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An Analysis of Inventory Managment and Control

Gene Philbrick

AN ANALYSIS OF INVENTORY MANAGEMENT AND CONTROL

by

Gene E. Philbrick

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This independent study report submitted by Gene E. Philbrick in partial fulfillment of the requirements for the Degree of Master of Science in the University of North Dakota is hereby approved by the Committee under whom the work has been done.

Chairman

Dean of the Graduate School

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ABSTRACT

The purpose of this paper is to isolate the important factors in inventory management and control and evaluate their effects on business decisions. In this report, the technical aspects which aim at giving the production and financial managers better control over inventories will be discussed. A thorough probing of inventory functions, costs, optimum lot size, and anticipation of future needs will be conducted to better aid top management set the rules and formulate the basic policy decisions for optimum inventory flow.

Good inventory management and control are essential to effective production and financial control. In all businesses, it is imperative that inventory controls be established which will provide materials, parts, and subassemblies as they are needed without tying-up huge sums which might be used in operating the program. The "how", in the form of decision rules, and customer service considerations, must be set by top management. This is our area of challenge and profit!

This report concludes that there is no single theory of inventory management and control, nor can one evolve a single set of rules for decision-making that will be optimal in all cases. An effective inventory control system can not be an isolated entity; but, must be closely coordinated with other planning and control activities such as sales forecasting, production planning, and capital budgeting, since it affects

all these activities. Furthermore, no prudent system of budgeting can be attained unless effective inventory management and control have preceded it.

I. INTRODUCTION

"Why are we always out of stock?" So goes the complaint of great numbers of businessmen faced with the dilemmas and frustrations of attempting simultaneously to maintain stable production operations, provide customers with adequate service and keep investment in stocks and equipment at reasonable levels.

But this is only one of the characteristic problems business managers face in dealing with production planning, scheduling, keeping inventories on hand, and expediting. Other problems -- just as perplexing and baffling, when managers approach them on the basis of intuition and pencil work alone -- are:

"How often should we reorder?"

"How should we adjust production, when sales are uncertain?"

"What capacity levels should we set for our shop operations?"

"How do we plan production and procurement for seasonal sales?"

The importance of inventory and management's control of inventory to the typical business is great. Inventory is important not only because it is a major asset; but, more critically, because it is a large current asset. Often, a good inventory control program can enable management to take scarce working capital out of inventory and apply it to areas of the business where it "will work harder" -- such as product development, sales training, and advertising.

Inventory is important, in addition, because the costs of ordering, storing, and handling inventory are usually large enough so that

even a small percentage reduction of these costs can make a meaningful difference to the company's income statement.

Inventory is created for two general purposes, namely protection and economy:

(1). To provide sufficient material to meet demands for the particular raw material, part, or finished product with a minimum of delay - (protection).

(2). To effect lower product costs by realizing the economies resulting from longer manufacturing runs and from purchasing larger quantities per order - (economy).

Definitions of the words "inventories" and "control" as they will be used in this report follow:

Inventories constitute a particular category of assets consisting of merchandise, raw materials and supplies, work-in-process, and finished goods. They are items held for sale, or for conversion, in the normal course of business.[1]

Control is the function of constraining and regulating as well as directing action for the maintenance of suitable levels of inventory.[2]

The literature on inventory control is unusual in that it ranges all the way from articles which describe the advantages of inventory control to highly mathematical papers which are of use only to the theoretician. This paper has attempted to emphasize the practical aspects of inventory control rather than those that are too theoretical for most businessmen.

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[1]Chris Luneski, "Some Aspects of the Meaning of Control," The Accounting Review, July, 1964, p. 592.

[2]"A Discussion of Various Approaches to Inventory Management," The Accounting Review, July, 1964, p. 701.

Statement of the Problem

The purpose of this paper is to isolate the important factors in inventory management and control and evaluate their effects on business decisions.

In this report, the technical aspects which aim at giving the production and financial managers better control over inventories will be discussed. A thorough probing of inventory functions, costs, optimum lot size, and forecasting will be conducted to better aid top management in setting the rules and in formulating the basic policy decisions for optimum inventory flow. The "how", in the form of decision rules, and customer service considerations, must be set by top management. This is our area of challenge and of profit!

II. INVENTORY CONTROL QUESTIONS

The question before management is: How big should inventories be? The answer to this is obvious -- they should be just sufficient to fulfill the needs of the firm. The follow-on question is then asked, "How do we determine what level is sufficient?" The answer to this question may be reached through adequate inventory controls.

The term "inventory control" suggests that a need exists for controlling inventories. "By controlling inventories, we mean that the firm must decide what levels of inventory can be economically maintained. These inventories consist of raw materials and component parts which the company procures from external sources and component parts and finished assemblies which the company manufactures itself and must be held for sale, or for conversion in the normal course of business."[3] The reason that a management decision must be made as to what quantities of purchased and manufactured items will be kept in stock is simple. There are certain cost advantages and disadvantages to be associated with every unit of inventory.

To illustrate, an additional unit of inventory will decrease the risk and, therefore, the cost of not being able to satisfy the demand for the item; but, on the other hand, it will increase the cost of storage. However, for a given item, there will be some level of inventory which will yield a total cost which will be lower than the total cost generated by any other level.

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[3]Raymond R. Mayer, Production Management, (New York: McGraw-Hill Book Co., Inc., 1962), p. 315.

What the firm's management must do is determine what this most economical level is for each purchased and manufactured item and then maintain the inventory at this level. This is what we call inventory control, or in other words controlling the cost of inventories through good management.

The question "How big should inventories be?" is made more difficult by the fact that generally each individual with a management group tends to answer the question from his own point of view. He fails to recognize costs outside his usual framework. He tends to think of inventories in isolation from other operations. The sales manager commonly says that the company must never make a customer wait; the financial manager says that large inventories are draining off cash which should be used to make a profit.

Such a situation occurs a majority of the time. The task of all production planning, purchasing scheduling, or inventory control functions, in fact, is typically to balance conflicting objectives, such as those of minimum purchase or production cost, minimum inventory investment, minimum storage and distribution cost, and maximum service to the customers.

Production versus Time

Often businessmen blame their inventory and scheduling difficulties on small orders and product diversity: "You can't keep track of 100,000 items." "Forecasts mean nothing." "We're just a small job shop." Many businessmen seem to feel that their problems in this respect are unusual; whereas, actually the problems faced by a moderate-sized manufacturer with a widely diversified product line are almost typical of business today.

Because of the diversity of products sold by most firms, the costs of paperwork, setup, and control represent an extremely heavy drain on many a company's profit and a severe cost to its customers. The variety of output has often blinded management to the opportunities for more systematic production flow and for the elimination of many of the inefficiencies of job-shop operation by better organization and planning.

The problem of planning and scheduling production or inventories pervades all operations concerned with the matter of production versus time -- that is, the interaction between production, distribution, and the location and size of physical stocks. It occurs at almost every step in the production process: purchasing of raw materials, production of in-process materials, finished production distribution of finished products and service to customers. In multiplant operations, the problem becomes compounded because decisions must be made with reference to the amount of each item to be produced in each factory; management must also specify how the warehouses should be served by the plants.

Action versus Analysis

The questions uninformed businessmen raise in connection with management and control of inventories are basically aimed at action rather than questioning and resolving the functions the inventory is performing in the situation. The questions are stated, unsurprisingly, in the characteristic terms of decisions to be made: "Where shall we maintain how much stock?" "Who will be responsible for it?" "What shall we do to control balances or set proper schedules?" A manager necessarily thinks of problems in production planning in terms of centers of responsibility.

However, action questions are not enough by themselves. In order to get at the answers to these questions as a basis for taking action, it is necessary to back off and ask some rather different kinds of questions: "Why do we have inventories?" "What effects the inventory balances we maintain?" "How do these effects take place?" From these questions, a picture of the inventory problem can be delineated which shows the influence of inventories and costs of the various alternative decisions which the management may ultimately want to consider.

This type of analytical question has been answered intuitively by businessmen with moderate success in the past. Consequently, most of the effort toward improved inventory management has been spent in other directions; it has been aimed at better means for recording, filing, or displaying information and at better ways of doing the necessary clerical work. This is all to the good, for efficient data-handling helps. However, it does not lessen the need for a more systematic approach to inventory problems that can take the place of intuition.

As business has grown, it has become more complex; and, as business executives have become more and more specialized in their jobs or farther removed from direct operations, the task of achieving an economical balance intuitively has become increasingly difficult.

One of the principal difficulties in the intuitive approach is that the types and definitions of cost which influence appropriate inventory policy are not those characteristically found on the books of a company. Many costs, such as setup or purchasing costs, are hidden in the accounting records. Others, such as inventory capital

costs, may never appear at all. Each cost may be clear to the operating head primarily responsible for its control; because it is a "hidden" cost, however, its importance may not be clear at all to other operating executives concerned. The resulting confusion may make it difficult to arrive at anything like a consistent policy.

In the last five years in particular, operations research teams have succeeded in using techniques of research scientists to develop a practical analytic approach to inventory cost questions, despite growing business size, complexity, and division of management responsibility.[4]

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[4]Arthur H. Smith, "Improved Techniques for Inventory Management and Control," An Application of Operations Research Approach, (A Case Study at General Mills, Minneapolis, Minn.), September, 1964, Sec. 3, p. 17.

III. INVENTORY FUNCTIONS

The basic functions of inventories serve to decouple successive operations in the process of making a product and getting it to the consumers. For example, inventories make it possible to process a product at a distance from customers or from raw material supplies, or to do two operations at a distance from one another. Inventories make it unnecessary to gear production directly to consumption or to force consumption to adapt to the necessities of production. Therefore, inventories free one stage in the production-distribution process from the next, permitting each to operate more economically.

The essential question is: At what point does the uncoupling function of inventory stop earning enough advantage to justify the investment required? To arrive at a satisfactory answer we must distinguish between (a) inventories necessary because of the time required to complete an operation and to move the product from one stage of production to another, and (b) inventories employed for organizational reasons, for example, to let one unit schedule its operations more or less independently of another.

Movement Inventories

Inventory balances needed because of the time required to move stocks from one place to another are often not recognized, or are confused with inventories resulting from other needs -- that is, for example, economical shipping quantities (to be discussed in a later section).

The average amount of movement inventory can be determined from the mathematical expression $I = S \times T$ in which S represents the average sales rate, T the transit time from one stage to the next, and I the movement inventory needed. For example, if it takes two weeks to move materials from the plant to a warehouse, and the warehouse sells 100 units per week, the average inventory in movement is 100 units per week times 2 weeks, or 200 units. From a different point of view, when a unit is manufactured and ready for use at the plant, it must sit idle for two weeks while being moved to the next station (the warehouse); so, on the average, stocks equal to 2 weeks' sales will be in movement.[5]

Movement inventories are usually thought of in connection with movement between distant points -- plant to warehouse. However, any plant may contain substantial stocks in movement from one operation to another. Movement stock is one component of the "float" or in-process inventory in a manufacturing operation.

When sales or time-in-transit changes, the quantity of movement stock is changed. Time-in-transit is largely a result of method of transportation; although, improvements in loading or dispatching practices may cut transit time by eliminating unnecessary delays. Other influences of time-in-transit on total inventories will be described in connection with safety stocks.

Organization Inventories

Management's most difficult problems are with the inventories purchased to satisfy the idea that the more inventory carried between stages in the manufacturing-distribution process, the less coordination is required to keep the process running smoothly.

Despite superficial differences among businesses in the nature

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[5]John F. Magee, Production Planning and Inventory Control, (New York: McGraw-Hill Book Co., Inc., 1958), pp. 17, 18.

and characteristics of the organization inventory they maintain, the following three functions are basic:

(1). Lot size inventories are probably the most common in business. They are maintained wherever the user makes or purchases material in larger lots than are needed for his immediate purposes, for example:

> It is common practice to buy raw materials in relatively large quantities in order to obtain quantity price discounts, keep shipping costs in balance, and hold down clerical costs connected with making out requisitions, checking receipts and handling accounts payable. Similar reasons lead to long production runs on equipment calling for expensive setup, or to sizable replenishment orders placed on factories by field warehouses.[6]

(2). Fluctuation stocks, also very common in business, are held to cushion the shocks arising from unpredictable fluctuations in consumer demand, for example:

> Warehouses and retail outlets maintain stocks to be able to supply consumers on demand, even when the rate of consumer demand may show quite irregular and unpredictable fluctuations. In turn, factories maintain stocks to be in a position to replenish retail and field warehouse stocks in line with customer demands.[7]

Short-term fluctuations in the mix of orders on a plant often make it necessary to carry stocks of parts of subassemblies, in order to give assembly operations flexibility in meeting orders as they arise while freeing earlier operations from the need to make momentary adjustments in schedules to meet assembly requirements. In most cases, anticipating all fluctuations is uneconomical, if not impossible. But a business cannot get along without some fluctuation stocks unless it is willing and able to frequently make its customers wait until the material needed can be purchased conveniently or until their orders

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[6]Mayer, p. 185.

[7]Mayer, p. 186.

can be scheduled into production conveniently. Fluctuation stocks are part of the price we pay for our general business philosophy of serving the consumers' wants and whims rather than having them take what they can get at the time.

(3). Anticipation stocks are needed where goods or materials are consumed on a predictable but changing pattern through the year, and where it is desirable to absorb some of these changes by building and depleting inventories rather than by changing production rates with attendant fluctuations in employment and additional capital capacity requirements.

The need for seasonal stocks may also arise where materials are produced at seasonally fluctuating rates, but where consumption is reasonably uniform. It is fair to say that in most businesses the risks and excessive costs of back orders so outweigh inventory costs that a substantial protection in the form of safety stocks is justified. These safety stocks must be large enough so that inventories can be restored, after an unexpected sales spurt, by a smooth and and moderate adjustment in production rate.

Sales, marketing, and production executives alike have an immediate, vital interest in safety stocks. In these days of strong but often unpredictable sales, safety stocks afford, for the factory as well as for the sales office, a method of buying short-term protection against the uncertainties of customer demand. They are the additional inventory on hand which can be drawn upon in case of emergency during the period between placement of an order by the customer and receipt of the material to fill the order. However, in practice their potentials are often needlessly lost.

One reason for the failure is a very practical one. Because safety stocks are designed to cope with the uncertainties of sales, they must be controlled by flexible rules so that conditions can be met as they develop. But sometimes the need for flexibility is used as an excuse for indefiniteness: "We can't count on a thing; we have to play the situation by ear". And, in any sizable organization, when people at the factory level start "playing it by ear", one can be almost sure that management policy will not be regularly translated into practice.

Numerous studies have shown that the methods used by existing inventory systems in industry often violate sound control concepts. The economy of the company is maintained, in the face of instability and inefficiency in the inventory control system, only because of constant attention, exercise of overriding common sense, and use of expediting and other emergency measures outside the routine of the system.

Actually, it is possible to have inventory controls which are not only flexible but also carefully designed and explicit. But the task needs special analytical tools; in a complicated business it defies common-sense judgment and simple arithmetic. Methods must be employed to take direct account of uncertainty and to measure the response characteristics of the system and relate them to costs. Such methods are the distinctive mark of a really modern, progressive inventory control system.

Basically, there are two different methods of inventory replenishment systems designed to handle uncertainty about sales: fixed order, commonly used for bins of parts or other materials; and

periodic reordering, frequently used for inventories involving a large number of items under clerical control. While the two are basically similar in concept, they have somewhat different effects on safety stocks, and choice of one or the other, or some related variety, requires careful consideration.

The fundamental problem of setting safety stocks under either system is balancing a series of types of costs which are not found in the ordinary accounting records of the company--costs of customer service failure, of varying production rates (including hiring and training expenses), of spare capacity, and others. Often specialists can find the optimum balance with relatively simple techniques once the cost data are made explicit. However, part of the needed data can come only from top management. For example, the tolerable risk of service failure is generally a policy decision.

Striking A Balance

The "joker" is the fact that the gains which these organization inventories achieve in the way of less need for coordination and planning, less clerical effort to handle orders, and greater economies in manufacturing and shipping are not in direct proportion to the size of the inventory. Even if the additional stocks are kept well balanced and properly located, the gains become smaller, while at the same time the warehouse, obsolescence, and capital costs associated with maintaining inventories rise in proportion to, and sometimes even at a faster rate than the inventories themselves. To illustrate:

Suppose a plant needs 2,000 units of a specially machined part in a year. If these are made in runs of 100 units each, then 20 runs with the attendant setup costs will be required each year.

If the production quantity were increased from 100 to 200 units, only ten runs would be required--a 50% reduction in setup costs, but a 100% increase in the size of a run and in the resulting inventory balance carried.

If the runs were further increased in length to 400 units each, only five production runs during the year would be required--only 25% more reduction in setup costs, but 200% more increase in run length and inventory balances.[8]

The basic problem of management of inventory policy connected with the three functional types of inventories discussed is to strike a balance between the increasing costs and the declining return earned from additional stocks. It is because striking this balance is easier to say than to do, and because it is a problem that defies solution through intuitive understanding alone, that new concepts are necessary.

This problem of the management of inventory includes production scheduling and varies widely from company to company. Where finished items can be stocked, the important cost factors to weigh may be storage, clerical procedures, setup, supervision, etc. But where finished items cannot be stocked, the problem is one of setting capacity levels large enough to handle fluctuating loads without undue delay, which involves the cost of unused labor and machines. Despite the great variety of situations that are possible, specific mathematical approaches and theories are available for use in solving almost any type of company problem.

However, there is no alternative which has only advantages. Inherent in the solution of the problem is the fact that inventories do perform the important function of offsetting errors in forecasting,

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[8]John L. O'Donnell and M. S. Goldberg, Elements of Financial Administration, (Columbus, Ohio: Charles E. Merrill Books, Inc., 1962), p. 133.

permitting the leveling out of production schedules, enabling the firm to procure and produce in economic lot sizes, and minimizing the adverse effects of differences between actual and scheduled progress; they do all this at a price.

IV. INVENTORY COSTS

This brings us face to face with the question of the costs that influence inventory policy, and the fact that they are characteristically not those recorded, at least not in a directly available form in the usual industrial accounting system.

> Accounting costs are derived under principles developed over many years and strongly influenced by tradition. The specific methods and degree of skill and refinement may be better in particular companies; but in all of them the basic objective of accounting procedures is to provide a fair, consistent, and conservative valuation of assets and a picture of the flow of values in the business.[9]

The definition of costs for production and inventory control will vary from time to time -- even in the same company -- according to the circumstances and the length of the period being planned for. The following criteria apply:

(1). The costs shall represent "out-of-pocket" expenditures; that is, cash actually paid out or opportunities for profit foregone. Overtime premium payments are out-of-pocket; depreciation on equipment on hand is not. To the extent that storage space is available and cannot be used for other productive purposes, no out-of-pocket cost of space is incurred; but to the extent that storage space is rented or could be used for other productive purposes, a suitable charge is justified. The charge for investment is based on the out-of-pocket investment in inventories or added facilities, not on the "book" or accounting value of the investment.

(2). The costs shall represent only those out-of-pocket expenditures or foregone opportunities for profit whose magnitude is affected by the schedule or plan. Many overhead costs, such as supervision costs, are out-of-pocket; but neither the timing nor the size is affected by the schedule. Normal material and direct labor costs are unaffected in total and so are not considered directly; however, these, as well as some components of overhead cost, do represent out-of-pocket investments, and accordingly enter the picture indirectly through any charge for capital.[10]

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[9]Stanley Z. Bronner, "Organizational Aspects of Inventory Management," NAA Bulletin, Dec. 1961, Section 1, p. 41.

[10]Charles F. Margeson, "Financial Aspects of Inventory Control," Financial Executive, April, 1959, p. 164.

Direct Influence

Among the costs which directly influence inventory policy are:

(1). Costs that depend on the amount ordered:

(a). Quantity discounts - In the case of purchased materials, the firm is often in a position to obtain a reduction in the unit purchase price if it purchases these items in larger lots. Since the same average number of units will be purchased per year regardless of the lot size, a lower unit purchase price will reduce the average annual purchase cost. However, a decision to increase lot sizes in order to take advantage of available quantity discounts is a decision to increase the average inventory of these materials. In brief, the factor of quantity discounts encourages the purchase of larger lots and, hence, the maintenance of larger purchased materials and parts inventories.

(b). Setup costs - Setup costs are incurred every time a firm inaugurates production of a given item. These costs are fixed per setup because the same expense is incurred in setting up equipment which will then be used to manufacture one unit as is incurred in setting up equipment which will then be used to manufacture one thousand units. The only exception to this statement would be in the case of a decision to manufacture larger lot sizes which would result in the use of different manufacturing methods and, hence, a different setup. But for a given method of production, setup costs will remain constant. Consequently, since the same average number of units will be produced per year regardless of the lot size, larger lot sizes mean fewer setups per year and, therefore, lower setup costs per year. However, as the lot size increases,

the average inventory of the item being produced will increase; and this cost element encourages the maintenance of larger inventories of manufactured parts and products.

(c). Production control and procurement costs - Every time a given product is to be manufactured, the production control department must check on the availability of the factors of production, schedule the work, prepare various forms and instructions for the shop, and determine the progress of production. The nature of these activities is such that the cost of performing them may be independent of the size of the order or may increase somewhat as the order size increases, but at a relatively lower rate. As a result, as lot sizes increase, fewer orders will be processed and average annual production control cots will decrease. This will encourage the production of larger lots and, therefore, the maintenance of higher average inventories of the items involved.

Similarly, when materials or parts are to be purchased, purchasing requisitions must be prepared, purchase orders must be placed, and paper work of a clerical nature must be performed when the materials are received. As in the case of production control activities, the cost of these procurement activities may be independent of the size of the order or may increase by a smaller percentage than the percentage increase in the size of the order. Consequently, the firm would have an incentive to reduce the number of purchase orders by increasing the size of purchased lots and, therefore, the average level of its inventories. Doing so would reduce average annual procurement costs for purchased materials and parts.

(d). Shipping costs - These costs represent another factor to the extent that they influence the quantity of raw materials purchased and the resulting raw stock levels, the size of intraplant or plant-warehouse shipments, or the size and the frequency of shipments to customers.

(2). Production Costs:

(a). Overtime and shift premium costs - This is a cost element which suggests a need for leveling out of production demand schedules generated by the sales forecast. For example, the management may find that there will be periods in which the plant capacity is inadequate. To provide the necessary capacity during these peak periods, the firm could schedule overtime work or add a second shift. If this is done the company will usually have to pay an overtime premium or a shift premium to those employees assigned to the second or third shift.

Obviously, this will raise labor costs for a given level of annual output. In addition, employees who work overtime or are assigned to the second or third shift ordinarily operate at a lower efficiency than do the other employees. This further tends to increase annual labor costs. A possible alternative is to have the shop produce in advance during periods of lower demand. This, of course, will result in an increase in inventories of finished parts and products, but will eliminate or minimize the additional costs to be associated with overtime or extra-shift operations. Therefore, the existence of this cost element encourages the maintenance of higher average inventories of finished parts and products.

(b). Shakedown costs - "These learning costs show up wherever output during the early part of a new run is below standard in quantity or quality."[11] A cost of undercapacity operation may also be encountered. For example, where a basic labor force must be maintained regardless of volume, it is accounted for as a directly variable labor cost.

(c). Hiring, training, and layoff costs - If the company chooses not to schedule overtime and extra-shift work during periods of peak demand, it also has the alternative of hiring additional personnel during these periods and laying them off during periods of reduced demand. However, there are certain costs to be associated with this alternative. When new personnel are to be hired, they must be recruited and interviewed, their applications must be processed, appropriate records must be established, and very often they must be trained. Similarly, laying off personnel involves some paper work, interviews, and very often severance pay. All this can represent an appreciable expense to the company. Further, if the firm obtains a reputation of being unable to offer stable employment, it may encounter difficulties in its attempt to recruit qualified personnel. Those that are recruited may be relatively inefficient, with the result that labor costs for a given level of annual output will increase. Again, all these costs suggest a need for leveling out the demand for manpower, and this can be done by building up inventories during periods in which a reduced demand exists for a company's

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[11]Frank J. Andress, "The Learning Curve as a Production Tool," Harvard Business Review, January-February, 1954, p. 84.

products. Like overtime and shift premium costs, these cost factors encourage the maintenance of higher inventories of finished parts and products.

It is also important to note that if the company attempts to eliminate hiring, training, and layoff costs by retaining excess personnel on the roll during slack periods, average annual labor costs will be higher than they need be. As long as these redundant costs exist, the incentive to level out the real demand for manpower will remain.

(3). Costs of Handling and Storing Inventory:

(a). Handling costs - Materials and parts must be transported from the receiving department to the storeroom, from the storeroom to the point of use, etc., etc. . . . and finally from the last work station to the stock room. On occasion, the cost per move will be constant for a certain range of quantities handled. Or in some cases, the increased cost of handling is not as great at the increase in the quantity being handled. In all such cases, handling costs per unit produced or purchased will decrease as the quantities handled are increased. These quantities will also increase as the manufactured and purchased lot sizes increase.

As in the case of setup and like costs, lower unit handling costs will yield lower annual handling costs because the amount of material handled per year will be unaffected by the amount of material handled at any one time. Therefore, the factor of handling costs encourages the procurement and production of larger lot sizes, which is synonymous with maintaining higher inventories.

In other cases, however, it may be that increased inventories will result in the overcrowding of storage areas. When this is

true, the handling of materials may become more difficult and, therefore, more time-consuming. Consequently, annual handling costs will tend to increase. When this occurs, it proves to be a force which encourages the firm to carry small inventories.

(b). Storage costs - As a rule, an increase in the level of inventories carried by the company is accompanied by an increase in storage costs. Storage costs include such things as the cost of floor space, the cost of heat, light, and maintenance for the area in which the inventories are stocked, and the cost of insurance. When these costs increase as inventories increase, this factor encourages the maintenance of lower inventories.

Yet, there are cases in which an increase in inventories has no effect or a negligible effect on average annual storage costs. It may be that the additional required floor space costs the company nothing, because if it were not used for storage, it would just lie idle. Similarly, an increase in the amount of space allocated to the storage of stock may have no effect on the amount of heat, light, and maintenance required. Also, a slight increase in the value of inventories may not necessitate an increase in the amount of insurance being carried. If this is true, the factor of storage costs becomes irrelevant.

(c). Obsolescence and spoilage costs - These cost factors may take several forms, including:

(1). Outright spoilage after a fixed period.

(2). Risk that a specific unit in stock or a individual product number will:

a. become technologically unsalable, except at a discount or as spare parts.

b. go out of style.

The exact nature of deterioration varies from product to product. Certain food and drug products, for example, have specified maximum shelf lives and must either be used within a fixed period of time or be scrapped. Some kinds of style goods, such as many lines of toys, Christmas novelties, or women's clothes, may effectively "spoil" at the end of a season, with only reclaim or scrap value. Some kinds of technical equipment undergo almost constant engineering change during their production life; thus, component stocks may suddenly and unexpectedly be made obsolete.

(d). Thievery - Materials, parts, tools, and supplies are all subject to being taken home. Unfortunately, men will pilfer almost anything they can carry home that belongs to the company. Somehow they seem to think that stealing from the company is not really stealing. In fact, in the case of small tools, carrying them home may be accidental. However, the failure to return them is certainly intentional.

One electronics company found it had no end of trouble with disappearing diodes, transistors, tubes, and etc. It wasn't only the value of the items that made trouble, but what was worse was the fact that they were actually running out of production stock! They finally adopted the policy of giving free parts to those men that asked for them. The problem of unauthorized disappearances of parts and their undue cost was thereby drastically reduced.

By making a show of policing thievery, most high-value

stealing of goods will be prevented. Actually, the purpose is not, primarily, to catch people involved in petty stealing because they have to then be fired on the spot; but one must keep stealing to a minimum loss and definitely prevent all organized large-scale thievery.

Companies furnishing hand tools for production may allow their men to sign the tools out for home use and make it so easy for them to take things home "officially" that there is no reason for them to steal. Companies may even let their men charge themselves for tools taken home resulting in much lower losses after initiating this change in policy.

Toolroom employees and the stock room employees need watching, too. They are normally not above helping themselves, especially when they know that there is little or no inventory loss control. A supervisor's desk placed in a good position to view the stock and the tool rooms can greatly reduce this practice.

Materials disappear too, particularly scrap. It is generally considered best to let the men take home small pieces for their hobbies or alternatively, sell them at "five and ten cent" prices from a scrap shop.

Good inventory control can reduce the temptation for employees to steal or to be careless with materials and parts. Shortages caused by such actions can sometimes hold up production. Organize the records to reveal what is happening to spare parts, tools, and other equipment and let the employees know they are being watched.

Supervisors should be instilled with the desire to act as if the inventories have value. They should also keep aware of slovenly

material and tool handling or usage and make on the spot correction of infractions.

Capital Investment

Evaluating the effect of inventory decisions and scheduling policies upon capital investment and the worth of capital tied up in inventories is one of the most difficult problems for management in the resolution of inventory policy questions.

Think for a moment of the amount of capital invested in inventory. This is the out-of-pocket, or avoidable, cash cost for material, labor, and overhead of goods in inventory. For example, raw materials are normally purchased in accordance with production schedules; and, if the production of an item can be postponed, buying and paying for raw materials can likewise be put off.

Usually, the raw material cost represents a part of the out-of-pocket inventory investment in finished goods. However, if raw mater-

must be purchased when available, regardless of the production

ıle, the raw material component of finished product cost does not

ɜent avoidable investment and, therefore, should be eliminated

ɔhe computation of inventory value for planning purposes.

ʌs for maintenance and similar factory overhead items, they are usually paid for the year round, regardless of the timing of production scheduled. Therefore, these elements of burden should not be counted as part of product investment for planning purposes either. However, if the maintenance costs actually vary directly with the production rate, they should be included, of course.

Moreover, it is dangerous to assume that, as a "short-term" investment, inventory is relatively liquid and riskless. A businessman might say, "After all, we turn our inventory over six times a year." In reality, inventory investment may or may not be short-term and riskless, depending on the circumstances. No broad generalization is possible, and each case must be decided on its own merits.

For example: A great deal of inventory carried in business is as much a part of the permanent investment as the machinery and buildings. The inventory must be maintained to make operations possible as long as the business is a going concern. The cash investment released by the sale of one item from stock must be promptly reinvested in new stock, and the inventory can be liquidated only when the company is closed. How much more riskless is this than other fixed manufacturing assets?

To take an extreme case, inventory in fashion lines or other types of products having high obsolescence carries a definite risk. Its value depends wholly on the company's ability to sell it. If sales are insufficient to liquidate the inventory built up, considerable losses may result.

At the other extreme, inventory in stable product lines built up to absorb short-term seasonal fluctuations might be thought of as bearing the least risk, since this type of investment is characteristically short-term. But even in these cases there can be losses. Suppose, for instance, that peak seasonal sales do not reach anticipated levels and substantially increased costs of storage and obsolescence have to be incurred before the excess inventory can be liquidated.[13]

It might now be pointed out that the cost of the dollars invested in inventory may be underestimated if bank interest rate is used as the basis, ignoring the risk-bearing compensation. How many businessmen are actually satisfied with uses of their companies' capital funds which do not earn more than a lender's rate of return? In choosing a truly appropriate rate -- a matter of financial management policy -- the executive must answer some questions:

1. Where is the cash coming from -- inside earnings or outside financing?
2. What else could we do with the funds, and what could we earn?

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[13]Samuel Eilon, Elements of Production Planning and Control, (New York: The MacMillan Company, 1962), p. 163.

3. When can we get the investment back, if ever?
4. How much risk of sales disappointment and obsolescence is really connected with this inventory?
5. How much of a return do we want, in view of what we could earn elsewhere or in view of the cost of the money to us and the risk the inventory investment entails?[14]

(2). Investment in Facilities:

Valuation of investment in facilities is generally important only in long-run planning problems--as, for example, when increases in productive or warehouse capacity are being considered.

Facilities investment is also important where productive capacity is taxed, and where the form of the plan or schedule will determine the amount of added capacity which must be installed. The facilities investment should represent out-of-pocket investment, or as an alternate, foregone opportunities to make an out-of-pocket investment elsewhere.

Customer Service

An important objective in most production planning and inventory control systems is maintenance of reasonable customer service. An evaluation of the worth of customer service, or the loss suffered through poor service, is an important part of the problem of arriving at a reasonable inventory policy.

The result of being unable to establish satisfactory delivery dates may be the loss of potential orders. The cost of these lost orders is the profit the firm would otherwise have realized. In addition, there is also the possibility that if the customer finds it necessary on occasion to place his order with another supplier,

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[14]William R. Spriegel and Richard H. Lanburgh, Industrial Management, (New York: John Wiley and Sons, Inc., 1963), p. 33.3.

he may continue to order from this new supplier. Therefore, this loss of subsequent profits becomes an additional cost to the firm since future orders will now not be forthcoming.

This cost is typically very difficult to arrive at, as it includes the paperwork costs of rehandling back orders and, usually much more important, the effect of customer dissatisfaction on future profits.

In some cases it may be possible to limit consideration to the cost of producing the needed material on overtime or of purchasing it from the outside and losing the contribution to profit which it would have made. On the other hand, sometimes the possible loss of customers and their sales over a substantial time may outweigh the cost of direct loss in immediate business; and it may be necessary to arrive at a statement of a "reasonable" level of customer service--that is, the degree of risk of running out of stock, or perhaps the number of times a year the management is willing to run out of an item.

In other cases, it may be possible to arrive at a reasonable maximum level of sales which the company is prepared to meet with 100% reliability, being reconciled to have service suffer if sales exceed this level.

One of the purposes of inventory control analysis is to help management arrive at a realistic view of the cost of poor service, or of the value of building high service. It is necessary to lay out clearly what the cost in inventory investment and schedule changes is to achieve the desired degree of customer service. Sometimes when these costs are clearly brought home, even a 100% service-minded management is willing to settle for a more realistic "excellent" service at moderate cost, instead of striving for "perfect" service entailing extreme cost.

V. OPTIMUM LOT SIZE

One of the inventory problems which plague businessmen the most is that of the optimum size of lot to purchase or produce for stock. This happens also to be one of the oldest inventory problems. This does not lessen the fact that it is one of the most profitable for a great many companies to attack today with new techniques.

Common Practices

This problem arises because of the need to purchase or produce in quantities greater than will be used or sold. Thus specifically, businessmen buy raw materials in sizable quantities -- carloads, or even trainloads -- in order to reduce the costs connected with purchasing and control, to obtain a favorable price, and to minimize handling and transportation costs. They replenish factory in-process stocks of parts in sizable quantities to avoid, where possible, the costs of equipment setups and clerical routines. Likewise, finished stocks are maintained in warehouses in quantities substantially greater than the typical amount sold at once.

Where the same equipment is used for a variety of items, the equipment will be devoted first to one item and then to another in sequence, with the length of the run in any individual item to be chosen, as far as is economically possible, to minimize change-over cost from one item to another. It also reduces the production time lost because of clear-out requirements during changeovers. Blocked operations of this sort occur frequently, for example, in the petroleum industry, on packaging lines, or on assembly lines where change-

over from one model to another may require adjustment in feed speeds and settings and change of components.

In all these cases, the practice of replenishing stocks in sizable quantities compared with the typical usage quantity means that inventory has to be carried. It makes it possible to spread fixed costs, such as setup and clerical costs, over many units and thus reduce the unit cost. However, one can carry this principle only so far; for, if the replenishment orders become too large, the resulting inventories get out of line. The capital and handling costs of carrying these inventories can more than offset the possible savings in production, transportation, and clerical costs. Here, again, a balance must be struck between these conflicting considerations.

Even though formulas for selecting the optimum lot size are presented in many texts,[15] few companies make any attempt to arrive at an explicit quantitative balance of inventory and changeover or setup costs. Why?

For one thing, the cost elements which enter into an explicit solution frequently are very difficult to measure. For example, it may be possible to get a fairly accurate measure of the cost of setting up a particular machine; but it may be almost impossible to derive the cost of making out a new production order. Warehouse costs may be accumulated separately on the accounting records, but these rarely show what the cost of housing an additional unit of material may be. Seldom do the capital cost or computed interest cost results, connected with inventory investment, ever appear on the company's accounting records.

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[15]James W. Pritchard and Robert H. Eagle, Modern Inventory Management, (New York: John Wiley and Sons, Inc., 1965).

Furthermore, inventory is traditionally valued in such a way that the true incremental investment is difficult to measure for purposes of scheduling. Often, companies attempt to strike only a qualitative balance of these costs to arrive at something like an optimum or minimum-cost reorder quantity.

We can now visualize the value of an analytic solution does not rest solely on one's ability to "plug-in" precise cost data to get an answer. An analytic solution helps clarify questions of principle, even with only crude data available for use.

"However, 33% of the manufacturing firms today still have not accepted the philosophy of optimum reorder quantities from the over-all company standpoint. Only five per cent of these firms depend on some type of EOQ variation."[16] Instead, production review or traffic opinion is relied upon for decisions. Here, too, the analytic solution can be of help, even when the cost data is incomplete.

In addition, it is noted that in fewer than sixty per cent of the small manufacturing firms reporting in a survey of operating control techniques, stated that they had the basic information for effective control of inventory. The others relied on frequent counting or informal reports. Only thirty-seven per cent of these firms even made written "sales forecasts".[17]

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[16]"Exclusive Survey of American Production and Inventory Control Society," Factory, April, 1961, p. 141.

[17]William G. Dick, "Operating Controls in Small Manufacturing Firms," Small Business Administration Bulletin, No. 134, Washington, D.C., May, 1963.

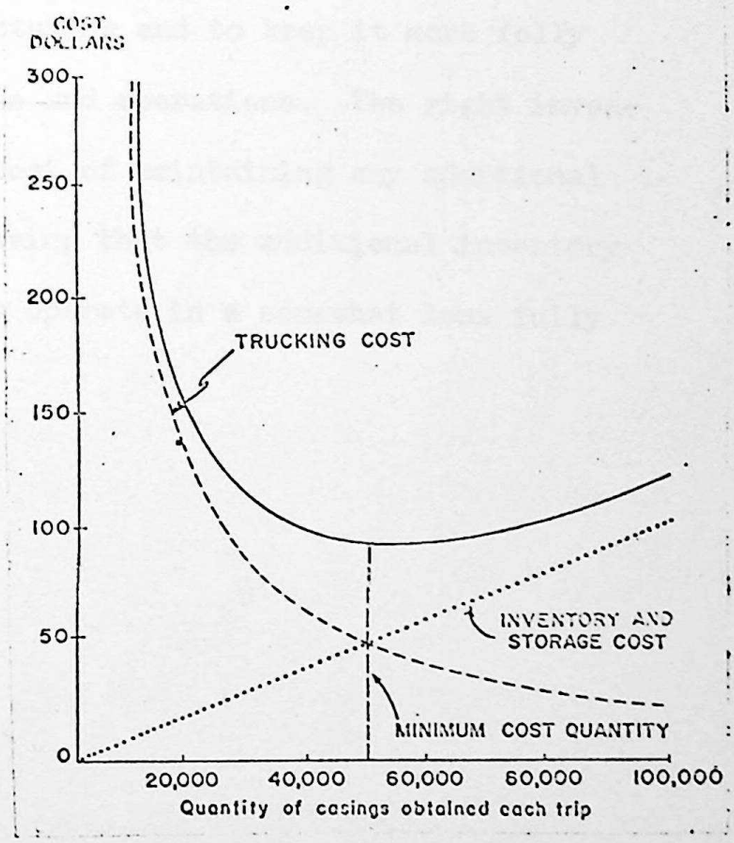
Analytical Results

When the analytic approach is applied to a firm's problems, it reveals certain relationships which are significant and useful to executives concerned with inventory order quantities:

(1). The appropriate order quantity and the average inventory quantity vary with the square root of sales. This means that with the same setup costs and ordering costs, the larger the sales volume for an item, the less inventory per unit of sales is necessary. This eliminates, of course, one of the sources of inefficiency in many inventory control systems -- namely, the system of rigidly ordering and maintaining inventories equal to one month's sales.

(2). The total cost in the neighborhood of the optimum economic order quantity is also relatively insensitive to small changes in the ordered amount. Exhibit I illustrates this proposition. Thus, all that is needed is just to get in the "right ball park", and a good answer can be obtained even with fairly crude cost data.

EXHIBIT I. ANNUAL COST OF BUYING, MOVING, AND STORING CASINGS COMPARED WITH REORDER QUANTITY



[18]Robert H. Bock and William K. Holstein, Production Planning and Control, (Columbus: Charles E. Merrill Books, Inc., 1963), p. 195.

With the establishment of these relationships, the first essential to the analytical approach can thus be gained--that is, defining the appropriate inventory function. In some cases, the function is to permit purchase or manufacture in economical quantities or lengths; in other cases it will be grossly different.

The important point is that the basic function is identified wherever it may be found--in manufacturing, purchasing, or warehouse operation.

The only way to cut inventories is to organize operations so that they are tied more closely together. For example, a company can cut its raw materials inventory by buying in smaller quantities closer to needs, but it does so at a cost; this cost results from the increased clerical operations needed to tie the purchasing function more closely to manufacturing and to keep it more fully informed of manufacturing's plans and operations. The right inventory level is reached when the cost of maintaining any additional inventory cushion offsets the saving that the additional inventory earns by permitting the plant to operate in a somewhat less fully organized fashion.

VI. ANTICIPATION OF FUTURE NEEDS

Inventory control really starts when it is determined how much of each product to make. Most companies manufacture nearly all their products to stock. They make the products before they are sold, before they know who they will be sold to, and even before they know how many they will be able to sell.

Forecasting

Forecasts of customer demand are fundamental to the operation of a business. Any company's survival depends on its ability to adapt its products and its operations to its customers' needs, to stimulate a need or desire for its products, and to efficiently service its products when the demand arises. The problem of how to forecast demands as accurately as possible is essential to the development of master production schedules. The field of sales forecasting is a complete study in itself.

In a general way, most large companies forecast their business goals from five to ten years in advance. They use these long range forecasts in deciding on new building programs and product development work. Production and inventory control is concerned with using forecasts for the near future, however, not the distant future. It is sometimes concerned with the company's sales for as far as fifteen months ahead. The types of sales forecasts used are:

(1). General Business Level Forecasts:

Most companies' sales depend a great deal on general business conditions, so initially a firm is likely to need a general business forecast. The economic research departments of large companies are constantly studying business conditions and the reports of business conditions made

by outside economic research organizations.

There are also a great number of public and private economic research forecasting organizations that send out their forecasts for a fee. There are numerous professional forecasting agencies, weekly newsletters, and government agencies all periodically reporting on the economic status and health of the nation.

Since most companies' production and inventory levels are affected by general business levels, they definitely need to be knowledgeable with general business forecasts before they can forecast their own business.

(2). Industry's Forecasts:

A company's sales, in any short period, depend upon how well its industry is doing. Hence, step two involves determining how the industry is flourishing. Industry information is obtained thru trade associations and conferences, private organizations, U. S. Department of Commerce, and business magazines and journals. Companies whose business derives from that of other firms must look at sales forecasts for their customers' industries when making their own sales forecasts.

(3). The Company's Forecasts:

The third step in forecasting is to consider the company's own sales estimates. These are determined from the:

(a). Consensus of opinion of the organization's top officials,

(b). Orders currently "logged",

(c). Salesmen and distributors, concerning their territory conditions and customer buying plans, and

(d). Records of past sales of individual products and classes of products.

(4). Function of Sales Forecasts:

Ordinarily the production department doesn't forecast sales. Its function is to analyze sales forecasts (production previews) made by others into starting points for determining:

(a). Master production schedules.

(b). Factory capacity requirements.

(c). Production programs.

These are, in turn, the bases for placing material and part purchase orders, planning production processes, and providing the needed men, machines, and tooling.

(5). Uses of Sales Forecasts:

Either the sales forecast or the master production schedule may be in very general terms: a) in total dollars, or b) in a list of specific items. If it is only in general terms, it must be refined to make it usable for production and inventory planning purposes. It must be converted to specific units and quantities that can be measured, analyzed, and later compared to actual performance. Then guides must be provided or developed to show trends, to anticipate increasing or decreasing future demand, and to establish desirable goals in line with the general sales forecast.

A firm is concerned with products being manufactured and parts and raw materials purchased for stock; therefore, the sales forecast is tempered by inventory policy. It may be desirable, because of business trends, to increase or decrease the inventory of finished goods, parts, work-in-process, or raw materials. So, the master production schedule may be more or less than the sales forecast.

(6). Approaches to Sales Forecasts:

The approaches to sales forecasts are widely varied among companies. This is so partly because of the rarity of satisfactory general forecasting methods, partly because expediency and available data have a strong influence and partly because most companies fail to recognize how many forecasts they make. The general classes of approaches used for making the different types of demand forecasts are shown in Exhibit II.[19]

Exhibit II
Forecasting 119

Use	Time span	Characteristics	Techniques
Business planning: Product planning Research programing Capital planning Plant location and expansion	Generally five years or more; sometimes less	Broad outline forecast, often qualitative only	Technical-economic studies; economic and population studies; marketing studies
Intermediate operation planning: Capital and cash budgets Sales planning Production planning, especially in seasonal business Setting production and inventory budgets	Generally six months to two years; at least through one cycle in seasonal business	Used for analysis of alternative operating plans; numerical; not necessarily detailed by item; estimate of reliability needed	Collective opinion; trend analysis; seasonal index analysis; correlation with economic indices; combination techniques
Short-run production control: Adjusting production and employment levels to account for departures of total inventory from plan	One to six weeks; span equals lag between decision to adjust operating rates and time output is actually affected	Forecasts of operating activity, not item forecast	Statistical trend extrapolation; explosion of short-term product or product-class forecasts
Forecast of item requirements: Placing purchase orders Scheduling items into production Replenishing warehouse stocks: controlling decisions when and how much to replenish	Span equals lead time between placing order or scheduling run and receipt or completion. Estimate of error, or maximum demand needed to protect service	Designed for routine use in manual, punched-card, or electronic systems	Explosion of end-product demand; graphical; statistical or numerical techniques

[19]E. H. MacNeice, Production Forecasting, Planning and Control, (New York: John Wiley and Sons, Inc., 1961), p. 119.

(7). Techniques to Sales Forecasts:

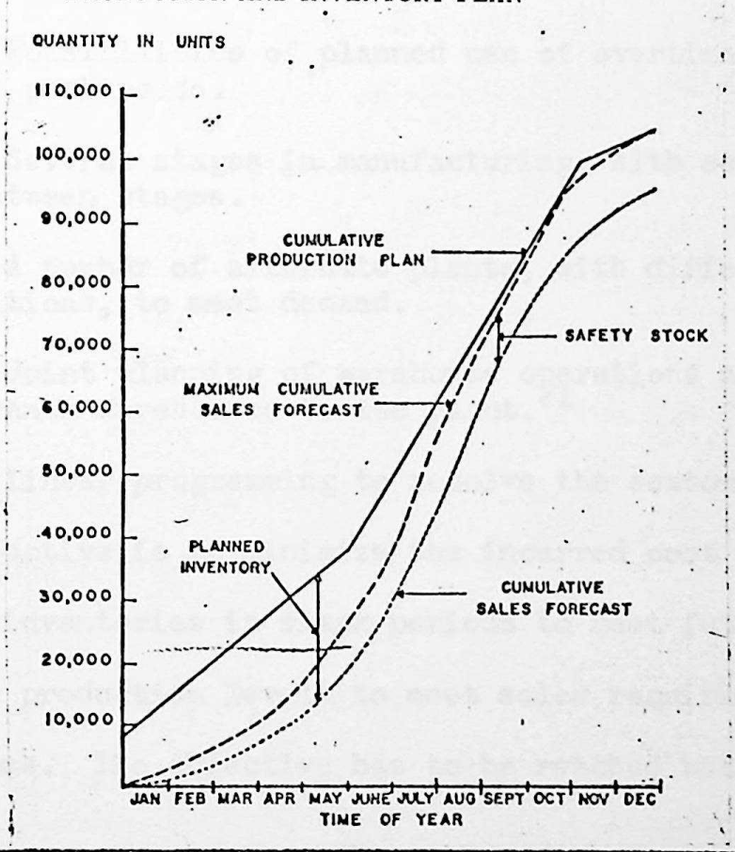
Techniques are highly diverse and depend strongly on the nature of the company, the data-handling facilities, analytical skills available, and particularly on the types of customer and industry information that exist. In addition, forecast techniques for controlling inventory stocks and procurement of items depends greatly on the number and value of the items controlled plus the type of information retrieval system in use.

Planning Production

(1). Graphical Techniques:

Where the problem of planning against forecasted sales is not made too complicated by a variety of items, processes, and stages, simple graphical or arithmetic techniques can often be useful, for example:

ILLUSTRATIVE SALES FORECAST AND PRODUCTION AND INVENTORY PLAN [20]



[20]John F. Magee, "Inventory Problems of Uncertainty," Harvard Business Review, March-April, 1956, p. 107.

Once the sales forecast plus the safety stock has been obtained, the task is to draw in the production curve as shown in Exhibit II on the previous page. The total costs of inventory and production depend on the form of the production curve, and characteristically the object is to choose this curve or production plan to minimize the expected total of these costs.

(2). Advanced Techniques:

Sometimes the problem of planning production to meet seasonal demand is too complicated for simple, graphical techniques, and more specialized techniques are needed, such as linear programming.

Linear programming is useful where the problem is complicated by numerous conditions as:

(a). Several product lines using the same facilities or staff.

(b). Possibilities of planned use of overtime and extra shift premiums to meet peak needs.

(c). Several stages in manufacturing, with seasonal storage possibilities between stages.

(d). A number of alternate plants, with different cost and employment situations, to meet demand.

(e). Joint planning of warehouse operations and of the assignment of branch warehouses to the plant.[21]

When using linear programming to resolve the seasonal planning program, the objective is to minimize the incurred cost totals required to carry inventories in slack periods to meet future sales peaks, to change production levels to meet sales requirements, or to resort to overtime. The objective has to be reached within several

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[21]John F. Magee, "Linear Programming -- Lecture 13," Notes from the 1963 M.I.T. Summer Course on Operations Research, (Cambridge, Mass., The Technology Press, 1963).

limitations:

(a). The normal and overtime capacity restrictions.

(b). The inventory size requirements for each line are planned large enough to meet the sales requirements.

(c). The amount of variation that can be tolerated in the planned production rate.

Sales Characteristics

Sales characteristics which strongly influence the production and inventory control system and the relative importance of different functions include:

(1). The unit of sales -- dozens, tons, or carloads?

(2). The size & frequency of orders -- daily, weekly, or continuous?

(3). The sales uniformity or predictability.

(4). The service requirements or allowable delay in filling orders.

(5). The distribution pattern -- factory to customer, thru jobber?

(6). The accuracy, frequency, and detail of sales forecasts.

Production Characteristics

The production characteristics which influence the methods of production and inventory control include:

(1). The form of organization -- job shop or product line.

(2). The number of manufacturing stages.

(3). The degree of specialization required at each production stage.

(4). The required physical processing and handling requirements.

(5). The capacity of production and warehousing.

(6). The production flexibility and kinds of processing required.

(7). The quality requirements, shelf-life limits & obsolescence risks.

Role of Forecasting

Whether forecasts are needed or possible is not the question; they are made formally or informally every time a decision is made to build or replenish an inventory. The question is whether the necessary forecasts are being made as well as they might be, if formally recognized, and if available statistical and market research techniques were used.

VII. CONCLUSION

The inventory functions and methods of analysis which have been described in this paper illustrate the way in which inventory questions originally framed in action terms can be restated as analytical questions. The original questions are those characteristically asked by operating management; they are concerned with the who, when, and where of inventory control. The analytical questions are different: What are the functions of the inventory? What are the costs and other elements related to inventory level? At what level is the inventory best performing its functions?

The two basic inventory functions are: (1) to purchase time, and (2) to separate successive operations or stages in the manufacturing or distribution process. These functions make the different divisions and groups in a company's manufacturing and distribution system less dependent on each other, and lessen the need for highly organized control.

The economics of these functions and the appropriate inventory balances are determined by a variety of cost or value elements. However, the essential costs are characteristically not the costs reported in summary accounting records. The cost information needed often requires reorganization or restatement of the accounting costs to arrive at definitions suited to the specific problem at hand.

Actually, the same basic criteria govern investment in inventories as in other capital assets: What is the best balance between

added earnings, cost savings, and intangible benefits, on the one hand, and investment and maintenance costs, on the other?

Arriving at the right balance point in inventories is often more difficult than in other capital decisions. Inventory functions are more complex, the advantages more subtle, and the balance of gains and costs much more difficult to find. It is perhaps as a direct result that inventory decisions have been based more on intuition than on logic and arithmetic. This has led to inefficiency. Intuition-based policies are seldom easy to administer, to keep current, or to comprehend. Indeed, many businessmen's deep concern over inventory policy is not that they think they are wrong, but that they do not know.

Underlying the slowly developing inventory theory, is the search for new sets of useful concepts, new methods for making necessary measurements, and means of employing measurements to use the new concepts. As production and distribution processes grow in scope, complexity, number of stages, number of products handled, and geographical dispersion; the intricacy of the system exceeds the limits of intuition, logic, and arithmetic alone. The techniques of the research scientist, together with the mathematical tools now at his disposal, are bound to become increasingly valuable in helping management to analyze and control its inventory policies.

BIBLIOGRAPHY

Books

Alijan, George W. (ed.). Purchasing Handbook. New York: McGraw-Hill Book Co., Inc., 1958.

American Management Association. Meeting The Productivity Challenge. New York: American Management Association, 1960.

American Management Association. Successful Production Planning and Control. New York: American Management Association, 1955.

Backer, Morton. Handbook of Modern Accounting Theory. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1955.

Baumback, Clifford M. (ed.). Management of Lot-Size Inventories. Chicago: American Production and Inventory Control Society, 1963.

Bethel, L. S. Industrial Organization and Management. 4th. ed. New York: McGraw-Hill Book Co., 1962.

_____. Production Control. 2nd. ed. New York: McGraw-Hill Book Co., 1948.

Biegel, J. C. Production Control: A Quantitative Approach. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963.

Bock, Robert H. and Holstein, William K. Production Planning and Control. Columbus: Charles E. Merrill Books, Inc., 1963.

Buchan, Joseph and Koenigsberg, Ernest. Scientific Inventory Management. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963.

Buffa, Elwood S. Modern Production Management. New York: John Wiley and Sons, Inc., 1963.

Carroll, Phil. Overhead Cost Control. New York: McGraw-Hill Book Co., 1964.

Carson, Gordon B. (ed.). Production Handbook. 2nd. Ed. New York: Ronald Press Co., 1963.

Colton, Raymond R. Industrial Purchasing Principles and Practices. Columbus: Charles E. Merrill Books, Inc., 1962.

Dooley, Arch R. Basic Problems, Concepts, and Techniques. New York: John Wiley and Sons, Inc., 1964.

Eilon, Samuel. Elements of Production Planning and Control. New York: The MacMillan Co., 1962.

Encyclopaedia Britannica.

Greene, James H. Production Control: Systems and Decisions. Homewood, Illinois: Richard D. Irwin, Inc., 1965.

Heyel, Carl. Management For Modern Supervisors. New York: American Management Association, 1962.

Hoffman, Raymond A. Inventories. New York: Ronald Press Co., 1962.

Holt, Charles C. Planning Production, Inventories, and Work Force. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1960.

Hopeman, Richard J. Production Concepts, Analysis and Control. Columbus: Charles E. Merrill Books, Inc., 1965.

Hopkins, A. L. Tools and Techniques of Modern Industrial Management. Champaign, Illinois: University of Illinois, 1958.

Koepke, Charles A. Plant Production Control. New York: John Wiley and Sons, Inc., 1961.

Knowles, A. S. and Thompson, R. D. Production Control. New York: The MacMillan Co., 1943.

Landy, Thomas M. Production Planning and Control. New York: McGraw-Hill Co., 1950.

Lindsay, Franklin A. New Techniques For Management Decision-Making. New York: McGraw-Hill Co., 1958.

Lundy, J. L. Effective Industrial Management. New York: The MacMillan Co., 1958.

MacNeice, E. H. Production Forecasting, Planning and Control. New York: John Wiley and Sons, Inc., 1961.

Magee, John F. Production Planning and Inventory Control. New York: McGraw-Hill Book Co., Inc., 1958.

Mayer, Raymond R. Production Management. New York: McGraw-Hill Book Book Co., Inc., 1962.

McGarrah, Robert E. Production and Logistics Management. New York: John Wiley and Sons, Inc., 1963.

Moore, Franklin G. Production Control. New York: McGraw-Hill Book Co., Inc., 1959.

Morse, Philip M. Queues, Inventories and Maintenance. New York: John Wiley and Sons, Inc., 1958.

Muth, John F. Industrial Scheduling. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963.

National Electronic Distributors Association. Inventory Control Theory and Practice. U.S.A.: National Electronic Distributors Association, 1962.

O'Donnell, Hohn L. and Goldberg, M. S. Elements of Financial Administration. Columbus: Charles E. Merrill Books, Inc., 1962.

Pritchard, James W. and Eagle, Robert H. Modern Inventory Management. New York: John Wiley and Sons, Inc., 1965.

Pritzker, Robert A. and Gring, Robert A. Modern Approaches to Production Planning and Control. New York: American Management Association, Inc., 1960.

Reinfeld, Nyles V. Production Control. New York: Ronald Press Co., 1951.

Ritchie, W. E. Production and Inventory Control. New York: Ronald Press Co., 1951.

Spriegel, William R. and Lanburgh, Richard H. Industrial Management. New York: John Wiley and Sons, Inc., 1963.

Starr, Martin K. and Miller, David W. Inventory Control: Theory and Practice. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1962.

Starr, Martin Kenneth. Production Management, Systems, and Synthesis. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964.

Stockton, R. Stansbury. Basic Inventory Systems: Concepts and Analysis. Boston: Allyn and Bacon, Inc., 1965.

Timms, Howard L. The Production Function in Business. Homewood, Illinois: Richard D. Irwin, Inc., 1962.

Voris, William. Production Control. Homewood, Illinois: Richard D. Irwin, Inc., 1956.

_____. Production Control Text and Cases. Homewood, Illinois: Richard D. Irwin, Inc., 1961.

Wasson, Chester R. The Economics of Managerial Decision. New York: Appleton-Century-Crofts, 1965.

Weston, J. Fred. Managerial Finance. New York: Holt, Rinehart and Winston, 1962.

Articles and Periodicals

"A Discussion of Various Approaches to Inventory Management," The Accounting Review, (July, 1964), 699-702.

Alt, Franz L. "Safety Levels in Military Inventory Management," Operations Research, (November, 1962), 786-794.

Ammer, Dean. "It Doesn't Always Pay You to Cut Inventories," Purchasing, Vol. 51, (July 31, 1961), 40-41.

Andress, Frank J. "The Learning Curve as a Production Tool," Harvard Business Review, (January-February, 1954), 75-87.

Avery, F. B. "Economical Manufacturing Quantities," Industrial Management, Vol. 63, No. 3, (March, 1952), 169-170.

Baumbeck, Clifford M. and Konopa, Leonard J. "Inventory Control: How EOQ Can Help," Management Review, Vol. 51, (April, 1962), 56-62.

"Biggest Slash in Inventory Credited to Air Force," Air Force Times, (October 16, 1963), 5.

Briggs, Warren G. "A Simple Technique for Economic Order Frequency Determination," APICS Quarterly Bulletin, Vol. 3, No. 2, (April, 1962), 18-25.

Bronner, Stanley Z. "Organizational Aspects of Inventory Management," NAA Bulletin, (December, 1961), 41.

Brown, R. G. "Dynamic Inventories; Controlling Their New Power," Modern Materials Handling, (March, 1963), 44-47.

Carroll, R. P. and Schneider, F. E. "Developing Order Points and Quantities for Inventory Control," NAA Bulletin, Vol. 42, (December, 1960), 67-73.

Cooke, M. J. "The Non-ABC's of Material Control," APICS Quarterly Bulletin, Vol. 6, No. 3, (October, 1965), 7-19.

"Commissaries Criticized for Bad Inventory Habits," Air Force Times, (October 2, 1963), 7.

"Control by Importance," Steel, (December 20, 1965), 42-43.

"Control Stocks Without Forecast," Iron Age, (December 10, 1964), 136.

Davis, D. F. "The Inventory Squeeze Between Financial and Production Management," Systems and Procedures Journal, (May-June, 1965), 38-43.

DeRose, Louis J. "Principles and Techniques of Inventory Control," APICS Quarterly Bulletin, Vol. 3, No. 1, (January, 1962), 16-23.

Doster, Leroy S. "Improved Techniques for Inventory Management and Control," NAA Bulletin, Vol. I, (December, 1961), 41.

Eaton, J. A. "New, The LIMIT Technique; It's Easy To Pick Right Lot Sizes," Modern Materials Handling, (February, 1964), 38-43.

Eilon, Samuel. "Problems in Stock Depletion," Engineer, (October 26, 1962), 706-708.

Elmaghraby, Salah E. "Explosion and Netting Problems in the Planning of Materials Requirements," Operations Research, (July, 1963), 530-535.

"Exclusive Survey of American Production and Inventory Control Society," Factory, (April, 1964), 138-145.

Ferrera, William L. "What Managerial Functions Does Accounting Serve," Financial Executive, (July, 1964), 21-22.

Greenberg, John P. "Blanket Orders Buy Time for P.A.'s," Purchasing, (May 19, 1966), 62-64.

Guthart, Leo A. "The ABC's of EOQ's," Purchasing, (June 6, 1960), 78-81.

Hansen, Bertrand L. "Reducing Inventories and Cut Back Orders," Tooling and Production, (December, 1958), 41-43.

Heinaman, Steven T. "Return on Investment Approach to Inventory," NACA Bulletin, (July, 1955).

Higgins, W. Rodgers. "Valuation of Readily Marketable Inventories," Journal of Accountancy, (July, 1964), 25-32.

Hinck, Robert H. "Managing Your Inventories for Profit," Dun's Review, (February, 1959), 48-49.

Hoffman, W. H. "Approach to Improved Applications of Economical Order Quantities," Systems and Procedures Journal, Vol. 13, (November, 1962), 13-15.

"How Joy Trims Inventory Costs," Steel, (October, 1965), 124-126.

"How Much Inventory for Your Sales Volume?" Chemical Engineering, (December, 1964), 36-42.

"Inventories -- Trade Signal," Financial World, (April 6, 1966), 3.

"Inventory Expenses Cut," Steel, (February 22, 1965), 31.

"Is EDP Vital to Stock Control," Iron Age, (May 21, 1964), 197.

Kapner, S. L. "How to Control Elusive In-Process Inventory Costs," Modern Materials Handling, (December, 1962), 72-73.

Katz, Leonard. "How to Second Guess Stockouts," Purchasing, (April 7, 1966), 90-91.

Killorin, Francis H. "Scientific Inventory Control," Modern Materials Handling, (October, 1955), 111-113.

Lander, Jack R. "E.O.Q.: It Can Be Easy," APICS Quarterly Bulletin, (April, 1963), 42-45.

Lawson, W. H. "Elements of Inventory Simulation," Automation, (January, 1964), 65-67.

Lee, L. H. and Mulvaney, R. B. "Now A Talking Computer Answers Inventory Inquiries," Electronics, (August 16, 1963), 30-32.

Luneski, Chris. "Some Aspects of the Meaning of Control," The Accounting Review, (July, 1964), 590-595.

Magee, John F. "Guides to Inventory Policy," Harvard Business Review, (January-February, 1956), 49-60.

_____. "Inventory Problems of Uncertainty," Harvard Business Review, (March-April, 1956), 105-117.

Margeson, Charles F. "Financial Aspects of Inventory Control," Financial Executive, (April, 1959), 162-167.

McErlain, Charles S. "Inventory Control Made Simple As EOQ," Tool and Manufacturing Engineering, (February, 1966), 33-34.

Merkle, Norman R. "The Relationship Between The Computer and Inventory Management," APICS Quarterly Bulletin, Vol. 6, No. 2, (April, 1965), 47-52.

NAA Bulletin Editors. "Serving Sales Thru Planning of Production and Inventory," NAA Bulletin, Vol. 3, (January, 1959), 1-4.

Newberry, T. L. "Horse 'n Buggy Inventory Control," Textile Industry, (October, 1963), 76-78.

Oberg, Stanley M. "Forecast or Flounder," APICS Quarterly Bulletin, Vol. 6, No. 3, (July, 1965), 56-67.

Pittsley, James L. and Hill, Harold H. "A Significant Cash Dividend from Scientific Inventory Management," NAA Bulletin, (May, 1965), 47-51.

Putnam, Arnold O. "Managing Distribution and Inventories for Profit and Reliable Customer Service," APICS Quarterly Bulletin, Vol. 6, No. 4, (October, 1965), 52-66.

Salter, William T. "Determining Cost Factors in Order Quantity Formulae," APICS Quarterly Bulletin, Vol. 6, No. 3, (July, 1965), 8-21.

Schaffir, K. H. and Hertz, D. B. "A Forecasting Method for Management of Seasonal Style-Goods Inventories," Operations Research, (January-February, 1960), 45-52.

Schomer, Arthur J. "An Approach To Inventory Management," Journal of Accountancy, (August, 1965), 75-77.

Scofield, Herbert.L. "A New Look at Inventory Control," Signal, (September, 1965), 64-66.

Scully, W. J. "Inventory Cuts Bearing Costs," Foundry, (November, 1962), 169-171.

Seiffert, Herbert H. "Synchronized Inventory Control -- One Company's System," NAA Bulletin, Vol. 1, (December, 1961), 51-55.

Sloane, Leonard. "Blank Check P.O. Gets Straight A's at Columbia," Purchasing, (April 7, 1966), 83-86.

Small, Donald W. "Efficient Inventory Control Thru Monthly Reporting," NAA Bulletin, Vol. 1, (February, 1960), 5-8.

Smith, Arthur H. "Improved Techniques for Inventory Management and Control," NAA Bulletin, Vol. 3, (September, 1959), 17-20.

Stevens, Douglas C. "Organizing for Production and Inventory Control," APICS Quarterly Bulletin, Vol. 6, No. 3, (July, 1965), 75-81.

"Surplus Inventories: Liquidate or Retain?" Chemical Engineering, (August 5, 1963), 134-36.

Strickland, R. M. "Cost of Capital Rate for Inventory Decisions," NAA Bulletin, Vol. 1, (August, 1965), 30-32.

"Terminology for Production and Inventory Control," American Machining and Metalworking Manufacturers, (October 28, 1963), 145-147.

Veinott, A. F., Jr. "Optimal Policy in a Dynamic, Single Product, Non-Stationary Inventory Model With Several Demand Classes," Operations Research, (September, 1965), 761-768.

Welch, W. Evert. "Improved Techniques for Inventory Management and Control -- Statistical Inventory Control," NAA Bulletin, Vol. 3, (September, 1959), 59-64.

"Who's Afraid of Automated Buying," Sales Management, (September 18, 1964), 79-82.

Winters, P. R. "Multiple Triggers and Lot Sizes," Operations Research, Vol. 9, (September, 1961), 621-634.

Wolf, F. N., Jr. "How DOD Controls Machine Tool Inventories," Machinery, (February, 1966), 101-102.

Reports

American Production and Inventory Control Society. Proceedings of the 1965 National Technical Conference. A Report Prepared by the APICS of the Delivered Addresses. Los Angeles: American Production and Inventory Control Society, October 22, 1965.

Bessler, Stuart A. and Veinott, Arthur F., Jr. Optimal Policy For A Dynamic Multi-Echelon Inventory Model. Technical Report No. 5, Decision Studies Group, Palo Alto, California and Department of Industrial Engineering, Stanford University, Stanford, California, February 23, 1966.

Brown, George W., Lu, John Y., and Wolfson, Robert J. Dynamic Modeling of Inventories Subject to Obsolescence, Rand Corporation, Santa Monica, California, November, 1963.

Dick, William G. Operating Controls in Small Manufacturing Firms, Small Business Administration, Bulletin No. 134, Washington, D.C., May, 1963.

Durham, H. P. Macroeconomics of the DOD Inventory Reduction Program, San Jose State College, A report prepared as a course requirement for Economics 200 Seminar in Current Economics Problems, January 19, 1966.

Fabrycky, W. J. Procurement and Inventory Theory, Vol. 1: The Multi-Source Item Concept, Office of Engineering Research, Oklahoma State University, June, 1965.

Fabrycky, W. J. and Ghare, P. M. Procurement and Inventory Theory, Vol. 2: The Manufacture or Purchase Decision, Office of Engineering Research, Oklahoma State University, June, 1964.

Fabrycky, W. J. and Banks, Jerry. Procurement and Inventory Theory, Vol. 3: The Multi-Item, Multi-Source Concept, Office of Engineering Research, Oklahoma State University, July, 1965.

Hadley, G. and Whitin, T. M. A Review of Alternative Approaches to Inventory Theory, Rand Corporation, Santa Monica, California, September, 1964.

Hastings, Delbert C. Forecasting in Small Business Planning, Small Business Administration, Washington, D.C., April, 1961.

Hearle, Edward F. R. and Mason, Raymond J. Studies in Data System Development: The OCAMA Weapon System Project, Rand Corporation, Santa Monica, California, April, 1965.

Hobson, Leland S. and Schrader, George F. Planning and Controlling Production for Efficiency, Small Business Administration, Bulletin No. 177, Washington, D.C., July, 1965.

Hopeman, R. J. Cost Factors in Carrying Inventory, Encyclopaedia Britannica, Chicago, Illinois, 1965.

Kriebel, Charles H. Team Decision Models of an Inventory Supply Organization, Carnegie Institute of Technology, Pittsburgh, Pennsylvania, June, 1965.

Magee, John F. Linear Programming - Lecture 13, Notes from 1963 M.I.T. Summer Course on Operations Research, Cambridge, Mass., 1963.

Mulvihill, Donald F. Inventory Control for Small Wholesalers, Small Business Administration Management Research Summary, Washington, D.C., August, 1963.

Schneider, David. Pointers on Raw Materials Inventory Control, Small Business Administration, Bulletin No. 155, Washington, D.C., 1963.

Sherman, Kenneth Nathaniel. Inventory Control, Small Business Administration, Bulletin No. 75, Washington, D.C., September, 1964.

Smith, Arthur H. Improved Techniques for Inventory Management and Control, An application of the operations research approach in a case study at General Mills, Minneapolis, Minnesota, September, 1964.

John C. Computer Applications in Development and Evaluation of Constraints on the Simple Lot Size Inventory Model, Master of Science Thesis, Texas A & M University, January, 1966.

Olver W. Keep Job Backlogs Down to Cut Lead Times, Iron Age Management Report, February, 1966.

Zehna, Peter W. Detecting Demand Changes, Decision Studies Group, Palo Alto, California, December, 1965.