1991

Testing the Economic Order Quantity Model on Maintenance Inventory

Teresa J. K. Hall
University of Northern Iowa

Testing the Economic Order Quantity Model on Maintenance Inventory

Submitted in Partial Fulfillment
of the Requirements of 33:270
Research Projects in Industrial Technology

Teresa J.K. Hall
University of Northern Iowa
Summer 1991

ABSTRACT

This pilot study seeks to determine the effect a non-traditional method of inventory control may have on industrial maintenance repair parts inventory. The application of mathematical models designed for production inventory to Maintenance, Repair and Operating (MRO) inventory has not been widely researched, although theorists and practitioners feel there is potential for some models. The Economic Order Quantity (EOQ) theory has proven to be effective in production inventory circles. This pilot study examined the effectiveness of the EOQ in terms of holding cost of the inventory and number of out-of-stock conditions versus the Weighted Moving Average method currently in use at Deere Foundry. The results found no significant difference in holding costs between the two methods. The number of stockouts were largely similar. However, two items in the study had 75% fewer stockouts than the Weighted Moving Average method. This finding may support further research into application of the EOQ to maintenance inventory.

Table of Contents

CHAPTER 1

Introduction

The ability to balance maintenance, repair and operating (MRO) inventory levels with optimum service levels has been a continuing dilemma for manufacturing management (Gardner, 1990). While maintenance has a mission to support manufacturing and reduce production downtime (Herbaty, 1983), the primary goal of inventory management is to offset the expense of carrying inventory against the hazard of not having enough inventory to cover demand (Gilbert & Finch, 1985). MRO purchasing organizations are responsible for analyzing trends and making judgments regarding the stock levels of thousands of separate items. Each item, or group of items, has discrete factors that affect demand behavior, minimum stock levels, order quantity, item cost and lead time (Zanakis, Austin, Nowading & Silver, 1980; Silver, 1981; Mitchell, 1987).

Production inventory has benefited from mathematical models developed for its specific traits and needs. The application of production inventory control models on MRO inventory is not widely practiced (Handley, 1984), but has the potential to generate cost savings by lowering investment levels or improving parts availability during demand.

Purpose

The purpose of this research project is to:

1. Do a pilot study to determine the feasibility of applying the Economic Order Quantity model to broad sections of Deere Foundry MRO inventory.

2. Determine if the Economic Order Quantity model, when applied to MRO inventory, can ensure reasonable inventory levels large enough to cover demand, yet lower investment costs.

3. Determine the method that causes the least number of stockouts over the historical demand period.

Statement of the Problem

The focus of this project is to determine if the Economic Order Quantity model (EOQ) has any impact on MRO inventory in terms of levels of inventory investment or changes in the number of inventory stockouts.

Research Questions

1. What effect does the Economic Order Quantity formula have on maintenance repair parts inventory investment levels?

2. Does the Economic Order Quantity model cause a higher number of out-of-stock conditions compared to the Weighted Moving Average method?

Significance of the Study

Mecimore and Weeks (1987) found that, in large manufacturing organizations, service part ordering and stock level policy was determined by past experience and intuition. Few MRO inventory organizations used mathematical models for inventory control. In organizations that are using statistical inventory control, such as Deere Waterloo Foundry, resistance to changing methods is somewhat justified since testing alternate models is time consuming for operations personnel with little time for or experience with this type of experimentation.

The Economic Order Quantity (EOQ) formula may have the potential to generate cost savings for those MRO items with constant levels of demand by lowering stock levels over large blocks of time. EOQ is designed to regulate inventory based on ordering and holding costs. The high expense of some MRO inventory may lend itself to EOQ application.

Delimitations of the Study

Although MRO inventory encompasses a diverse group of items, this study will only deal with machine maintenance repair items in an expense stores system at one facility of a local manufacturer. Office supplies, building and grounds maintenance and systems repair contracts will not be addressed.

The population is 70,000 (estimated) service parts used for machine repair in Deere Waterloo Foundry. The sample will be limited to a group of ten parts with a history of steady, yet unpredictable, pattern of demand selected from one unit of equipment at Deere Waterloo Foundry.

Assumptions of the Study

The study assumes that the historical data from the population is reasonably accurate and reflects common traits of inventory for maintenance such as Poisson distribution of requests and stochastic demand. The study also assumes some inventory items may be interdependent on others in the sample.

Definition of Terms

Inventory. An idle resource such as "tools, purchased parts, raw materials" and supplies that are on hand when required (Riggs, 1987, p. 456). For the purpose of this study, inventory will be defined as purchased parts in a service parts stockroom available to maintenance personnel on demand.

Demand. A 'purchase' or withdrawal of an item of inventory from the stores system. It is also a requisition for an item listed in the inventory, but not currently in stock.

Stochastic demand. A pattern of inventory needs that are said to be probabilistic or uncertain (Hadley & Whitin, 1963). Demand in this study will be considered uncertain and random for any item available in the inventory.

Poisson distribution. Describes the situation where demand occurs randomly during a time period and the quantity of demand depends on the length of time (Heizer & Render, 1991). This study will assume that demand will be random over the length of the study and will be proportional to the time period of observation.

Economic Order Quantity Theory. The optimum quantity of an item purchased with regard to ordering and carrying costs of inventory (Wallace & Dougherty, 1987).

Weighted Moving Average. An averaging method that gives weight to factors affecting demand changes. Thus as demand increases, inventory levels will only rise after the average demand has increased significantly.

Stockout. When the inventory level is reduced to zero.

CHAPTER 2

Review of Literature

Inventory control is a popular topic for a broad spectrum of practitioners, theorists and researchers (Silver, 1981; Fetter & Dalleck, 1961; Mecimore & Weeks, 1987). Mathematical models have been tested, applied and proven under a variety of circumstances. Yet, there remains a gap between model development and utilization by managers of inventory.

Turban (cited in Zanakis, 1980) in 1972 found that, regarding operations research, major corporations applied traditional inventory concepts very infrequently. In a study conducted in 1987, Mecimore and Weeks found that only 8.7% of the surveyed companies used mathematical models to set service part order quantities and only 11.3% used models for safety stock levels. The findings showed that 40 to 45% of the persons responsible for service parts inventory management used experience and intuition as their primary method for determining these inventory levels (Mecimore & Weeks, 1987).

Theoretical research often produces less than perfect results, exemplified by the models developed for inventory control (Kaplan & Frazza, 1983). Modeling is an excellent management tool when appropriately applied (Riggs, 1987; Heizer & Render, 1991). All too often, however, the model is too complex to easily apply or doesn't account for the special circumstances of MRO inventory (Gilbert & Finch, 1985).

Part of the problem of application lies in the assumptions made on the part of researchers and theorists. Theories have been developed for production inventory based on assumptions such as stationary demand for items in the inventory (Graves, 1985), or that restocking the inventory occurs easily and with regularity (Mamer & Smith, 1985). None of these assumptions apply broadly to MRO inventory. On the other end of the spectrum are models that address specialized or obscure nuances of the inventory control function. Fetter and Dalleck (1961) outlined not less than seven models for inventory control with a myriad of decision rules to accompany them, but qualified their effort by advising future readers that "...it is up to the analyst to devise a model that produces useful results..." (p.5)

Zanakis, et al (1980) summarized the entire modeling dilemma best:

> The result of this [effort] is an impressive collection of elegant, often exotic models, striving for mathematical optimality at the expense of unrealistic assumptions, input data and computational requirements. . . .a typical inventory manager has a limited quantitative background and must make inventory control decisions on a routine basis for thousands (or even tens of thousands) of distinct items (p.104).

The underlying problem, however, remains. There are few models that can be effectively and consistently applied to the special traits of MRO inventory such as long and unpredictable lead times, stochastic demand and the need to achieve the service goals of the organization (Handley, 1984).

There have been sporadic attempts to deal with the issues that are important to MRO. As manufacturing organizations reap the benefits of Material Requirements Planning (MRP) and Material Resource Planning (MRP II), maintenance management can also benefit. Bojanowski (1984) outlined a plan called service requirements planning (SRP) that used a ranking system for identifying critical machines. This strategy addresses the planning problems maintenance personnel encounter, but doesn't adequately cover MRO inventory control aspects of operations management.

MRO inventory in any purchasing organization accounts for 80-85% of all purchasing transactions, yet only 15-20% of total purchasing dollars (Semich, 1989; Mitchell, 1987). These small, frequent orders are attributed to common use maintenance items or office supplies. The item that has infrequent demand or specialized application is more likely to take up shelf space and investment dollars while waiting for demand to occur. Yet, the expense of a stock out can have a much higher cost to the organization if production is stopped for lack of a critical repair part (Calaway, 1984).

Once the MRO organization has made the commitment to carry inventory, there is the responsibility to wisely invest budgeted dollars. Since stochastic demand is the rule rather than the exception, forecasting demand is scientifically limited. Forecasting reorder points, order quantities, as well as determining optimal ordering methods while balancing service level goals are functions MRO procurement personnel must consider (Handley, 1984).

Controlling order size based on the holding cost of the inventory and the cost of order generation is an arena in which EOQ has been designed to function. MacFarlane (1984) calls for utilizing the EOQ formula in MRO inventory control measures, yet cautions against strict observation of the application rules. Since MRO does not precisely follow the assumptions of constant, predictable demand and fixed ordering costs, EOQ should be limited to the portion of MRO inventory that best fits the model (MacFarlane, 1984).

The ability to assure inventory will be available to meet maintenance demand is an economic and productive advantage for any manufacturing organization. Using inventory control methods proven in production circles may be a step toward development of a mathematical model developed specifically for MRO inventory.

By testing alternate methods, managers of MRO inventory can determine the model that best satisfies organizational goals. Managers who are able to determine optimum inventory levels with some degree of confidence can control investment dollars in inventory, maintain service levels to production and, thereby, meet their organizational objectives and goals (Anderson, Cleveland & Schroeder, 1989 ; Gardner, 1990).

CHAPTER 3

Research Design and Methodology

The research design for this pilot study was descriptive. The study did not seek to specifically account for the causes of demand on the inventory, merely to show how the EOQ model affects inventory levels and the costs involved with storing that inventory. By contrasting these costs and the number of stockout conditions with the actual holding costs and actual number of stockout conditions created by the current method, Weighted Moving Average, the effectiveness of EOQ could be judged.

The dependent variables in this study were the inventory levels and the order quantity. The holding cost of the items was also a dependent variable since it could fluxuate with the method of inventory control applied. The independent variables were the EOQ model and the Weighted Moving Average methods of inventory manipulation.

The Economic Ordering Quantity (EOQ) formula was applied to ten items selected from Deere foundry MRO inventory that had a historical demand pattern that was reasonably constant. By reviewing demand over the past two years, those items that had a pattern of usage were deemed suitable for the study. Using the historical data, the inventory levels and the number of stockouts for the past two years were documented for the Weighted Moving Average method.

The EOQ theory uses the formula:

$$Q^2 = 2DS/H$$

Where: Q = order quantity D = demand (6 mo.)
S = setup or ordering costs H = holding cost

Ordering and holding costs in this study were values currently used by Deere Foundry accounting. Ordering costs were estimated to be 40 dollars per order and holding cost was 20% of the purchase price per annum. Demand was calculated as a simple average of the past two years of inventory activity.

In the current method of inventory control at Deere Foundry, the Weighted Moving Average was based on the minimum quantity of each item desired in inventory at any one time. This figure was derived from consensus opinion of stockroom and maintenance management personnel and a review of historical inventory performance. The minimum quantity was adjusted up or down as the average demand fluctuates accordingly. The reorder point was when the inventory reached the minimum quantity required for stock.

The EOQ was calculated for each of the ten items and an optimum order quantity determined. This quantity was the beginning inventory. The historical demand was used to simulate depletion of the inventory. The reorder point for the EOQ was determined by the average demand per month multiplied by the lead time (difference between order date and receipt of order). The lead time for all items in this study was one month. The optimum quantity of inventory (EOQ) was ordered when the simulated inventory level reached the reorder point for the item. By comparing the simulated order quantity and the resulting inventory levels versus the actual historical demand, a pattern could be developed for simulated inventory levels over the two year time period.

The annual cost of holding inventory at Deere Foundry has been determined to be 20% of the purchase cost (value of the item at time of purchase). Calculating the cost of holding simulated inventory, created by the EOQ (method A) during the demand cycle, versus the holding cost for inventory created by the Weighted Moving Average method (method B), generated a comparison of the two methods in terms of dollars per year holding cost. Due to monthly fluxuations in inventory levels, the historical demand was divided into monthly sectors to simplify calculation of the holding costs for Method A and Method B.

The number of stockouts also was counted during the simulation with EOQ and during the historical demand period for WMA. Under the simulation, stockouts for EOQ were determined to occur as historical demand depleted the simulated inventory.

CHAPTER 4

Results

Reported in this chapter are the results of the comparison of the Economic Order Quantity (Method A) and the Weighted Moving Average (Method B) and their impact on the maintenance inventory. Item number seven was rejected due to insufficient historical data. Item number eight was rejected because the part was classified as obsolete by Deere foundry during the historical period under study.

Effect on Holding Costs

After the historical demand was applied to the Method A inventory, the holding costs were calculated and compared to Method B holding costs. The total holding costs for both methods during the historical demand period are shown in Table 1.

Table 1

Holding Cost Comparison for Method A and Method B

Item	Method A	Method B
1	$46.42	$48.42
2	$323.40	$227.98
3	$259.53	$289.53
4	$1508.09	$1062.50
5	$109.08	$32.32
6	$479.40	$418.20
9	$81.81	$38.18
10	$962.95	$647.15

This data is also shown graphically in Appendix A. Although each method produced slightly lower holding costs for individual items, as a whole, there was not a significant difference between Method A of Method B in terms of holding costs.

Effects on Number of Stockouts

The number of stockouts in the inventory during the historical demand period and during the simulation were similar for most of the items in the study. However, two items, number five and six, had 75% less stockout conditions under Method A as shown in Table 2.

Three items had differences in number of stockouts of one versus zero. This was not considered to be a significant difference.

Table 2

Comparison of Number of Stockouts for Method A and Method B

Item	Method A	Method B
1	0	0
2	2	2
3	2	2
4	1	0
5	1	4
6	1	4
9	1	0
10	0	1

CHAPTER 5

Conclusions and Recommendations

The data does not appear to show that the Economic Order Quantity produces lower holding costs for maintenance inventory than the Weighted Moving Average method of inventory control. The differences between the two methods in terms of holding costs were not significant for the eight items used in this pilot study.

The number of stockouts were not significantly reduced for a majority of the items in this study. The two items that showed marked reduction in the number of stockouts may provide support for using the EOQ in limited circumstances. These two items had a constant pattern of demand over the historical period. This steady demand pattern is consistent with production inventory and fulfills one of the assumptions the EOQ makes about inventory (Heizer & Render, 1991).

The EOQ may have potential to reduce stockout conditions in maintenance inventory if it is applied with a set of decision rules for each item in the application. The cost of a stockout of an item to production must be determined by operations management. Balanced against the cost of holding inventory, the cost of production downtime can justify using EOQ to control inventory levels of some critical items.

The results of this pilot study show some promise, but are inconclusive. Applying the EOQ theory to MRO inventory items with specific demand patterns could produce less frequent stockout conditions.

The EOQ uses the cost of holding the inventory as part of the formula. Theoretically, this should produce lower holding costs in EOQ managed inventory. Application to a larger sample of inventory may determine which items are best suited to EOQ as an inventory control measure. From this larger study, decision rules for application of EOQ to maintenance may be determined.

References

Anderson, J.C., Cleveland, G., & Schroeder, R. G. (1989). Operations research:A literature review. Journal of Operations Management, 8(2), 133-158.

Balsley, H.L., & Clover, V.T. (1988). Research for business decisions:Business research methods. (4th ed.). Columbus, OH: Publishing Horizons, Inc.

Bojanowski, R.S. (1984). Improving factory performance with service requirements planning. Production and inventory management, 25 (2), 31-44.

Calaway, L.R. (1984). An analytical approach for stocking critical spares. In MRO Stores Seminar Proceedings. (pp.107-116). Falls Church VA: American Production and Inventory Control Society, Inc.

Fetter, R.B. & Dalleck, W.C. (1961). Decision models for inventory management. Homewood,IL: Richard D. Irwin, Inc.

Gardner, E.S., Jr. (1990). Evaluating forecast performance in an inventory control system. Management Science, 36, 490-499.

Gilbert, J.P. & Finch, B.J. (1985). Maintenance management: Keeping up with production's changing trends and technologies. Journal of Operations Management,6 (1), 1-12.

Graves, S.C. (1985). A multi-echelon inventory model for a repairable item with one-for-one replenishment. Management Science,31, 1247-1257.

Hadley, G., & Whitin, T.M. (1963). Analysis of inventory systems. Englewood Cliffs, NJ: Prentice-Hall.

Handley, R.W. (1984). Controlling MRO inventories. In MRO Stores Seminar Proceedings (pp. 83--88). Falls Church, VA: American Production and Inventory Society, Inc.

Heizer, J., & Render, B. (1991). Production and operations management. (2nd ed.). Boston: Allyn and Bacon.

Herbaty, F. (1983). Cost-effective maintenance management: Productivity improvement and downtime reduction. Park Ridge, NJ: Noyes Publications.

Kaplan, A., & Frazza, S. (1983). Empirical inventory simulation: A case study. Decision Sciences, 14, 62-75.

MacFarlane, I. (1984). Benefits and methods for conducting a spare parts evaluation program. In MRO Stores Seminar Proceedings. (pp.152-161). Falls Church, VA: American Production and Inventory Control Society, Inc.

Mamer, J.W., & Smith, S.A. (1985). Job completion based inventory systems: Optimal policies for repair kits and spare machines. Management Science, 31, 703-718.

Mecimore, C.P. & Weeks, J.K (1987). Techniques in inventory management and control. Montvale, NJ: National Association of Accountants.

Mitchell, L.B. (1987). Spare parts inventories. Plant Engineering, 41, 44-48.

Riggs, J.L. (1987). Production systems: Planning, analysis and control. (4th ed.). New York: John Wiley & Sons.

Semich, J.W. (1989). Using JIT to control the MRO monster. Purchasing, pp. 54-59.

Silver, E.A.(1981). Operations research in inventory management: A review and critique. Operations Research, 29, 628-645.

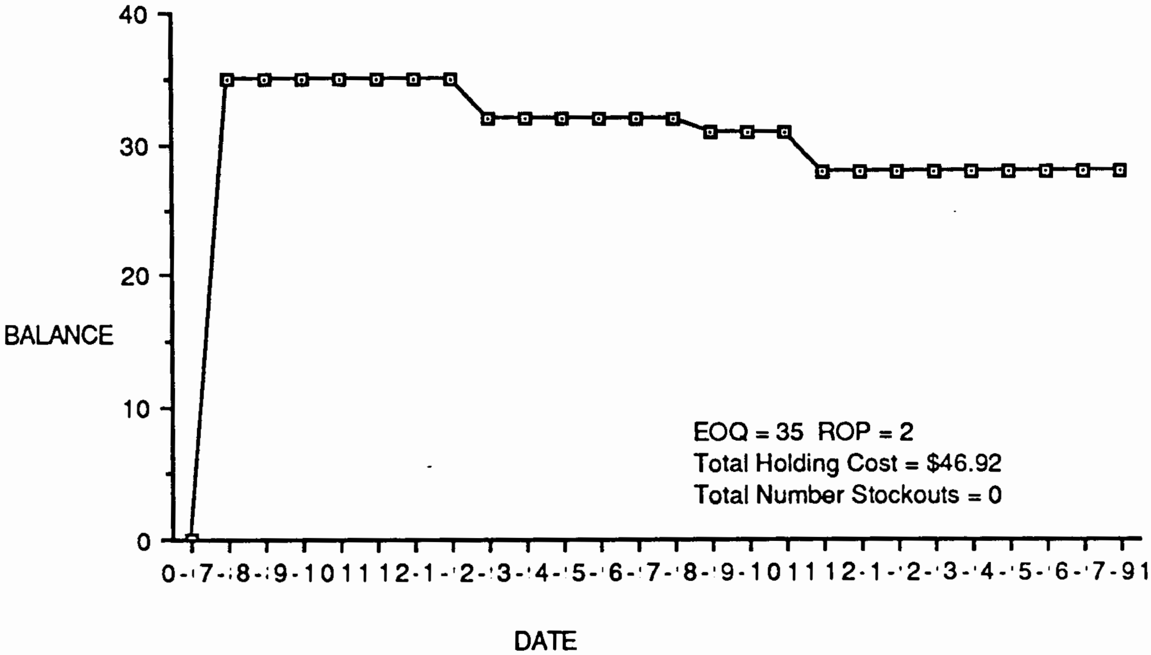
Wallace, T.F. & Dougherty, J.R. (1987). APICS Dictionary (6th ed.). Falls Church, VA: American Production and Inventory Control Society, Inc.

Zanakis, S.H., Austin, L.M., Nowading, D.C., & Silver, E.A.(1980). From teaching to implementing inventory management. Interfaces, 10(6), 103-110.

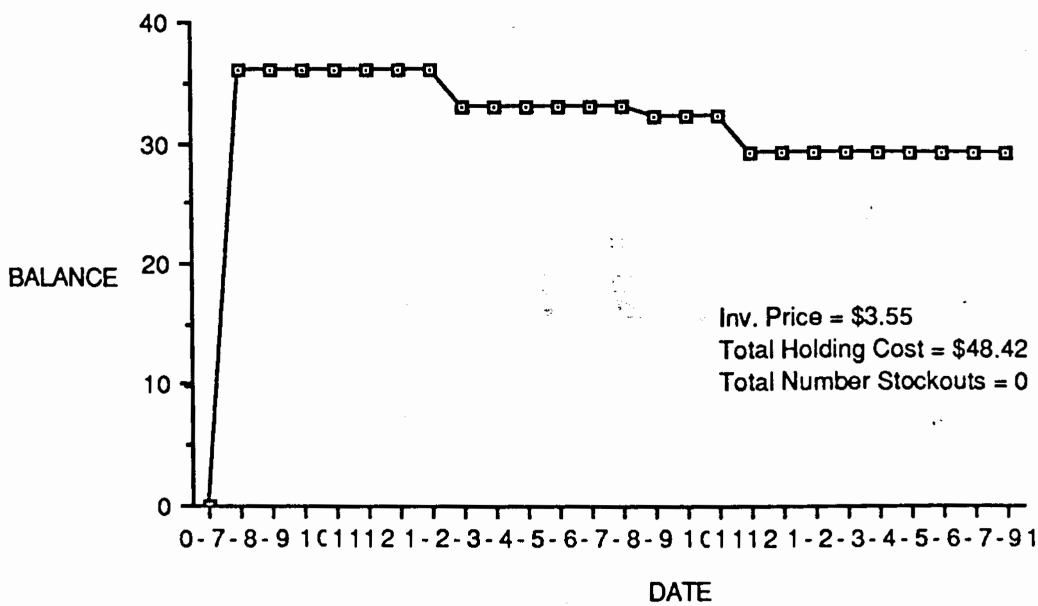
APPENDIX A

This appendix contains all the historical data sorted by item number, the tabled representation of this data and corresponding graphs. Also included are samples of original historical data from Deere and Co.

Data from "Method A Part #1"



Data from "Method B Part #1"



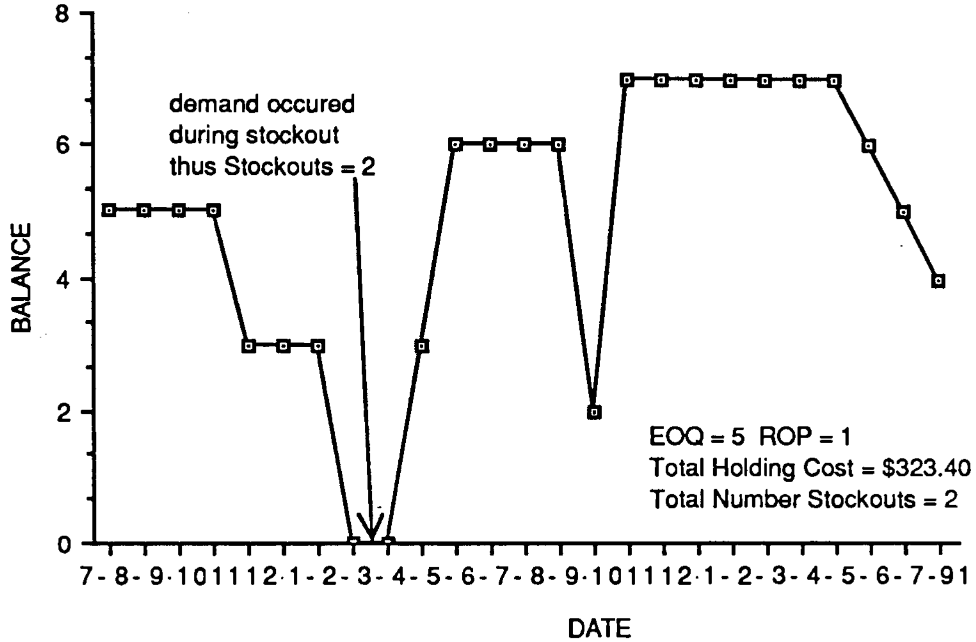
Method A Part #1 Thu, Jul 25, 1991 12:26 PM

	DATE	DEMAND	ORDER	RECEIPT	BALANCE	HOLDING COST
1	0-00				0.000	0.000
2	7-89				35.000	2.100
3	8-89				35.000	2.100
4	9-89				35.000	2.100
5	10-89				35.000	2.100
6	11-89				35.000	2.100
7	12-89				35.000	2.100
8	1-90				35.000	2.100
9	2-90	3.000			32.000	1.920
10	3-90				32.000	1.920
11	4-90				32.000	1.920
12	5-90				32.000	1.920
13	6-90				32.000	1.920
14	7-90				32.000	1.920
15	8-90	1.000			31.000	1.860
16	9-90				31.000	1.860
17	10-90				31.000	1.860
18	11-90	3.000			28.000	1.680
19	12-90				28.000	1.680
20	1-91				28.000	1.680
21	2-91				28.000	1.680
22	3-91				28.000	1.680
23	4-91				28.000	1.680
24	5-91				28.000	1.680
25	6-91				28.000	1.680
26	7-91				28.000	1.680
27						
28				0.060		46.920

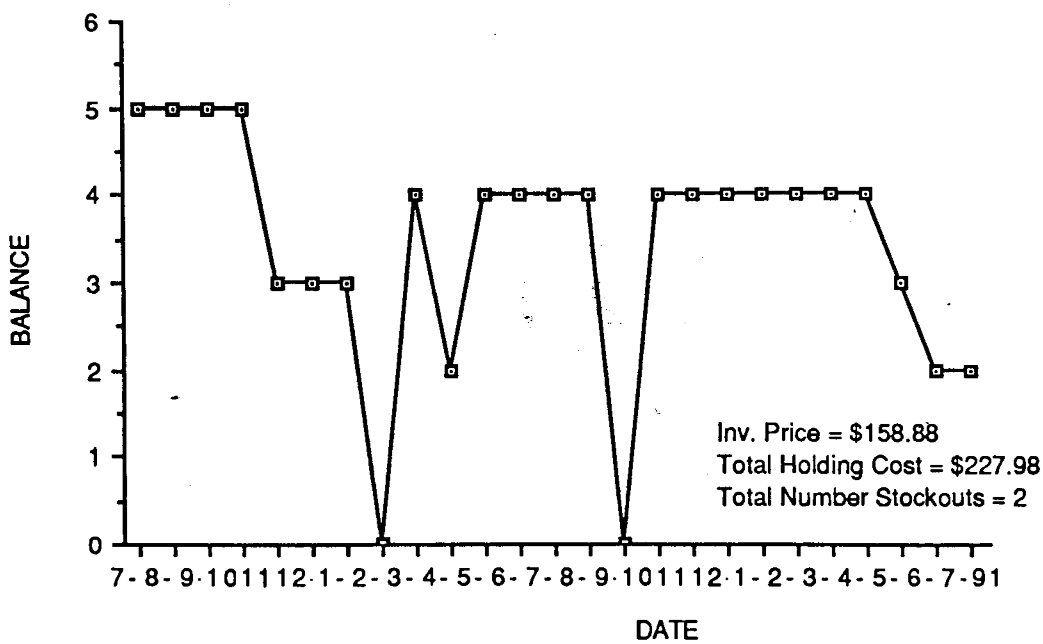
Method B Part #1 Thu, Jul 25, 1991 12:25 PM

	DATE	DEMAND	ORDER	RECEIPT	BALANCE	HOLDING COST
1	0-89				0.000	
2	7-89				36.000	2.160
3	8-89				36.000	2.160
4	9-89				36.000	2.160
5	10-89				36.000	2.160
6	11-89				36.000	2.160
7	12-89				36.000	2.160
8	1-90				36.000	2.160
9	2-90	3.000			33.000	1.980
10	3-90				33.000	1.980
11	4-90				33.000	1.980
12	5-90				33.000	1.980
13	6-90				33.000	1.980
14	7-90				33.000	1.980
15	8-90	1.000			32.000	1.920
16	9-90				32.000	1.920
17	10-90				32.000	1.920
18	11-90	3.000			29.000	1.740
19	12-90				29.000	1.740
20	1-91				29.000	1.740
21	2-91				29.000	1.740
22	3-91				29.000	1.740
23	4-91				29.000	1.740
24	5-91				29.000	1.740
25	6-91				29.000	1.740
26	7-91				29.000	1.740
27				0:060	0.000	
28						48.420

Data from "Method A Part #2"



Data from "Method B Part #2"



Method A Part #2 Thu, Jul 25, 1991 12:26 PM

	DATE	DEMAND	ORDER	RECEIPT	BALANCE	HOLDING COST
1					0.000	
2	7-89				5.000	13.270
3	8-89				5.000	13.270
4	9-89				5.000	13.270
5	10-89				5.000	13.270
6	11-89	2.000			3.000	7.950
7	12-89				3.000	7.950
8	1-90				3.000	7.950
9	2-90	3.000	5.000		0.000	0.000
10	3-90	5.000	5.000	5.000	0.000	0.000
11	4-90	2.000	5.000	5.000	3.000	7.950
12	5-90	2.000		5.000	6.000	15.900
13	6-90				6.000	15.900
14	7-90				6.000	15.900
15	8-90				6.000	15.900
16	9-90	4.000	5.000		2.000	5.300
17	10-90			5.000	7.000	18.550
18	11-90				7.000	18.550
19	12-90				7.000	18.550
20	1-91				7.000	18.550
21	2-91				7.000	18.550
22	3-91				7.000	18.550
23	4-91				7.000	18.550
24	5-91	1.000			6.000	15.900
25	6-91	1.000			5.000	13.270
26	7-91	1.000			4.000	10.600
27						
28				2.650		323.400