dollar volume, splitting them into classes of A, B, and C. Class A contains the items with highest annual dollar volume and receives the most attention; Class B items receive less attention, and Class C items, containing low dollar volume are routinely controlled. The ABC principle is that a relatively small number of items accounts for a large proportion of activity, and careful control of those few items can provide a high degree of overall control (Pareto's rule). Relevant data can be analyzed in a spreadsheet as organized in Figure 11.

VALUE DISTRIBUTION ANALYSIS
DESCENDING ANNUAL SALES
General Stores

COL / ROW	A	B	C	D	E	F	G
1	CAP	ITEM	ABBREV	CUMM %	SALES	CUMM %	ABC
2			DESC	ITEMS	($000)	OF SALES	CLASS
3							

figure 11

Maximizing Customer Service Level

Customer service level is a measurement of the effectiveness with which the inventory management system responds to actual demand, which requires analysis of stockout and backorder data. Suggested spreadsheets are illustrated in figure 12 for a summary view and in figure 13 for detail.

SERVICE LEVEL

DATE	IN STOCK %	SERVICE LEVEL
DEC	97.5	86.0
JAN	97.6	88.9
FEB	97.4	92.6
MAR	97.5	90.5
APR	97.2	88.0
MAY	97.2	88.2
JUN	97.1	87.1
JUL	97.1	85.9
AUG	97.3	91.1
SEP	97.2	83.2
OCT	96.9	87.6
NOV	96.9	88.5

IN STOCK % = # BO / # ORDERS FILLED + # BO

SERVICE LEVEL = # ITEMS WITH QTY OH / TOTAL # ITEMS

figure 12

ITEMS OUT OF STOCK

GENERAL STORES

COL / ROW	A	B	C	D
1	CAP	ITEMS	TOTAL	OUT/TOTALS
2		OUT	ITEMS	PERCENT
3	1	1	123	.81
4	2	5	56	8.92
5	3	8	197	4.06
6	4	56	2042	2.74
7	5	18	503	3.57
8	6	21	440	4.77
9	7	3	65	4.61
10	8	8	170	4.70
11	9	8	116	6.89
12	10	3	204	1.47

figure 13

Mathematical models exist for solving the optimal inventory position, i.e., Monte Carlo simulation for waiting-line or queueing problems are conceptually similar: there are opposing costs of understocking and overstocking (services or material). Finding the optimal level of inventory which minimizes total costs is like the queueing decision of finding the optimal service demand. Shortage cost is the marginal profit lost or the penalty for being unable to meet demand. The cost may be high relative to the cost of the item if it is part of a production process. The seriousness of the shortage is relevant in calculating the penalty. In a distribution environment, the practical approach is simply to specify the tolerance of stockout or service level as a given value, and then to maintain inventory around that level.

SUMMARY AND CONCLUSIONS

Actual measurement of comparative customer service and inventory investment attributable to using a microcomputer are not complete, but it is already evident that it will contribute to efficiencies in performance reporting, forecasting demand for reorder procedures, and will be used for activity analysis and space computations in the initial loading of the automatic storage and retrieval system. Advantages of using a microcomputer are derived from the characteristics of having total control over the system, immediate response, low cost, and spreadsheets for fast, accurate ongoing analysis with both tabular and graphic representation.

For inventory management this is only the beginning in using microcomputers in either a leading or supporting role. The availability, cost-effectiveness, and sophistication of software packages, already abundant, is expected to grow. Those users who previously depended upon manual forecasting techniques and tracking methods, or upon a complex system and a large computer, will benefit from performing these functons on a microcomputer.

Credits

[1]. John C. Chambers, Satinder K. Mullick, Donald D. Smith, "How to Choose the Right Forecasting Technique", Harvard Business Review, July - August, 1971, p. 55.

[2]. EOQ Software Package by Execuware, Microcomputer Software for Executives from Aeronca, Inc., Charlotte, NC

Biographical Sketch

Betty Meadows is an Inventory Management Analyst in Procurement and General Services at Dupont's Savannah River Plant and was previously an analyst in computer systems there. Graduate of Winthrop College, BA in Economics, MAT, and MBA; in economics PhD program of study, University of South Carolina.

The information in this article was developed during the course of work under Contract No. DE-AC09-76SR00001 with the U. S. Department of Energy.